2011

WESTINGHOUSE BUILDING 4

Final Report

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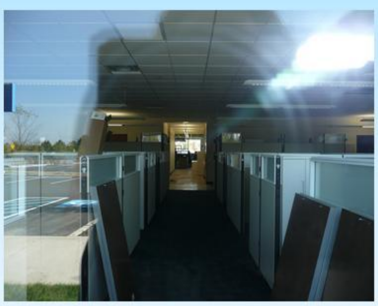
Jonathan Fisher CM
Westinghouse Electric Co. Building 4
Cranberry, Pennsylvania

Owner: The Ferchill Group, Chicago IL
Architect: LLI/IKM An Engineering & Architecture Joint Venture
Construction Manager: Turner Construction Company
Delivery Method: Design-Bid-Build
Stories Above Grade: 3 Stories
Cost: Private Information
Size: 121,905 SF

Architecture

- The building façade consists of a combination aluminum, insulated spandrel glass, and masonry brick systems
- Building layout is intended to maximize open floor space
- Building contains two stairwells, both insulated for 1 hr fire protection
- Each of the 3 floors contains 38,812 SF of usable office space

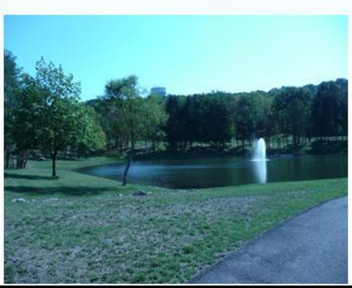


Structure

- Substructure: 60 Separate footings will be cast in place using 3,000 psi concrete
- Floors: The slab-on-grade and slabs in deck for floors 2 and 3 shall be poured using4,000 psi concrete
- Superstructure: Structural steel with wide flange shape with a minimum yield strength of 50,000 psi
- Roof: EPDM Membrane Roofing shall be used

Mechanical

- Air Handlers: 2 rooftop air handlers shall deliver a maximum of 105,600 CFM combined
- Air Conditioning: 2 rooftop evaporative cooling units shall be used to cool the building
- Sprinkler System: A standpipe sprinkler system shall be installed and will utilize a basement fire pump to attain proper sprinkler head pressure



Construction

- Project received it's Certificate of Occupancy 3 months early
- Project Duration: 13 months
- Site contains several nice fountains for occupant enjoyment
- Project insurance is OCIP

http://www.engr.psu.edu/ae/thesis/portfolios/2011/jmf5131/index.html

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1.0 Acknowledgements

In order for this project to be a success, input was required from different people in varying industries. Without their cooperation and input over the last two semesters this project would not have been possible. A special thanks to:

1.1 Westinghouse Electric Company

- Timothy Nowicki
- Stephanie Smith
- Dave Parente
- Phil Greco

1.2 Turner Construction Company

- Mike Weniger

1.3 Pennsylvania State University

- Rob Leicht
- Craig Dubler
- Tom Horensky
- Carl Hubbin

1.4 Solar Power Industries

- Bob Stoehr

1.5 Shockey Precast Concrete Group

- Bill Woody

2.0 Executive Summary

The purpose of this report is to provide building and project information on the Westinghouse Building 4 project as well as discuss three separate studies showing different aspects of the project. Areas of investigation include:

- Client Information
- Project background and history
- Project delivery system
- Key project team members
- Existing conditions
- Major building systems

In addition to the aforementioned topics, three analyses including: Using precast panels for the building façade, integrating a rooftop photovoltaic system into the building, and Using a Short Interval Production Schedule (SIPS schedule) to complete the building finishes. The combination of this building information and in-depth analyses will show how inefficiencies can be eliminated and sustainable practices can be incorporated into Westinghouse Building 4. These studies will also show how project duration and cost will be effected by changing the different aspects of the project.

2.1 Analysis 1

The first analysis conducted involves changing the façade of Westinghouse Building 4 from brick masonry to light-weight precast panels. This switch will eliminate waste and save time on the project. This activity is not on the critical path of the project so the savings will be in the material and labor costs of installation. By using a precast concrete panel it was found that the project team could save $84,000 and save about 22 days in construction time.

2.2 Analysis 2

Analysis 2 involves the integration of a rooftop photovoltaic array into the buildings systems. Generating a portion of the building’s power, the system would not only pay for itself in less than 15 years but also become a pinnacle in Westinghouse’s push to be seen as a “green” company. The up-front cost of the system would be substantial, but through grants from the government and utility company, the costs would be brought down to a manageable figure.

2.3 Analysis 3

The final analysis involves using a Short Interval Production Schedule, or SIPs schedule, to complete the interior finishes of the building. By using this type schedule 3 weeks could be saved on the project. This would equate to approximately $78,000 in general conditions cost, but would also allow Westinghouse Employees to occupy the building that much sooner. Early occupation of their new building would be a huge plus to Westinghouse because they are currently renting office space in other buildings while Building 4 is being completed.

3.0 Introduction

Westinghouse Electric Company has recently added 121,905 square feet of office space to their brand new headquarters facility in the form of a separate yet nearby building called Westinghouse Building 4. This new building is owned by The Ferchill Group out of Chicago, IL and is currently in its final stages of construction under the supervision of Turner Construction who is serving as the project General Contractor. The project is a 15 month project and is due to be occupied in early November of 2010. The Ferchill Group decided that a traditional design-bid-build delivery method would be most effective way to deliver this project. This was unexpected considering buildings 1, 2, and 3 on the same site were built in the past 2 years and to keep conformity amongst buildings a design-build delivery method might have been easier.

Westinghouse Building 4 is being built in Cranberry Pennsylvania in the Cranberry Woods office building complex. The building site can be accessed through the back entrance to the Westinghouse property. Being that Building 4 is in an office complex, rush hour times were avoided for truck deliveries. The township of Cranberry had major congestion problems involving route 79 and the PA turnpike exits that both emptied into the already busy streets of route 19. To fix this problem, the township of Cranberry added an extra lane of traffic on route 228 from route 79 that leads directly to the driveway of the Westinghouse Complex. This addition keeps all Westinghouse traffic from having to enter the streets of downtown Cranberry.

New construction in Cranberry Township is on the rise so construction companies and crews are abundant in the area. Westinghouse just completely its new main headquarters building just a few hundred yards from Building 4 so many of the subcontractors were able to continue work on this building after the main buildings were completed. Contractor parking on the site is no problem because the parking lots for the Westinghouse buildings were completed when the main headquarters was constructed.

A subsurface investigation was done at the site of Building 4 involving twenty four test borings. These tests revealed that the residual soil on the site will likely be able to be used as backfill, however pending laboratory tests the soil may require drying first. The geotechnical report also revealed that groundwater would likely be encountered during the excavation process. Subsurface drains and possibly pumps will be required on site during the excavation.

Figure 1 shows an aerial view of Building 4. Buildings 1, 2, and 3 are located directly to the South and many of the existing Parking lots will be shared by Building 4. As the picture shows, lie-down area and contractor parking was not an issue on the job.

Figure 1 shows an aerial view of Westinghouse Building 4.

3.1 Client Information

Westinghouse Building 4 is owned by The Ferchill Group, but is being built for the Westinghouse Electric Company. In recent years Westinghouse has expanded tremendously and required more office space for the employees.

Figure 2 shows the Westinghouse Emblem. The "Circle, Bar, W" is a well-known symbol of the company.

Westinghouse was forced to relocate from their previous building in Monroeville Pennsylvania due to zoning complications involving building additions. In the summer of 2009 Westinghouse employees began moving into their new home in the Westinghouse headquarters building 1, 2, and 3. During this move Westinghouse was still expanding faster than the pace of construction so additional office space was leased inside the Cranberry Woods complex. Out of necessity, due to this expansion, Westinghouse began immediate construction on Building 4 even before Building 2 and 3 were 100% complete. It is very important to Westinghouse that Building 4 is completed on time so they can begin moving out of their leased space and into their new building. In addition, having their employees in different buildings creates problems when scheduling meetings and other company events.

Schedule was the biggest factor for the Building 4 project in the eyes of Westinghouse. It was very important to the leaders of the company that their employees be able to move into the new building. All parties involved in the project held safety to the highest standards on the site as well. An Owner Controlled Insurance Program or OCIP was used for this project, which meant a city safety employee could be brought in as a third party safety manager on the site. Westinghouse is expanding very quickly right now largely due to their new safety systems that they are incorporating into their new power plant designs and the last thing they would want is negative publicity about safety on the headquarters buildings.

Cost and quality were also taken into consideration in the planning of this building. The cost was to be kept down while the quality was to be maximized and mimic that of the main buildings. The interior finishes and the general exterior facades of the building were also meant to be similar to those of the main 3 buildings. The keys to completion of the project in the owner's eyes are that it is finished and occupied on time. Furnishing the interior of the building on time and correctly running all low voltage technology wire are also key completion criteria.

3.2 Project Delivery Method

The Westinghouse Building 4 project is being delivered using a Design-Bid-Build delivery method. Turner Construction won the bid for this building and is carrying it out using lump sum contracts for the design team and guaranteed max price for all of their subcontractors. LLI/IKM is a joint venture architecture and engineering company and designed Westinghouse Building 4. Figure 3 below depicts this delivery method.

The traditional design-bid-build delivery method allows The Ferchill Group to have limited involvement in the project. This is important to them because they are based out of Chicago, IL. Subcontractors are local and were chosen on a lowest bid basis. Many of the subcontractors used for Building 4 also worked on Westinghouse Buildings 1, 2 and 3. The Ferchill Group owns all insurance policies for the project. The project guaranteed max price is based on a subcontractor breakdown of all of the system costs. Turner retains the ability to withhold 10% of all subcontractor contracts until 50% of the total project price has been completed. Subcontractors that complete their work early con apply for an early release of their retention should they so desire.

