ANALYSIS 2 – STRUCTURAL/MECHANICAL BREATH

Precast Architectural Brick façade in place of Norman brick and CMU.

Problem

The current façade design of the Ambridge Area High School uses the traditional construction of concrete masonry unit (CMU) backup with insulation and Norman face brick as the finish façade layer. Masonry work on the project took months to complete, and with masonry scaffolding surrounding the entire footprint of the building during that time, slows other enclosure trades who must wait for masonry work to finish (See detail below). In addition, finish trades inside the building may begin earlier if enclosure comes earlier.

Goal

The goal of this analysis is to examine whether replacing the current composite wall system with an architectural precast panelized system will help to reduce the construction schedule and allow building enclosure at an earlier date, as well as increase the thermal resistance of the wall system, aiming to lower heating and cooling costs. Structural impacts with incorporating this system will also be studied. Since the panels are built in a controlled environment, less material will be wasted and the quality of the finished product will hopefully be higher.

Mason scaffolding around building footprint.

Methodology

1. Determine quantity of brick and concrete masonry units to be replaced.
2. Select a panelized system to replace the brick.
3. Contact the manufacturer to determine potential cost and erection time savings.
4. Compare the two systems in terms of costs and schedule.
5. Examine R-values of both systems and estimate savings in mechanical loads.
6. Analyze structural impacts of precast system on the existing foundation system.
7. Assemble the data.

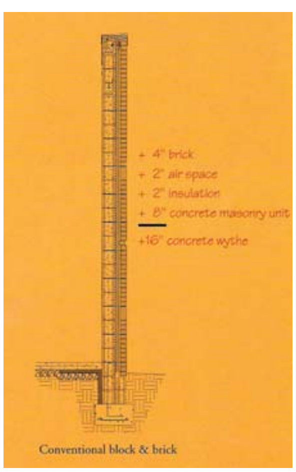
Tools

1. R.S. Means 2006 Edition
2. High Concrete – Precast Manufacturer
3. Penn State Architectural Engineering Faculty
4. ASHRAE Handbook of Fundamentals
5. AISC Steel Construction Manual
6. ACI Concrete Design Code

Outcome

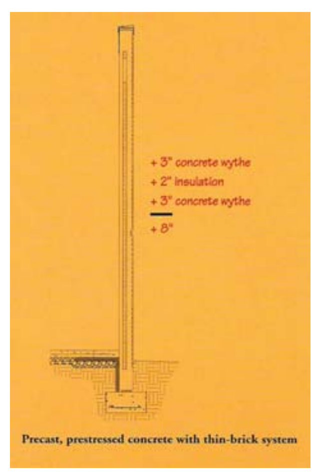
Several precast façade systems were available to replace the CMU and brick system. The insulated precast concrete panel with inset brick from High Concrete was chosen because of its similarities in structure to the existing façade. The interior finish of classrooms with the existing system is CMU with a sill constructed across the rooms. Appearance to the interior will be unchanged. Advantages of using architectural precast products include quicker erection speed, and less wasted materials and higher potential quality over brick because precast panels are produced in controlled environments. The diagrams below detail the construction of the existing CMU and brick wall assembly and the chosen precast concrete panel system.

After analyzing the two systems in terms of cost, schedule, mechanical loads and structural loads, Architectural precast panels are viewed to be equal or better than the original system in all aspects except initial cost. The following sections detail each area of analysis and the outcome of each.



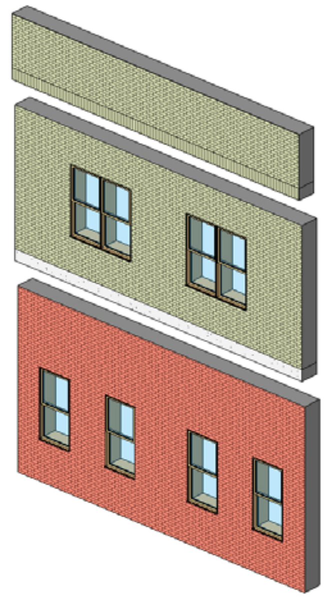
Left – Conventional wall assembly section

Right – Precast concrete wall assembly section.



Looking at the façade as built and the alternative as detailed below, the proposed system of precast panels would be stacked horizontally and have inset brick from the factory to match the desired aesthetics of the façade as originally designed.

Conventional brick and CMU façade as built with area of precast panel outlined.



Exploded view of precast panelized wall system for area detailed at left.