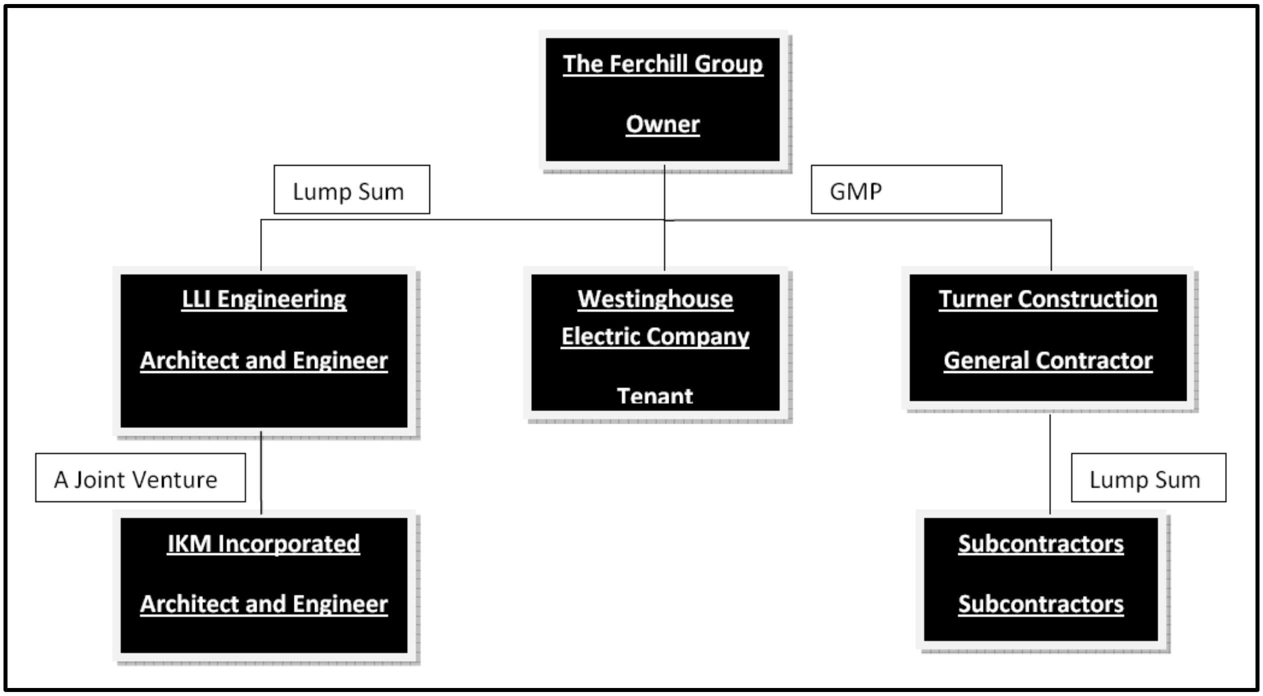


Figure 3 shows the Project Delivery Method used on the Westinghouse Building 4 project.

3.3 Project Staffing Plan

Figure 4 below is an organizational chart that shows the CM/GC staff and how they are assigned to the project. Turner Construction is the CM on the project and has a project executive that oversees the entire project and reports important information back to Turner headquarters. Directly reporting to the project executive are the project engineer and the project manager. The project manager spends most of his time behind the scenes ensuring that orders and materials arrive on time to the site. Reporting to the PM and reporting directly to the project executive is the project superintendent. This person is responsible for enlightening upper management of what is going on out on the jobsite. On this project there is also an assistant project manager that also reports to the project PM.

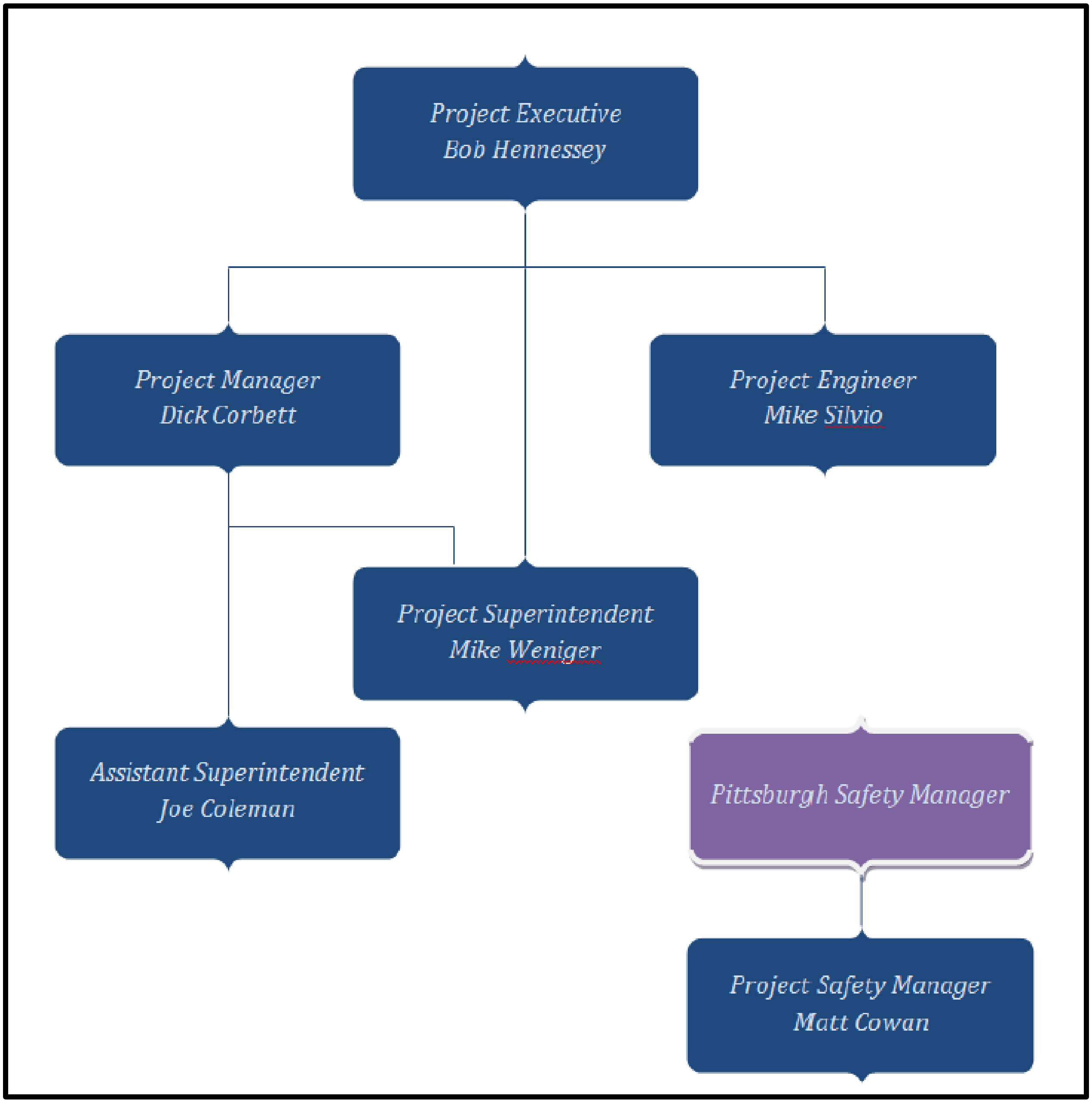


Figure 4 shows the Staffing plan that is to be used on the Westinghouse Building 4 project.

3.4 Site and General Architecture

When analyzing the site layout planning for this project there are several key elements that should be pointed out. Westinghouse Building 4 has a unique and valuable site for this project. Being a smaller project in a non-congested area, the building's workers were able to utilize the surrounding parking lots and space directly adjacent to the building. Shown on the site plan as the only major building sharing the site, Westinghouse Building 3 is owned by the same company and is thus more than happy to help out the project team and be accommodating in any way they can. Contractors on the job are allowed to park and store extra building materials outside the actual project property line which allows for less on site congestion.

The site plan shown was developed for the excavation and early steel erection phases of the project. A sloped cutback at the west side of the site allows for excavators and large equipment to enter the building footprint during excavation. Being the this excavation is only extending an average of 6 feet down this sloped cutback is all that is required and no additional equipment ramps are required. The 200 ton crawler crane that will be on site has an entire side of the building to itself to move back and forth along the building throughout construction. Any deliveries to the site will utilize the back entrance on the west side of the site and circle around the south of the building to drop their loads. This feature allows the north road of the site to be used only for dump trucks and concrete trucks to minimize traffic congestion around the site. Also, the site dumpsters and wood chipping area sit right next to the road to minimize the amount of site dump trucks have to traverse during trash removal.

All of the trailers and temporary toilet facilities sit onside the construction fence in the neighboring Westinghouse parking lot. This site features allows for enough space so that workers do not have to yell over the sounds of construction during meetings and close enough that walking to and from the bathroom is not a problem.

The temporary site power is a unique feature to the Westinghouse Building 4 project. Having just completed the first 3 buildings, Westinghouse was already planning for the fourth building to begin construction. The power supply shed on the site that feeds the main 3 buildings was constructed with the power hook ups for the fourth building. This made it very easy for the construction team to tap into the grid power to quickly set up the temporary power supply. This feature was also handy in the later stages of construction when the temporary power lines on the site were just simply converted to permanent ones.

Figure 5 below shows the site layout and depicts the different elements involved in the construction process. The figure also shows the distance and height relationship between Building 4 and Building 3. Considering these buildings are all part of the new Westinghouse Headquarters they will share parking spaces, communication lines, and power supplies. It is important to be aware of these relationships when analyzing Building 4.

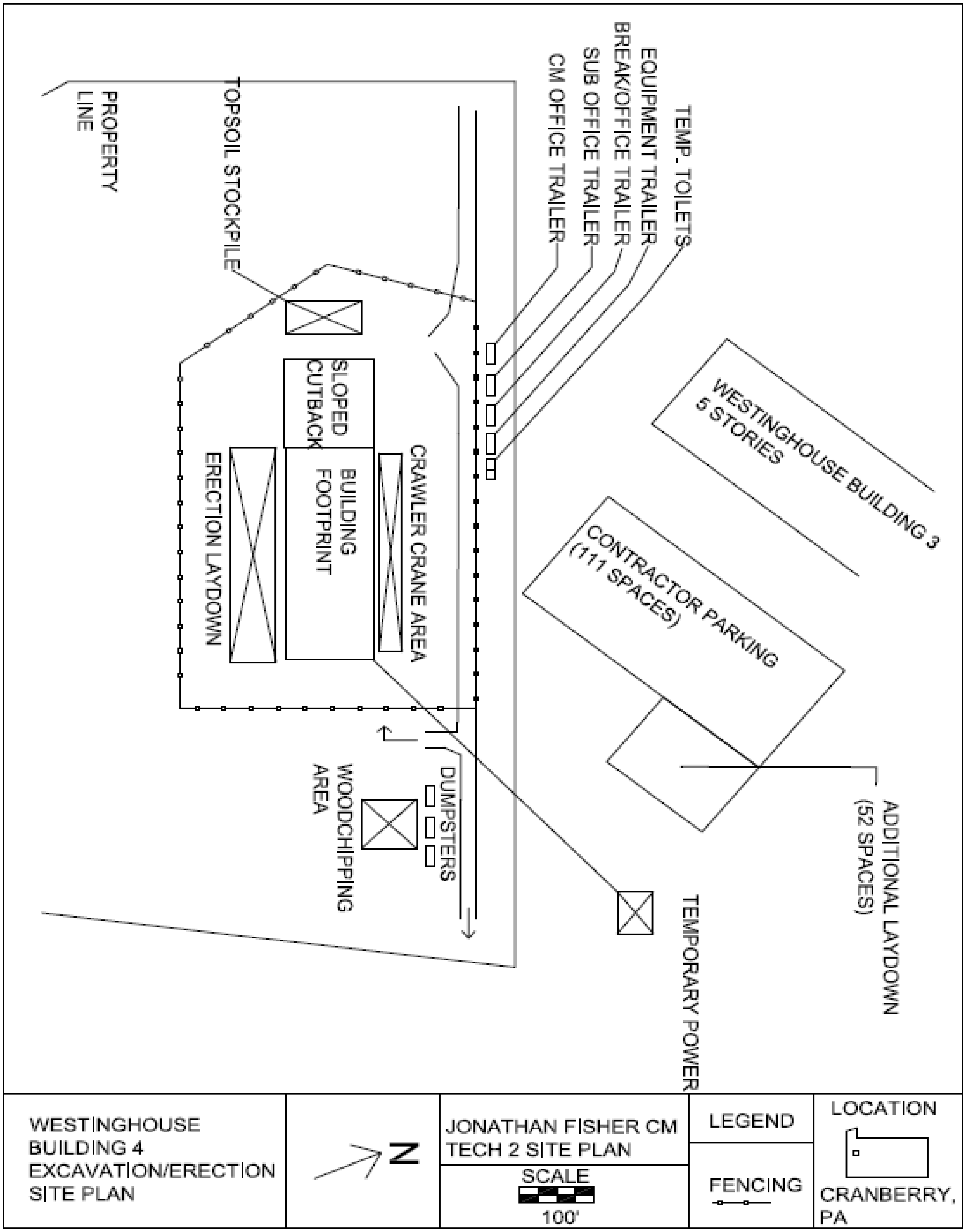


Figure 5 shows the site layout during the excavation phase of the project. This figure also shows the contractor parking and Building 4's location relative to Building 3.

3.5 Building Systems

Table 1 simply shows the different operations involved in the construction of Westinghouse Building 4.

YES	NO	Work Scope
	X	Demolition
X		Structural Steel Frame
X		Cast In Place Concrete
	X	Precast Concrete
X		Mechanical System
X		Electrical System
X		Masonry
	X	Curtain Wall
X		Support of Excavation

3.5.1 Structural Steel Framework: Structural steel frame is braced using L3X3X5/16 in a cross braced formation. The bracing is attached using typical wind moment connections. The 4 1/2" thick concrete that makes up each floor is reinforced using 4" high 3/4" dia. steel shear studs that are welded to the wide flange joists supporting the floor.

3.5.2 Cast in Place Concrete: Cast in place concrete shall be used in building frame elements, walls, foundations, slab-on-deck, slabs-on-grade, and mechanical equipment pads. The formworks for the CIP concrete shall conform to ACI 301 chapter 4 and ACI 347. All formwork is required to be supported underneath and never supported using the structural steel members of the building.

3.5.3 Mechanical Systems: There are 2 mechanical rooms on each floor of the building. These rooms are directly across the corridor from the stairwell on both sides of the building. The mechanical systems in the building include; 2 roof top air handlers, 2 rooftop evaporative cooling units, and a standpipe sprinkler system among many other systems. On every floor of the building there are several fire extinguisher hubs where personal fire suppression systems can be found.

3.5.4 Electrical System: Westinghouse Building 4 is fed by the utility company by a 1500 KVA transformer outside the building. The main switchgear of the building is a 3200A, 480/277V, 3PH, 4W, 65KAIC symmetrical system. The electrical rooms on each floor are fed 500A a piece through 2 sets of 4-500kcmil and 1 #1/0 GND all in 3” conduit. Once in the electrical room the electricity is distributed to the lighting panel board, general purpose and café panel board, and two electrical equipment panel boards. In the event of a power outage the building can be fed by a diesel generator outside the building. The generator can only deliver 600A to the building so only emergency and essential systems can be run on backup power.

3.5.5 Masonry: The exterior façade of Westinghouse Building 4 contains three separate layers of 4” polished masonry brick. The total square footage of masonry brick is approximately 19,440 SQFT appearing in 3 separate layers going up the building.

3.5.6 LEED Certification: The main LEED certification attempt with this building is in its large windows on each floor. These large windows are accompanied by light sensors on each floor, which automatically dim the lights during the day and save electricity. All areas of the building are also equipped with motion sensors to the lights are off while the building is unoccupied.

3.6 Structural System Summary

Westinghouse Building 4 utilizes a simple concrete spread footing substructure with a steel frame superstructure. Sixty footings total distribute the load from the floors above to the ground below. Table 2 below shows the total amount of material with the building. These quantities along with, which entity they came from allowed for the detailed structural systems cost to be done using RS Means Cost Works. To obtain these numbers a waste factor of 5% was used for the concrete and a waste factor of 10% was used for the formwork. All of the structural steel pieces would be cut via the shop drawings and no waste factor was applied.

Table 2 shows the total amount of the various structural materials required for Westinghouse Building 4

Material Totals		
System	Units	Total
CIP	CY	2772
Structural Steel	tons	442.812
Rebar	tons	30
Formwork	LF	9209

Table 3 shows the comparison between the estimated structure costs using the RS Means square footage estimate conducted in tech report 1 and the system costs using the RS Means Cost Works program. When looking at the results it is easy to see that the CIP estimate differs greatly. This anomaly occurs because the RS Means Square Footage Estimate only accounts for the concrete in the slab on grade. This leaves out a significant amount of concrete that lies in the building's footing, piers, and foundation walls. Had this extra concrete been accounted for it would be expected that the estimates would be much closer. The Structural Steel estimate however, is extremely similar in the two cases, only differing by 3 cents per square foot.

Table 3 shows a comparison between the structural system estimate conducted for tech report 1 and the estimate using RS Means Cost Works.

Structural System Cost				
	RS Means SF Estimate (Tech 1) Values		Cost Works Estimate	
System	Total	$/SF	Total	$/SF
CIP	$755,540.00	$6.24	$1,345,477.00	$11.12
Structural Steel	$1,686,787.00	$13.94	$1,682,598.00	$13.91

The structural steel in Building 4 is laid out in 7 different patterns. The system is very simple in general because this system is the same in is the same in all floor systems. Figure 6 shows the layout of the bays in a single floor and shows how the bays repeat themselves quite frequently. This repetition of bay and floor structural systems is a common feature of office buildings and buildings with congruent space uses on each floor. The building itself is symmetrical about its axis so it only make sense that its structural system would follow suite. It should be noted that the number 7 bays house the elevators and the number 5 bays house the vertical stairwells and mechanical runs.

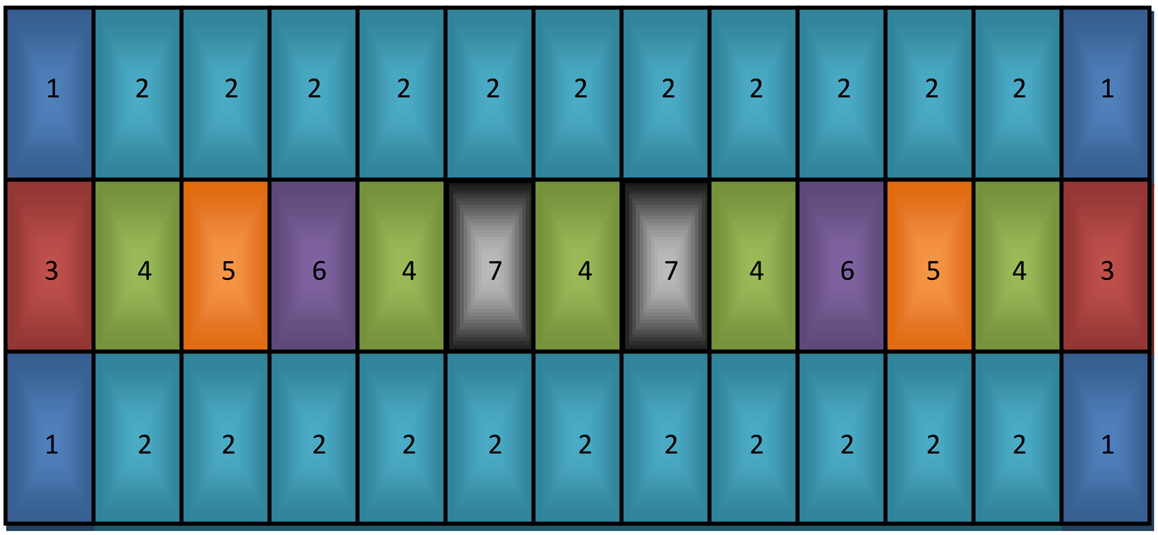


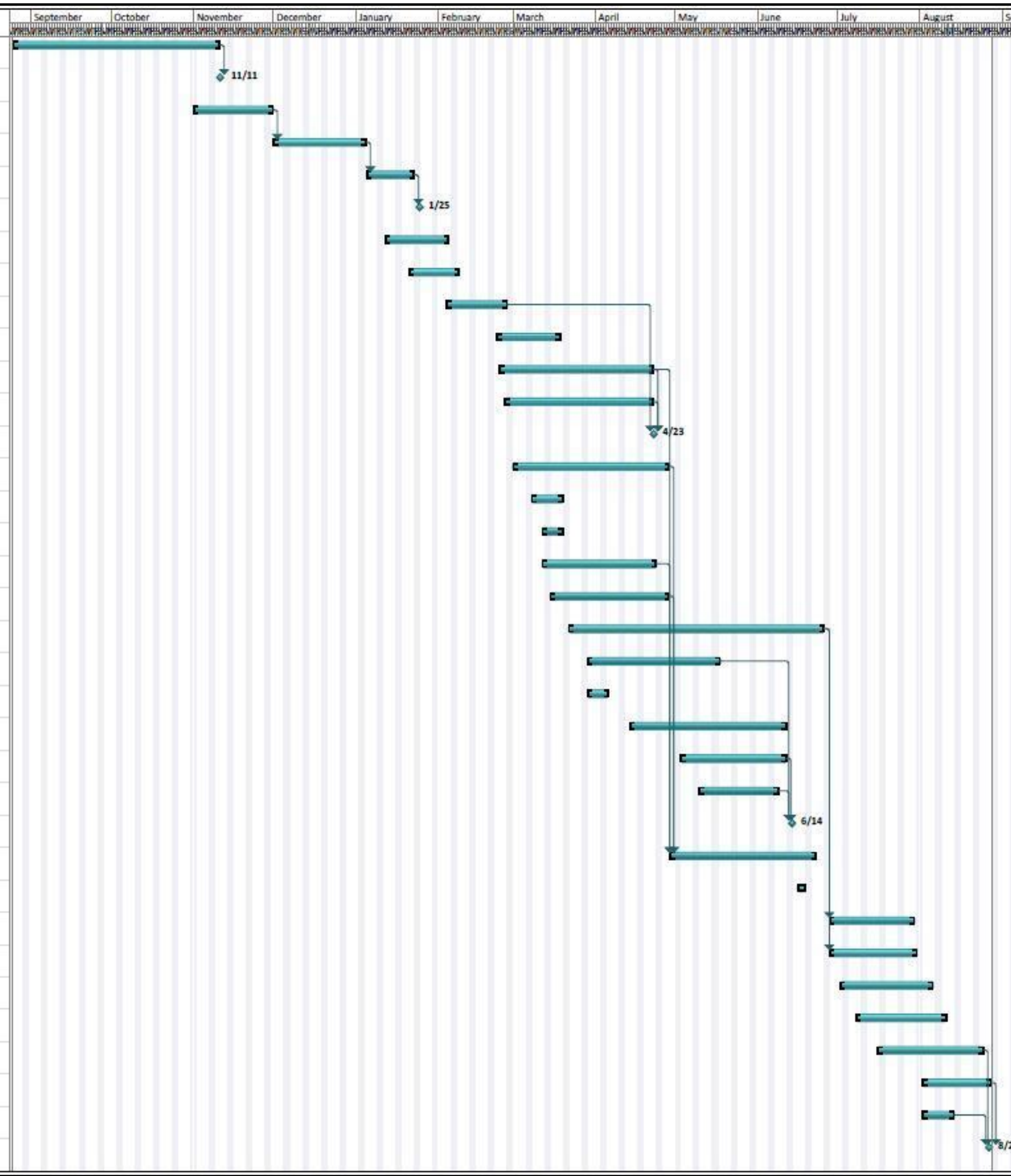
Figure 6 shows the labeling of the bays within Westinghouse Building 4. Repeating numbers represent identical bays.