Cost Impacts

As is the case with most precast assemblies, they have a higher initial cost attributed to offsite labor during the manufacturing process. Cost increases can be offset by faster erection speeds and an increase in quality of the finished product. The High Concrete precast system chosen to replace the existing CMU and Norman brick façade is approximately 67% more in first cost as compared to the original façade system. Please refer to the tables below for more information pertaining to costs.

Wall System Cost Comparison

System	Quantity	Unit	Cost/SF	Total Cost	
CMU & Brick	59541	SF	$35.89	$2,137,162.00	
Precast	59541	SF	$60.00	$3,572,460.00	
				$1,435,298.00	67.16% INCREASE

Assumptions:
Using actual schedule of values for masonry construction
Cost for precast panels quoted from High Concrete

Schedule Impacts

Precast assemblies are traditionally quicker to erect than are traditional composite masonry walls. Actual durations for masonry work were derived from the actual project schedule and lasted 85 days. This duration was double-checked against the R.S. Means production rate for this wall system to ensure a reasonable crew size of eleven masons. Production rates for precast panels came from a representative at High Concrete. After comparing the duration of the two systems, it is clear that precast wall panels have the potential to reduce the masonry schedule on Ambridge Area High School by just over 63 days. This early installation allows building enclosure to come earlier than originally scheduled and can reduce the overall project schedule by this same amount. With a reduction of the overall project schedule, the General Conditions costs could be reduced by $75,474 over 12 weeks as listed in General Conditions estimate. To contrast this potential schedule savings, High Concrete indicated the typical lead-time for the precast panels would be 6-8 weeks before delivery to site to allow for shop drawings and fabrication. Increased planning would need to occur to ensure timely delivery and erection of the precast façade. Please refer to the table below for direct schedule comparison between the two systems.

Wall System Schedule Comparison

System	Quantity	Unit	Production	Hours	Days	
CMU & Brick	59541	SF	0.125	676.60	85.0	
High Concrete	59541	SF	2,720	175.1	21.9	
Insulated Panels	180	Panels	8 Panels/Day			
					-63.1	**DECREASE**

Assumptions:
8 hour work day
Masonry crew - 11 Masons to meet actual schedule of 85 days
Masonry productivity rate from R.S. Means
Masonry price from actual project schedule of values
Precast production rate from High Concrete - 8 panels/day - 2720 SF/day

Mechanical Impacts

Possible impacts on the mechanical system may come from differing insulation values of wall systems. The wall system with the highest R value or its resistance to heat transfer will be the better system for the heating and cooling loads in the building. The following table calculates the R-value of each system respective to each component in the assembly.

R-Value Computation

Wall Type	**Component**	**Thickness (in)**	**Unit R-Value**	**Unit**	**Total R-Value**
Traditional Brick					
	Outside Air Film	∞	0.17	EA	0.17
	Norman Brick	4	0.09625	In	0.385
	Extruded Polystyrene Insul.	2	5.00	In	10
	Air Cavity	2	1.68	In	3.36
	Concrete Masonry Unit	8	0.1025	In	0.82
	Inside Air Film	∞	0.68	EA	0.68
			Total R-Value	hr-sf-F/ BTU	**15.415**
		16"	**U - Value**	BTU/ hr-sf-F	**0.065**

R-Value Computation

Wall Type	**Component**	**Thickness (in)**	**Unit R-Value**	**Unit**	**Total R-Value**
Precast Panel					
	Outside Air Film	∞	0.17	EA	0.17
	Concrete Panel	3	0.8	In	2.4
	Extruded Polystyrene Insul.	2	5.00	In	10
	Concrete Panel	3	0.8	In	2.4
	Inside Air Film	∞	0.68	EA	0.68
			Total R-Value	hr-sf-F/ BTU	**15.65**
		8"	**U - Value**	BTU/ hr-sf-F	**0.064**

After calculating a wall systems R-value, it is possible to compute any changes in the mechanical load requirements for the building.