When conducting the structural systems estimate using RS Means Cost Works the program assumes a value for equipment and Labor. This program also automatically assigns an appropriate value for the amount and size of rebar in each concrete quantity depending on its thickness and strength. Time and location factors are also automatically applied by selecting a start time of the project and project location. One assumption that was made during the concrete square footage was that the vertical shafts that run through the building were not subtracted from the square footage of the floors. This would only really come into play in the second and third floor because the roof and the slab on grade have fewer penetrations.

3.7 Project Schedule

The key element of the foundation on this project was the pouring of the slab on grade. The completion of this process meant that all of the foundation piles had been completed and steel erection could then begin. The placing of the last beam of the top floor of the building was a milestone for this project. Being that the building is only three stories high, the constructor waited until all steel erection was complete to move on to the steel decking placement on each floor. The Building Dry-In date was an important intermediate milestone on the project. The completion of the punch list was a major milestone of the finishes portion of the project. Completion of this process marked the ability to commence building startup and testing. A ghant chart showing the sequence of tasks is shown below.

ID		Task Mode	Task Name	Duration	Start	Finish
1			Design	56 days	Tue 8/25/09	Tue 11/10/09
2			Design complete	0 days	Wed 11/11/09	Wed 11/11/09
3			Excavation	22 days	Sun 11/1/09	Mon 11/30/09
4			Slab on Grade	25 days	Tue 12/1/09	Mon 1/4/10
5			Steel Erection	14 days	Tue 1/5/10	Fri 1/22/10
6			Steel Complete	0 days	Mon 1/25/10	Mon 1/25/10
7			Metal Deck	18 days	Tue 1/12/10	Thu 2/4/10
8			Stairs	13 days	Thu 1/21/10	Mon 2/8/10
9			Slab on Deck	17 days	Thu 2/4/10	Fri 2/26/10
10			SOFP	18 days	Tue 2/23/10	Thu 3/18/10
11			Ductwork	42 days	Wed 2/24/10	Thu 4/22/10
12			Interior Metal Framing	40 days	Fri 2/26/10	Thu 4/22/10
13			Interior Frame Complete	0 days	Fri 4/23/10	Fri 4/23/10
14			Sprinkler Mains and Branches	43 days	Mon 3/1/10	Wed 4/28/10
15			Sprinkler Standpipes	10 days	Mon 3/8/10	Fri 3/19/10
16			Remove Weather Protection	6 days	Fri 3/12/10	Fri 3/19/10
17			Electric Building Rough-In	31 days	Fri 3/12/10	Fri 4/23/10
18			Plumbing Rough-In	33 days	Mon 3/15/10	Wed 4/28/10
19			Drywall Tape and Finish	70 days	Mon 3/22/10	Fri 6/25/10
20			Masonry	36 days	Mon 3/29/10	Mon 5/17/10
21			Mechanical Piping	6 days	Mon 3/29/10	Mon 4/5/10
22			Set Efs 1-3	43 days	Wed 4/14/10	Fri 6/11/10
23			Glass and Glazing	30 days	Mon 5/3/10	Fri 6/11/10
24			Metal Panels	22 days	Mon 5/10/10	Tue 6/8/10
25			Façade Complete	0 days	Mon 6/14/10	Mon 6/14/10
26			Ceilings	39 days	Thu 4/29/10	Tue 6/22/10
27			Toilet Fixture Installation	3 days	Wed 6/16/10	Fri 6/18/10
28			Painting	24 days	Mon 6/28/10	Thu 7/29/10
29			Finish Power	25 days	Mon 6/28/10	Fri 7/30/10
30			Lighting	25 days	Fri 7/2/10	Thu 8/5/10
31			Flooring	24 days	Thu 7/8/10	Tue 8/10/10
32			Punchlist	28 days	Fri 7/16/10	Tue 8/24/10
33			Startup and Testing	20 days	Mon 8/2/10	Fri 8/27/10
34			Owner Training	10 days	Mon 8/2/10	Fri 8/13/10
35			Building Complete	0 days	Fri 8/27/10	Fri 8/27/10



4.0 Breadth Analysis #1: Analyze Existing Structure for Precast Fit Out

4.1 Problem Identification

Three strips of standard red brick and glass storefront alternate back and forth down the exterior of Westinghouse Building 4 to form an aesthetically pleasing building façade. The brick was placed by masons on site, which is a very time intensive and was an expensive process that involves excess waste materials and creates inefficiencies. To avoid these negative aspects of masonry construction, precast brick panels will be made in a controlled environment, shipped by truck to the site, and attached to the building using a crane and a custom attaching system.

4.2 Research Goal

The goal of this analysis is to create a faster more efficient method of combining and installing the façade system of the building. Ideally, the schedule and cost of the façade of the building will be reduced.

4.3 Methodology

- Research precast brick types and companies
- Research attachment methods of precast façade to existing building structure
- Contact industry professionals for advice on precast systems
- Contact precast manufacturers for design ideas and pricing
- Analyze any additional stress added to the structure
- Analyze schedule effects of having a precast façade
- Analyze the effect on the original problem with the facade
- Make any necessary changes to building structure to accommodate precast
- Research transportation option for the precast pieces

4.4 Resources and Tools

- ✓ Turner contact
- ✓ Industry professionals
- ✓ Structural Option classmates
- ✓ Shockey Precast Concrete precast manufacturer
- ✓ LLI/IKM Architects
- ✓ RISA structural analysis software
- ✓ Applicable literature

4.5 Expected Outcome

After analyzing all aspects of changing the building façade to precast, it should be apparent that precast panels are both, more economical and require a shorter amount of time to erect. Scheduling extra crane time will be required, but will not outweigh the other advantages of using the precast system.

4.6 Background

Westinghouse Building 4 was constructed just a hundred yard from the main headquarters. The initial conceptual design that the architect put together and was agreed upon, called for a less elaborate façade than the other buildings in the complex. It called for an all brick and glass façade with no real design twists. This was the design that Turner Construction budgeted for and bid on. Later, when the building design went before the design review board the initial façade design was deemed too simple. The board felt that the building would stand out as an aesthetic eye sore compared to the surrounding buildings. Buildings 1, 2, and 3 all incorporated layers of metallic panels in their facades, which added to the luster of the buildings. The board wanted to change Building 4's façade so that it more closely mimicked these surrounding building façade's.

When Turner and the architect went back to the drawing board another issue came up. Deciding who would pay for this added cost was a huge decision because the material cost of such panels would be around $120,000. Turner decided they would not try to charge the owner for this design change because they are a good client of theirs. Figure 7 below is a picture of Westinghouse Building 4. The added aluminum accents can be seen above the entrance way and all the way around the top of the building.

Figure 7 shows a picture of the exterior of Westinghouse Building 4. The 3 separate bands of brick are visible as well as the aluminum accents that had to be added to the building.

Precast construction is usually less expensive and shorter in duration. These two aspects of precast would be appealing to Turner becasuse it would give the company a chance to recover some of the cost of the added aluminum paneling. Also, precast construction is typically designed and built to a higher building code because the materials need to stand up against standard weather conditions and the rigors of transportion. Building codes can also differ between where the panels are built and where they will be installed. In this event the more stringent code is followed to ensure the most robust final product is produced. Quality and time are also more reliable with precast because the panels are constructed in a controled environment, out of the elements. Another benefit to precast is that it can come in a variety of shapes and colors. Different materials can also be used on the outer portion of the façade to give the exterior an advantage against different types of weather or sun conditions depending on the buildings location.

A main concern to precast, however, is its size and weight. These systems can be both heavy and thick which makes their integration into the building systems difficult. Tansporting large panels can also get very pricey because special trucks and permits are required to transport over-sized loads on public roads. All of these aspects of precast need to be considered before anctual system can be chosen and priced.

4.7 Panel Sizing

The façade on Wesintghouse Building 4 is comprised of 3 main bands of brick masonry. Due to different architectural features these rings are all different heights. In addition, the panels at the corners of the building would need to be 1'-10.75" wider than the rest of the panels in the band. This extra length is to allow the panels to extend out and cover the entirity of the corner column of the building. Figure 8 shows the layout of the building's façade and the height of the three bands of brick that would be replaced by precast panels. The verticle red lines show the placement of the columns in the building. As the diagram shows the center panels will all be 24' wide, but have varying heights. The top, middle, and bottom bands will be 3'-10 tall, 7'-5" tall, and 6'-1" tall respectively. Two layers of CMU block encircle the building at its base. These layers of CMU block will not be precast and will be installed as originally planned.

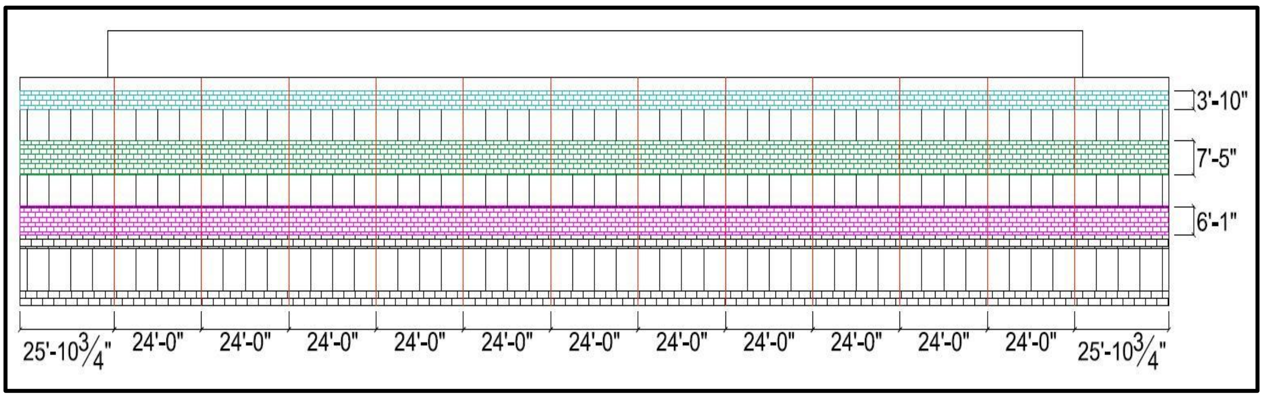


Figure 8 shows the layout of the proposed precast façade. The vertical red lines represent the building's columns and the colored brick sections represent the three different bands of brick.

Table 4 shows the size and quantity of precast panels that will be required in each band of brick.

Precast Panels				
	Length (ft)	Height (ft)	Quantity of Panels	Total (sqft)
Top Band	25.9	4.8	8	995
	24	4.8	28	3,226
Middle Band	25.9	7.4	8	1,533
	24	7.4	28	4,973
Bottom Band	25.9	6.1	8	1,264
	24	6.1	28	4,099
	Grand Total		108	16,089

Using this breakdown of panels all the way around the building yields a total of 108 separate precast panels. Table 4 shows the quantities of the different sizes of panels that will be ordered. Each band will require 8 panels of longer length for the corners and 28 panels for the interior portion of the façade. The top band, middle band, and bottom band of the façade will contain 4,221 square feet, 6,506 square feet, and 5,363 square feet of total area respectively. A minimum of an 80 ton crane will be required to lift these panels into place. The crane type will be a crawler crane and will move around the outside of the building as needed.

The panels will be prefabricated and shipped to site 10 at a time for 21 truck-loads. Because there is so much empty parking space around Building 4, delivery and lay-down will be no problem on the site.

4.8 Connection Detail

To avoid a structural redesign the existing parameters of the façade support system were analyzed. The existing façade is a 4" masonry brick façade that sits on an L7"X4"X3/8" bracket that runs along the length of the façade. There is a 4" gap between the brick and the back of the support that will allow for a total precast thickness of 8" before width becomes an issue. Through a system of structural steel, the weight of the façade is transferred to an exterior spandrel beam every 8 feet. Figure 9 shows the existing support structure and the components that stabilize and transfer the weight of the façade to the W24X55 spandrel beam.

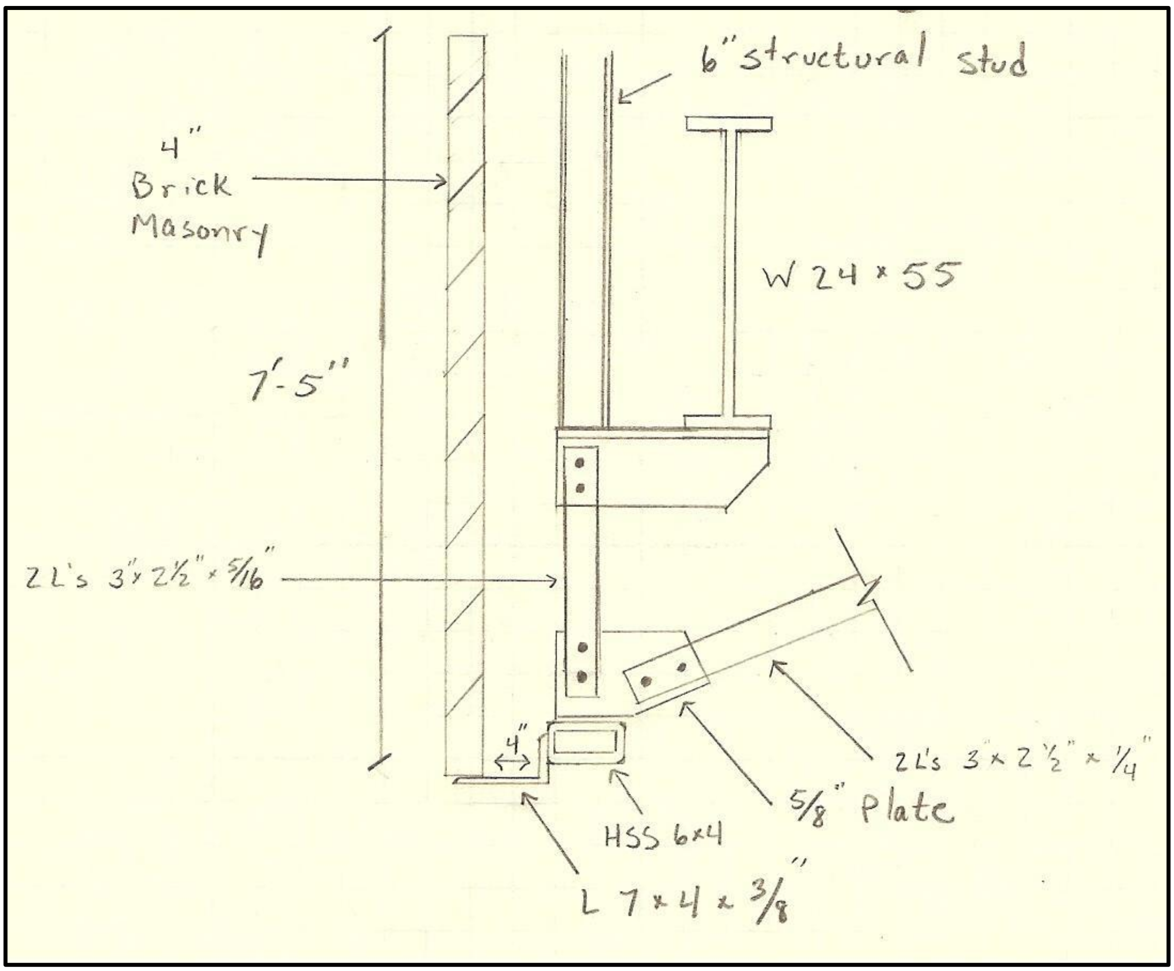


Figure 9 is a diagram of the existing support structure for the brick façade. This support system is spaced at 8' O.C.

Lateral support for the masonry wall is provided by a 6” structural stud that runs vertically 4” behind the masonry wall. These studs will be placed at 16” O.C. horizontally along the entire length of the façade. Ties will be placed at 16” O.C. vertically to adequately distribute the lateral pressures that the façade will create. The four inch gap behind the wall will also contain 2” thick rigid batt insulation, which will be the same requirement in the case of a precast façade.

4.9 Precast Selection

Choosing a precast system was difficult due to the criteria that it had to meet. Normal precast panels are ½” thick face brick with 6” or 8” of concrete backing to provide enough support for the system. This type of system weighs approximately twice what the current masonry façade weighs so this option would have required a complete structural redesign to support the added weight. The desired weight of the precast system had to be between 40-45 pounds per square foot or less. Also, the total thickness of the panels had to be 9” or less to allow for the 1” overhang at the end of the support flange, but not be so long that it interferes with the 6” structural studs. The precast system had to allow for, or provide the equivalent insulation characteristics as a 2” air gap plus 2” of rigid batt insulation.

A composite wall system designed by SlenderWall was chosen to form the theoretical exterior of Westinghouse Building 4. The composite wall is comprised of a ½” thick face brick attached to a 2” thick concrete and steel mesh backing. This system by itself would not be able to support itself safely so a 6” galvanized steel frame was added behind the concrete to provide the extra support. The challenge of this system was attaching the concrete to the steel supports, which have different coefficients of thermal expansion. To solve this issue the company developed a pivoting steel stud that is free the swivel as the two materials expand, contract or shift due to wind loading.

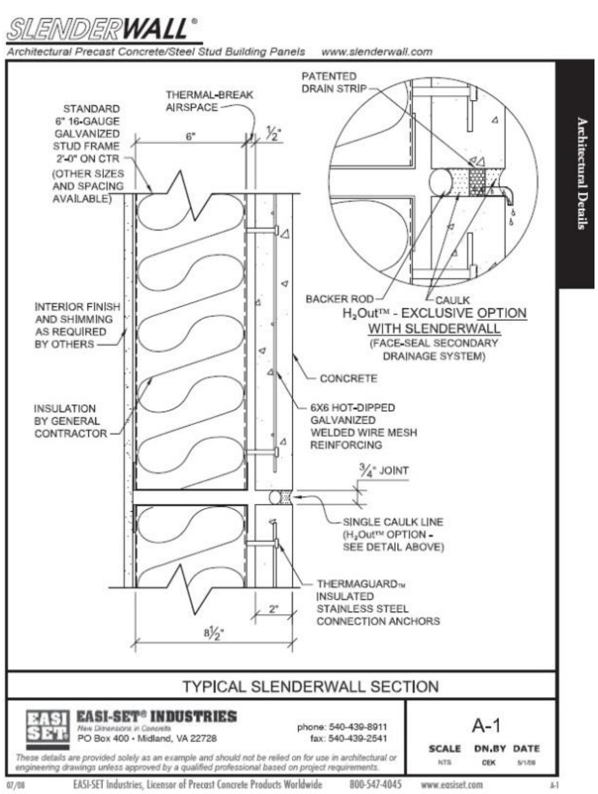


Figure 10 shows a typical wall section of a SlenderWall system.

Figure 10 shows a typical wall section of the selected SlenderWall design. The design incorporates all of the design features that will be crucial for meeting the design requirements. The main features required by the original structural system design that are met by this system are:

- ✓ 9” total thickness
- ✓ 2” rigid insulation space
- ✓ Less than 45 lb/sqft
- ✓ Easy connection to existing 6” structural stud

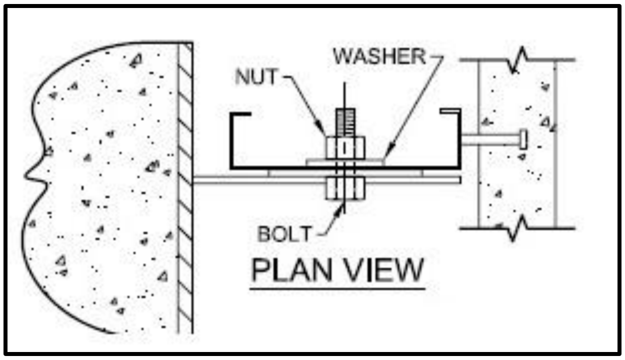


Figure 11 shows the plan view of the connection between the existing 6" structural steel stud and the 6" galvanized steel stud of the precast façade system.