Summer - Cooling Loads

To	86
Ti	70
ΔT	16

Winter -Heating Loads

To	15
Ti	70
ΔT	55

Heat Transfer Equation

qx = (T∞1 - T∞2) * A / Rt or qx = ΔT * A * U

Summer Heat Gain

System	Area (SF)	U-Value	ΔT	Heat Gain	
			F°	(BTU/hr)	(Tons)
Traditional Brick	59541	0.065	16	61800.58	5.15
Precast Panel	59541	0.064	16	60872.59	5.07

Difference	**0.08**	
Chiller Load	**283.1**	**TON**
Difference %	**0.027%**	

Winter Heat Loss

System	Area (SF)	U-Value	ΔT	Heat Loss
			F°	(BTU/hr)
Traditional Brick	59541	0.065	55	212439.51
Precast Panel	59541	0.064	55	209249.52

Difference	3189.99	
Boiler Load	6560000	**BTU**
Difference %	0.049%	

Mechanical Impacts (continued)

With a higher thermal resistance R-Value than the traditional system by less than .2 hr-sf-F/BTU, using precast has little to no effect on the overall thermal resistance of the exterior facade. The reduction in winter heat loss and summer head gain are both less than 1%, and thus will not positively or negatively benefit the loads to mechanical equipment. No necessary resizing of mechanical equipment is necessary to incorporate a precast façade.

Structural Impacts

The proposed insulated precast wall system manufactured by High Concrete would be an 8" thick precast panel with thin brick to match the masonry alternative. Panels would have a 3-inch exterior layer of concrete with brick inset, a 2-inch layer of extruded polystyrene insulation, and a 3-inch final layer of concrete. The concrete mix would consist of a 5000psi mix with welded wire fabric reinforcement throughout, #5 rebar at the panel perimeter and surrounding any openings, and a pre-stressed steel tendon at the central axis. Required slots for mounting and lifting would be cast as a part of the original product for timely erection in the field.

The original system of CMU back up and Norman brick was designed to pass gravity loads into the perimeter grade beams transferring them into the ground through the auger cast piles. The system is provided lateral support by the structural steel system at perimeter beam and column locations. The gross square footage of area to be replaced is 59,541 square feet. Using a weight of 45 pounds per square foot for this assembly, the total weight of the system is approximately 2,679,345 pounds or 1340 tons. The insulated precast system also is tied to the structure laterally and passes all gravity loads into the foundation system. The precast system weighs approximately two times that of the original assembly at 100 pounds per square foot totaling 2977 tons.

Wall System Structural Comparison

System	Quantity SF	Weight PSF	Total Weight (lb)	Total Weight (Ton)	
CMU & Brick	59541	45	2679345	1339.67	
Precast	59541	100	5954100	2977.05	
			DIFFERENCE	**1637.38**	**INCREASE**

As a result of this significant increase in load for the exterior wall system, an analysis of the existing foundation system was necessary to ensure it provides adequate bearing capacity. The grade beam carrying the load of the wall system was analyzed as a simply supported doubly reinforced concrete beam.

Structural Impacts (continued)

After further analysis of the existing foundation system, the grade beams were found to be sufficiently designed to carry the additional loads created by using the precast wall system. The table below shows a summary of the calculations performed to analyze grade beam A. For a complete set of calculations, please refer to Appendix D.

Load Analysis Summary for Grade Beam A

f'c= 4000 psi		
fy= 60 ksi		
w = 4800 plf		
Vu = 72 kips	ΦVn = 14.94 kips	F.S. = 4.8
Mu = 540 k-ft	ΦMn = 340.69 k-ft	F.S. = 1.59

Lateral load effects from wind associated with changing the wall system are unchanged as the system is still attached in the same way to the structural steel and has the same area.

Conclusion

After examining the results of this analysis, the panelized precast façade system meets or exceeds the existing façade system in all aspects but cost. Using precast has the potential to save 63 days on the schedule, remove the builders scaffolding from around the building footprint, allowing less congestion of trades and building enclosure to occur at an earlier date. Precast panels usually have a higher finish quality as they are constructed in a controlled environment and the imperfections of labor in the field are reduced.

While the precast system weighs slightly double that of the existing system, the existing foundation system is adequate to support this increased load. Lateral support is provided by the structural steel system as was the CMU and brick system requiring no added structural pieces. Mechanical impacts of incorporating precast are negligible as the heat loss and gain between the systems differ by less than 0.05%.

Cost is the only disadvantage to incorporating the precast system, which costs $3,572,460. This equates to an increase in cost of slightly over 67% from the existing system. When set against the overall cost of the project, using precast would show an increase of roughly 3.7%. Allowing other trades to perform work at an earlier date has the potential to reduce general conditions costs should substantial completion come an earlier date.

Using architectural precast to replace the CMU and brick façade for the Ambridge Area High School is a feasible alternative and could prove to be beneficial to the overall quality of the finished project.