Appendix A contains different sections and details that explain the basic design, layout and connections of the SlenderWall system. It also contains a connection diagram that shows how the new panels will connect to the existing 6" structural studs. ½" steel plate will attach to the existing structural studs and extend out toward the exterior of the building. These plates will be married to ½" thick steel plate that is attached to the 6" galvanized steel studs that make up the backbone of the façade. The two plates will be bolted together using two 1" bolts. These connections will be spaced at every 24" O.C. both vertically and horizontally. Figure 11 shows a plan view detail of a single support connection. The diagram shows the 6" galvanized stud and pivoting shear stud combination connected to one plate, while the other plate extends from the 6" existing structural stud.

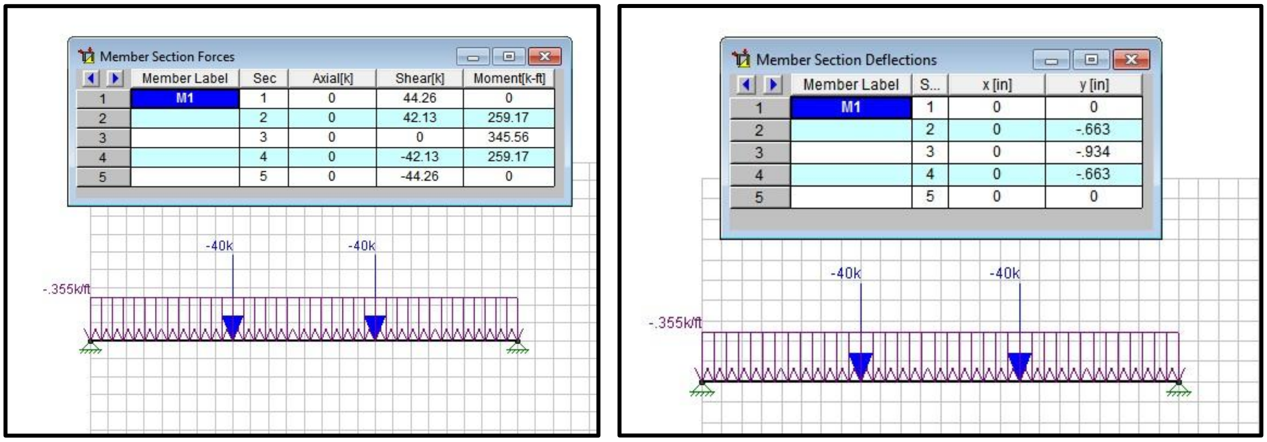
4.10 Structural Implications

A structural analysis was conducted to determine the beam forces, moments, and deflections under the weight of the masonry brick and the proposed precast system. First, hand calculations were done to find the Live and dead loads that would be acting on the floor inside the office building. These forces are transmitted to the outside spandrel beam through the floor girders that are spaced 8' apart. Next, the weight of the storefront glass system and façade were added to the spandrel beam as a distributed load. Maximum forces and moments were determined for the systems and compared. Being that the precast system is lighter than the masonry brick, the results of the calculations indicated that the proposed precast system would produce lesser loads on the structure and therefore the structure would not need to be resized. Table 5 shows a simple weight comparison of the masonry system and the precast system. As the table shows, the precast system will weigh 193,000 pounds less than the originally designed masonry brick façade.

Table 5 displays the weights of both the brick masonry and precast concrete systems.

Weight Comparison						
	Quantityof Panels	Masonry Unit Weight (lb/sqft)	Total Masonry Weight (lbs)	Precast Unit Weight (lb/sqft)	Precast Panel Weight (lbs)	Total Precast Weight (lbs)
Top Band	8	42	41,772	30	3,730	29,837
	28	42	135,475	30	3,456	96,768
Middle Band	8	42	64,398	30	5,750	45,998
	28	42	208,858	30	5,328	149,184
Bottom Band	8	42	53,085	30	4,740	37,918
	28	42	172,166	30	4,392	122,976
Total	108	42	675,753	30	482,681	482,681

It was determined that a load of 40 kips would be produced by the live and dead loads from inside the building. This quantity remained the same with both the masonry weight and the precast weight. However, a distributed dead load of .355 kips per foot was determined for the original masonry brick façade were the new precast system would only exert a force of .265 kips per foot. These quantities were used in a computerized analysis in RISA to verify the hand calculations and determine the beam deflection.

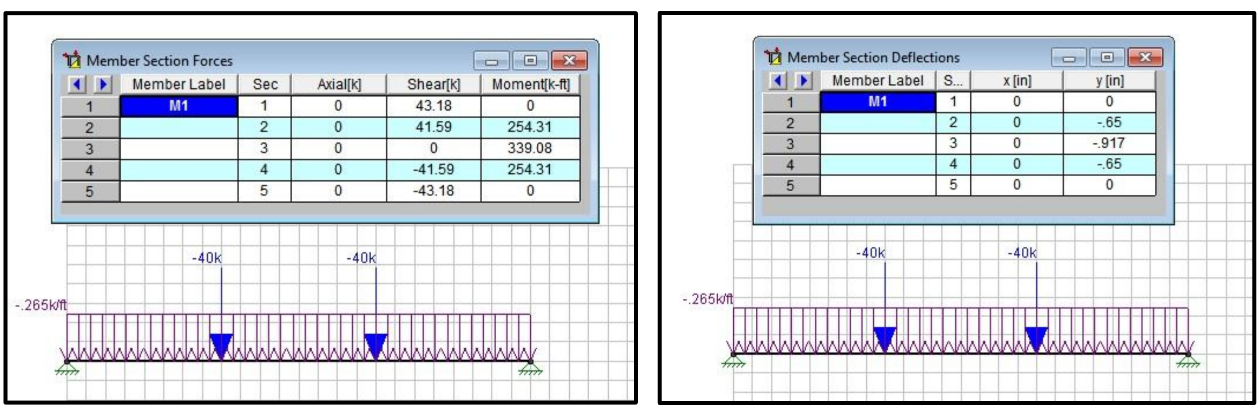


	Member Label	Sec	Axial[k]	Shear[k]	Moment[k-ft]
1	M1	1	0	44.26	0
2		2	0	42.13	259.17
3		3	0	0	345.56
4		4	0	-42.13	259.17
5		5	0	-44.26	0

	Member Label	S...	x [in]	y [in]
1	M1	1	0	0
2		2	0	-.663
3		3	0	-.934
4		4	0	-.663
5		5	0	0

Figure 12 shows the results of the RISA analysis for maximum beam moment (left) and max beam deflection (right) under the original façade load.

Figure 12 shows the results of the RISA analysis for the original masonry façade. It was determined through the RISA analysis that the total deflection of the exterior beam with the original masonry façade would be .934 inches. In doing the check for the deflection it was found that the beam would not pass the delta live load stipulations under the original loading conditions. It was noted that the structural engineer did not use the most stringent deflection limitations for the sizing of the W24X55 exterior spandrel beam. Since the original façade was masonry brick the exterior beam should have been sized using the most stringent deflection quantities. This would ensure that the masonry would not crack under the tension stress of deflecting support beam.



	Member Label	Sec	Axial[k]	Shear[k]	Moment[k-ft]
1	M1	1	0	43.18	0
2		2	0	41.59	254.31
3		3	0	0	339.08
4		4	0	-41.59	254.31
5		5	0	-43.18	0

	Member Label	S...	x [in]	y [in]
1	M1	1	0	0
2		2	0	-.65
3		3	0	-.917
4		4	0	-.65
5		5	0	0

Figure 13 shows the results of the RISA analysis for maximum beam moment (left) and max beam deflection (right) under the original façade load.

Figure 13 shows the results of a load analysis using RISA with the new loading conditions produced by the precast façade system. In this load case the distributed dead load produced by the building façade is only .265 kips per foot. Being that the precast system is .09 kips per foot lighter than the original system it was expected that the forces, moments, and deflections would be less with the new system. These predictions were verified by RISA and the new deflection in the spandrel beam was found to be just .917 inches. This calculation revealed that the proposed system still failed the delta live load check, but it was assumed that the system would still be acceptable because the overall deflections was less than the original system. Also, the new precast system has galvanized steel wire reinforcing integrated into the concrete. This steel reinforcing would cause the precast system to react much better in tension and thus further verify that the calculated deflection would be acceptable.

The hand calculation for the analysis of the spandrel beam can be found in **Appendix B.** These calculations include:

- ✓ Tributary area for both girder and the spandrel beam
- ✓ Reduced live load calculations
- ✓ Dead load calculations
- ✓ Force diagrams
- ✓ Moment diagrams

The results of the hand calculations were verified by the RISA analysis results.

4.11 Schedule Effect

Using a precast system would have great schedule benefits as the installation time for these systems is much less than standard stick built construction. After consulting an industry professional from Shockey Precast Concrete it was determined that approximately 8 panels could be installed each day using a 40 ton crawler crane. Table 6 shows the side-by-side duration comparison between the brick masonry and the proposed precast system. The chart is broken down by band of façade. It should be noted for this chart that only the reduction of time on site is shown. The panels will need to be fabricated and shipped to site, but these durations do not directly impact the construction so they were not taken into consideration.

Table 6 shows the comparison of construction time between the original masonry façade and the proposed precast system.

Duration Comparison				
	Quantityof Panels	Masonry Duration (days)	Precast Duration (days)	Schedule Reduction (days)
Top Band	8	2	1	1
	28	7	4	4
Middle Band	8	3	1	2
	28	11	4	7
Bottom Band	8	3	1	2
	28	9	4	5
Total	108	35	14	22

Using precast panels would save approximately 22 days in total. The majority of this time would be saved in the construction of the middle band. The middle band would contain the same number of panels, but they would be of greater size than the other two bands. Installing a greater square footage would, however, affect the duration of the brick masonry. This is why the greatest time delta occurs in the construction of the tallest panels. It is assumed that these panels can be shipped to site and set down in one of the many vacant parking lots while they wait to be installed. Keeping a steady flow of trucks is key to the success of installing the maximum precast panels each day. If trucks are delayed and the panels do not get to site then they cannot be installed as planned and thus the 8 panels per day would not be accurate. This added dynamic is something that would need to be closely monitored if precast panels were incorporated into the building façade.

The cost of 22 days of masonry labor could be saved using this precast system. However, the building façade is not on the critical path of construction so the overall construction duration would not be affected. Also, while the panels are being installed less manpower is required than with brick masonry. A crane operator and 2 masons would be required to hoist the panels into place and connect then to the structure. Given the connection type as explained above, a metal worker may also be required to ensure that the proper connections and bolt tension are applied to the new connections.

4.12 Cost Analysis

A cost comparison of a masonry façade versus a precast façade was done and the results are listed in Table 7 below. The masonry costs were taken from the RS Means cost estimate that was done earlier in the project. This total masonry contract was divided by the total square footage of masonry on the building then multiplied by the square footage involved in each band. The cost of the masonry was estimated to be approximately $47.24 per square foot for this project. That quantity covers both the material and labor cost of the original façade. Industry professionals estimate the finished and installed cost of a precast system to be just $42.00 per square foot.

Table 7 is a cost comparison between the original masonry façade and the proposed precast system.

Cost Comparison						
	Quantityof Panels	Masonry Unit Cost ($/sqft)	Masonry Total Cost	Precast Unit Cost ($/sqft)	Precast Total Cost	Cost Savings
Top Band	8	$47.24	$46,979.22	$42.00	$41,771.52	$5,207.70
	28	$47.24	$152,365.04	$42.00	$135,475.20	$16,889.84
Middle Band	8	$47.24	$72,426.30	$42.00	$64,397.76	$8,028.54
	28	$47.24	$234,896.11	$42.00	$208,857.60	$26,038.51
Bottom Band	8	$47.24	$59,702.76	$42.00	$53,084.64	$6,618.12
	28	$47.24	$193,630.57	$42.00	$172,166.40	$21,464.17
Total	108	$47.24	$760,000.00	$42.00	$675,753.12	$84,246.88

In total, it was estimated that over $84,000 could be saved by using a precast wall system. Seeing as the majority of the precast system is steel framing and concrete, the material costs should have been about the same, but money was definitely saved in the labor costs of the precast system. Also, because the precast system is fabricated in a controlled environment, quality control and schedule are much more easily regulated with a precast system. These savings could be used to offset the added cost of the aluminum accents that had to be added after the original façade was deemed too plain by the Cranberry Woods Complex management board.

More saving could be incurred by switching to a precast system if the beams were investigated and resized to a smaller size. This calculation would require in depth structural and steel calculations and was not investigated for this project.

4.13 Conclusion

In conclusion, it would be Turner's best interests to use a precast system for the façade of Westinghouse Building 4. The originally designed system contains enough space on the support flange to simply set the precast system right in the place of the masonry brick. The 4 inch gap between the outer edge of the support flange and the structural steel stud would provide for enough room to easily place the new 9" thick precast system. The 6" galvanized steel stud support structure of the precast would provide enough empty space to install the 2" of rigid batt insulation that the original design called for.

Because the precast system is lighter and reinforced with galvanized steel wire, the deflection in the spandrel be would be less and of lesser impact to the precast system. Resizing the beam or any other structural components would not be required, but could be done to investigate further cost savings. Without resizing any members the precast system still saves the project team an estimated $84,000, which would greatly help to offset the added cost of the building's required "flare".

Implementing a precast building façade will also save approximately 22 days on the projects schedule. This time could be reallocated to begin clean up and exterior landscaping to accelerate building occupation. As it stands, however, the building façade is not on the critical path of the project schedule and thus would not contribute to an early finish of the project.

Between the ease of implementation, schedule savings, and cost savings it would definitely save both time and money to use a precast system. In addition, an estimated 14 LEED credits could be obtained using precast on this project. Precast systems are recognized by their efficient use of both materials and energy in their construction.

5.0 Breadth Analysis #2: Installation of a Photovoltaic Array

5.1 Problem Identification

Westinghouse Building 4 is being built for the Westinghouse Electric Company, who advertises themselves as a ”green” power company because they design and build nuclear power plants. Being “green” and helping the environment ends for Westinghouse with their designing emission free plants. Advertising Westinghouse as a “green” company would go much further if the company could show that they are taking steps at their home office to utilize renewable energy sources in order to generate even more carbon free energy.

5.2 Research Goal

The objective of this analysis is to show that a photovoltaic array would not only pay for itself, but also generate profits over the systems lifetime. It will also be shown that a renewable electrical power source would be a valuable asset to Westinghouse as a “green” electric company.

5.3 Methodology

- Research possible PV arrays and their designs and layouts
- Calculate available square footage of roof space for PV array
- Calculate maximum electricity output in KWh
- Analyze roof structure and account for added weight of PV panels
- Alter construction drawings to incorporate PV wiring tie-in
- Determine time of return on the investment in the PV array
- Estimate total earnings over the lifetime of the PV array

5.4 Resources

- ✓ Industry Professionals
- ✓ PV manufacturers
- ✓ AE department specialist Dr. Riley
- ✓ Applicable literature

5.5 Expected Outcome

The results of this study will show that it is not only feasible to install a PV array on the roof of Westinghouse Building 4, but it is also an economically smart decision. A photovoltaic array will be able to recover its upfront cost over time and then begin generating positive revenue for the owner. The array will also prove to be a pinnacle in Westinghouse’s campaign to portray themselves as a green company.

5.6 Westinghouse Electric Company Interest in Solar Power Technology

The Westinghouse Electric Company is an engineering firm that designs the newest, most efficient, and safest nuclear power plants that are currently being built around the world. Recently Westinghouse has been taking advantage of the push for "green" energy sources in their TV commercials and advertisements for the company. They consider their industry "green" because nuclear power plants do not release any carbon dioxide in their production of electric energy. While Westinghouse is pushing the nuclear renaissance and emission free power, they are taking only limited steps in the sustainability of the company's home offices.

After interviewing several Westinghouse employees recurring trends with respect to solar technology popularity began to emerge. **Appendix C** shows the questions that the employees were asked with respect to a solar array being placed on the roof of Building 4 and the company's attraction to the idea. The first question asked the employees of Westinghouse what the company's "green" goals were. The general consensus was that the company wants to supply clean electric power, use environmentally friendly practices in their construction and operation, and even begin constructing LEED certified buildings in the future. These goals would all be met be some aspect of having a PV array installed on their buildings.

Question number two asked employees to state non-monetary benefits they felt a PV array would bring to the company. Improving public relations and intern relations were found to be the primary drivers of a solar endeavor. Since the Chernobyl and Three Mile Island nuclear incidents, Westinghouse and other nuclear energy providers have been trying to recover their image in the public eye. Right now green and sustainable technologies are being heavily publicized, which makes for a great opportunity for the company to receive some positive acknowledgement from the public. Also, green technologies are being pushed to the forefront of importance in schools and universities so attracting the next generation of employees by advertising the use of these technologies would benefit Westinghouse greatly.

Next, the employees were asked to comment on the relationship between nuclear electricity generation and solar electricity generation. Employees felt that knowing more about clean electricity generation beyond nuclear would be of great value. Part of the reason nuclear power is so clean is because the amount of material used per kilowatt generated is very small. This means less material needs to be mined, shipped, and burned in order to create the same amount of electricity. Similarly, solar power requires only sunlight to be productive. This low environmental cost to both systems would be an important selling point if Westinghouse were ever to integrate PV's into their nuclear power stations. In addition, knowing the costs and benefits of a small system like the one proposed for Building 4 would give the company an idea as to whether or not large scale PV arrays would be cost effective if they were ever installed at plant sites.

The next question employees were asked had to do with increasing demand for power and decreasing natural resource availability. Carbon based fuels supplies are constantly being estimated, but are also commonly considered unknown. Nuclear fuels are abundant, but require expensive enrichment processes to get the material up to the necessary grade. However, Westinghouse and other companies are already investing in spent fuel enrichment. This process involves taking the spent nuclear fuel and enriching it back to power grade material. Sustainable practices such as spent fuel enrichment show that the company cares about using clean practices to generate more power from every bit of material used. Again, since solar panels do not require any physical material to generate power they would be a beneficial part of Westinghouse's building and possibly even their power plants.

Finally, employees were asked to comment on the notion that smaller more abundant power stations would be more efficient than large widespread stations. This argument had two main sides. First, large power grids operate at about 50% efficiency with the majority of the losses being through the transmission of the electricity through the maze of distribution lines. Having smaller stations, even massive amounts of roof tops systems would cut down on these transmission loads and allow the grid to operate more efficiently. The other side of the argument is that power generation is much more efficient on a large scale rather than multiple small scales. Also, rooftop PV arrays are able to keep up with residential demand, but the small systems cannot yet keep up with the much larger demands of commercial buildings. However, employees did agree that if smaller more frequent generating plants were ever to be implemented; PV arrays would be the way to get the most out of the area required. These systems can be placed on the rooftops of buildings and do not require any major construction or substantial ground area, which makes them the most viable choice.

5.7 Photovoltaic Technology

Photovoltaic systems come in various shapes, sizes and complication level. The system chosen for Westinghouse Building 4 would be a monocrystalline wafer system. Monocrystalline wafer systems start as a molten bath of highly pure polysilicon and boron. The liquid is then slowly drawn and cooled so the final product is a large single sheet of silicon. This type of wafer has a typical efficiency of around 14% to 17% where its closest rival, the polycrystalline wafer system, only produces a top efficiency of about 14% at best.

To create a photovoltaic array many of these silicon wafers are combined into a module. These modules are then connected in series to one another to produce an array. By connecting the modules in series differing amperage and voltage across the modules can be easily combined to produce higher voltages and constant amperage. Figure 14 shows how this variation in volts and amps across a system relates to its total output. As the diagram shows, the voltages are added together while the amperage across the system would remain the same. This is an important key in this system because certain panels may be in the shade for parts of the day while others are in full sunlight.

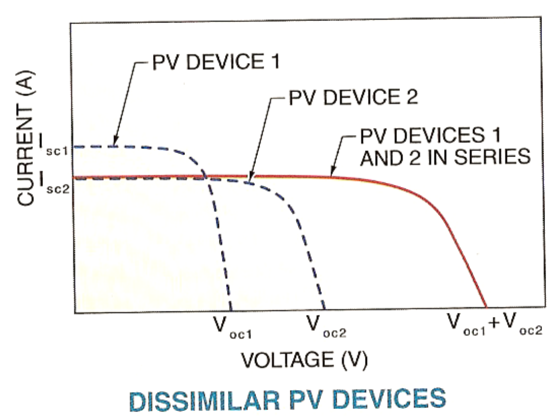


Figure 14 shows how connecting the solar modules in series will allow varying panel voltage and amperage to be combined into a steady and known electric energy source.

Since the panels will only output DC power, the next set in PV array design is integrating inverters and/or battery systems into a building. For the Westinghouse Building 4 PV array a Utility-

Interactive Inverter system will be installed. This type of system converts the DC power produced by the panels into AC power and puts it directly into a distribution panel that is also connected to the utility power. This system eliminates the cost and complexity of utilizing batteries in the system and allows the panels to directly supply power into the buildings systems. In addition, this type of system allows for sizing variance because the only limitations are space and owner budget. Since there are no systems directly relying on the PV array the system should be sized to maximize output with a given amount of space.

5.8 PV Practicality

Photovoltaic technology has come a long way in recent years in closing the gap between up-front cost and the rate of return. However, after interviewing Bob Stoehr from Solar Power Industries (SPI) it was made clear that the only practical way to utilize this technology is through government subsidies to help pay for the up from costs of the systems. Currently in the industry there are three main types of funding that help cover the costs of a photovoltaic array:

- Federal grants
- State money
- Utility funding through Solar Renewable Energy Credits (S-REC credits)

The funding that comes from these organizations is vital because without it the technology is almost cost prohibitive, which would stunt the advancement of the technology all together.

In recent years the federal government has been helping companies pay for these systems in an effort to reduce the United States' consumption of coal and natural gas. For building systems such as the one that would be installed on the rooftop of Westinghouse Building 4, the federal government will cover up to 30% of the cost. However, these federal funds are not received until after the system is paid for by the building owner.

Pennsylvania's government has programs in place on a state level that will help reduce the up-front costs of Photovoltaic systems as well. Unfortunately, this money has dried up in recent years, but the program does seem to run on a cyclical cycle so the funds could become available again in the near future. This is important to recognize because the programs in place when the array is built could be different than when the system is finished and the owner is looking for reimbursement. In addition to helping to pay for the system, PA state regulations inflate the cost of the system. Any solar array installed in PA that is over $25,000 is required to be installed using union labor. Union labor requires that every worker, from skilled craftsman to apprentice, be paid a prevailing wage of $50.00 per hour or more. This added labor cost to a project is considerable and is a large part of the reason that the installed price of the array is twice the cost of the system itself.

The final type of substantial financial help in paying for solar power systems comes from the utilities themselves. Federal regulations require utilities to produce about 1.5% of their electricity using renewable energy technologies. To calculate this percentage of energy utilities receive Solar Renewable

Energy Credits, or S-REC credits, based on how many megawatts of power they produce using solar technologies. One megawatt of power produced using solar technology is worth one S-REC credit and the number of credits required is based on the amount of electricity the company outputs every month. Not meeting the required number of S-REC credit can mean huge penalties for the utility companies. Helping to pay for rooftop systems like the one being placed on Westinghouse Building 4 is the cheapest and easiest way for utilities to meet these requirements without having to buy land and build whole solar farms themselves.

When all of these types of funding are available the cost of the system and the payback period are reduced significantly. However, these three sources of funds vary and fluctuate independently and can rarely be counted on to remain the same for long periods of time. To illustrate what a difference they can make, Table 8 shows the side by side comparisons in time to return using industry standards.

Table 8 shows the cost timeline of a theoretical photovoltaic system. This approximate cost/payback is used by industry professionals to estimate payback periods for their customers.

Estimated Cost of Photovoltaic Array				
120,000 kW system	Cost (per kW)	System Cost	Savings per year	Cost Recovery Time (years)
System cost (no funding)	$5.50	$660,000.00	$12,480.00	53
Federal Funding (30%)	$3.85	$462,000.00	$12,480.00	37
State and Federal funding (60% total)	$2.20	$264,000.00	$12,480.00	21
Utilities, State, and Federal funding (76% total)	$1.30	$156,000.00	$12,480.00	13

5.9 Solar Study

Designing the photovoltaic array for Westinghouse Building 4 began with analyzing the roof of the building. Extending from the roofs surface is a ten foot high aluminum rectangle that was added to both protect and hide the buildings mechanical systems from view. This aluminum wall both, decreases available roof space, and reduces the amount of light that hits certain areas of the roof. Figure 15 shows a sketch of Building 4's rooftop and the available space for PVs. The shaded area of the sketch shows the north facing portion of the roof that would be most affected by the aluminum structure. From this sketch it was determined that there is approximately 16,000 square feet of usable space on the building's roof.

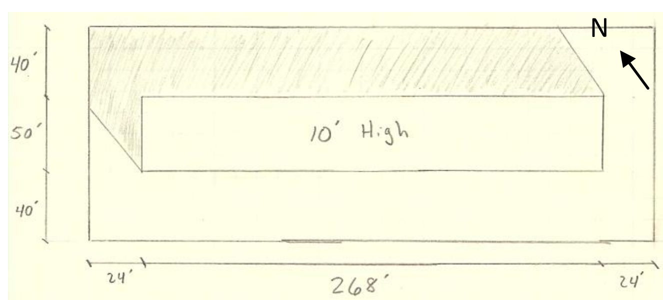


Figure 15 shows the available roof space and the area that will be most affected for the protruding aluminum walls on the roof.

Shadows cast by the protruding aluminum walls were of concern so a solar analysis was conducted. Summer and winter solstice dates of June 21, 2010 and December 21, 2010 were used to run the analysis. Sunrise and sunset times of the day were used in the analysis to determine the path of the shadow that would be cast over the available rooftop space. These solar analyses are shown below in Figures 16 and 17 and support that the proposed 16,000 square feet of rooftop space would be the best real estate for a PV array. To accurately calculate solar angles and durations a Sun Path Chart for 40 degrees north latitude was used and is depicted in **Appendix D**.

The first analysis conducted was of the winter solstice in Cranberry, PA. Cranberry sits at 40 degrees north latitude so the sun has an altitude angle of just 28 degrees during this time. Also, the sun is only above the horizon for 9 hours a day around this time of year. Due to the steep angle of the sun and the short duration of exposure this will be the least productive time for the panels. Small production during the winter months is not a crippling factor due to the interactive type system that is being used. During these months more power will be pulled off the grid to make up for the smaller amounts produced by the PV array. Figure 16 shows the morning and evening shadows cast across the roof during the winter solstice. When the sun rises, the aluminum wall casts a shadow towards the northwest corner of the roof. The shadow then creeps along the back side of roof until it settles on the northeast corner in the evening.

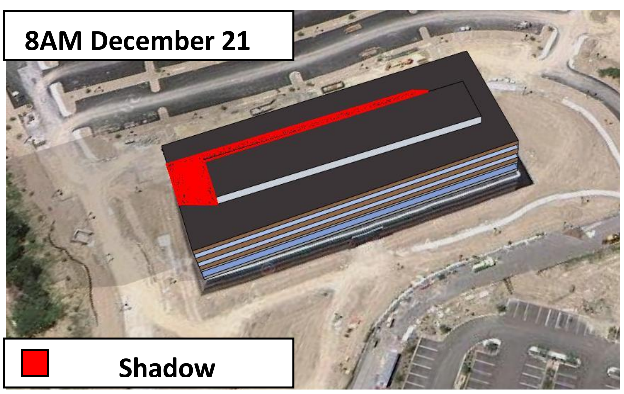


Figure 16 shows the solar path of the sun during the summer solstice. The picture on the left shows the shadow of the aluminum wall at sunrise and the right is the shadow cast at sunset.

Next, a solar study was done to show the shadows path during the summer solstice. This study was crucial because the majority of the PV array's power production is going to be during this time of year. The prime area of the roof is affected by the wall's shadow from approximately 5:30 AM until 10:00 AM. Even though some panels will be affected the entire array still has about 10 hours of production time throughout the day so the affect will be minimal. Also, PV panels can still remain up to 25% efficient when they are not directly facing the sun, which further reduces the losses during the peak production time of the year. Figure 17 shows the morning and evening shadows cast over the rooftop by the aluminum wall during the summer solstice. As the pictures show, the sun's azimuth range is much greater during the summer months. The sun rises 120 degrees to the East of South and sets 120 degrees West of South. This sun path creates the most dramatic shadow path during the year. As stated above, the shadow cast in the morning will be off of this south-facing section of wall by 10:00 AM during the summer months.

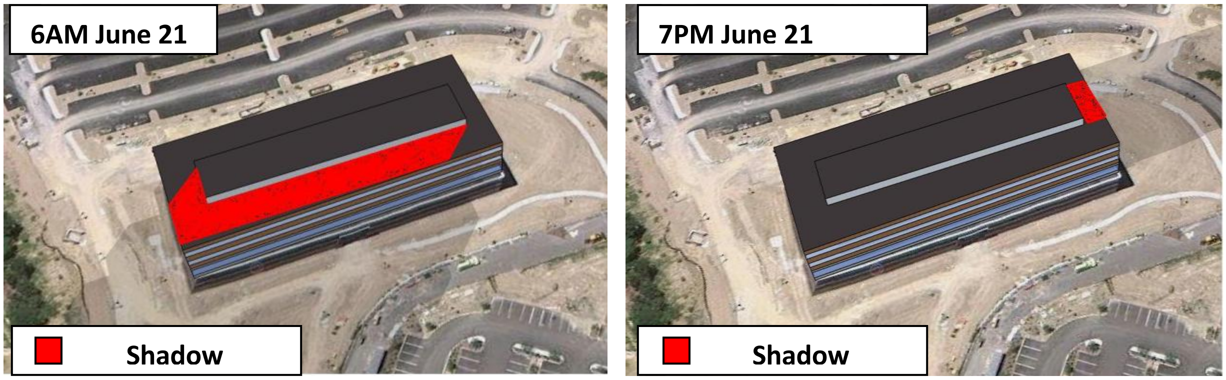


Figure 17 shows the solar path of the sun during the summer solstice. The picture on the left shows the shadow of the aluminum wall at sunrise and on the right is the shadow cast at sunset.

5. 10 PV Array Layout and Projected Production

Space and owner finances are the two main stipulations that go into designing a PV array. For the rooftop PV array for Building 4, approximately 12,000 square feet of area is available for prime sunlight conditions. This valuable, sun-soaked real estate lies along the south facing portion of the roof in front of the aluminum wall that sits atop the building. Westinghouse will be willing to invest the money in a PV array because they are a future thinking company that can see more benefit to the array than just the financial gains. Table 9 shows the design parameters for designing the solar array.

Table 9 shows the parameters used to design the rooftop array for Westinghouse Building 4.

Parameters for PV Design	
Location	Cranberry, PA
Latitude	40.7° N
Roof Orientation	Directly South
Available Roof Space	12,000 sqft
Roof Pitch	Flat
Solar Hours	4.4 kWh/m^2/day
Wind Conditions	Mild
Snow Loads	20 psf

Being that Building 4 sits at approximately 40° North latitude the panels should be angled at 25° from the horizontal in the south facing direction to optimize their solar catching capabilities. A rule of thumb for solar arrays is to place them at the same angle as matches the locations North latitude. This angle can fluctuate plus or minus 15° depending on when you are trying to capture the most sunlight. Since this array is not meant to power a specific building system it is best to optimize the fixed angle to capture the most sunlight during the summer months.

Of the 12,000 square feet of available space, 8,008 square feet will be purely PV used to generate electricity. Two and a half foot minimum walkways will be left around all panels to allow for installation and maintenance. To minimize rooftop design changes a self-ballasting racking system will be used on the rooftop. These systems are best utilized on flat surfaces because they do not require any roof penetrations to anchor the system. Instead, the weight of the system combined with concrete blocks is used to anchor the system to the roof. Industry professionals agree that self-ballasting systems require the desired roof to have a calculated live load of 5-6psf factored into the roof structure in order for the building to be safe. After discussing this with the project manager on site it was determined that the roof of Westinghouse Building 4 would not require any additional supports to safely handle the proposed PV array. The biggest danger to these systems is wind. Since, Building 4 has a 10' high wall protruding from it, backside wind on the panels will be at a minimum. Figure 18 shows the proposed the layout of the PV array on the rooftop of Building 4. This design maximizes the amount of power that can be generated by the system with the given space.

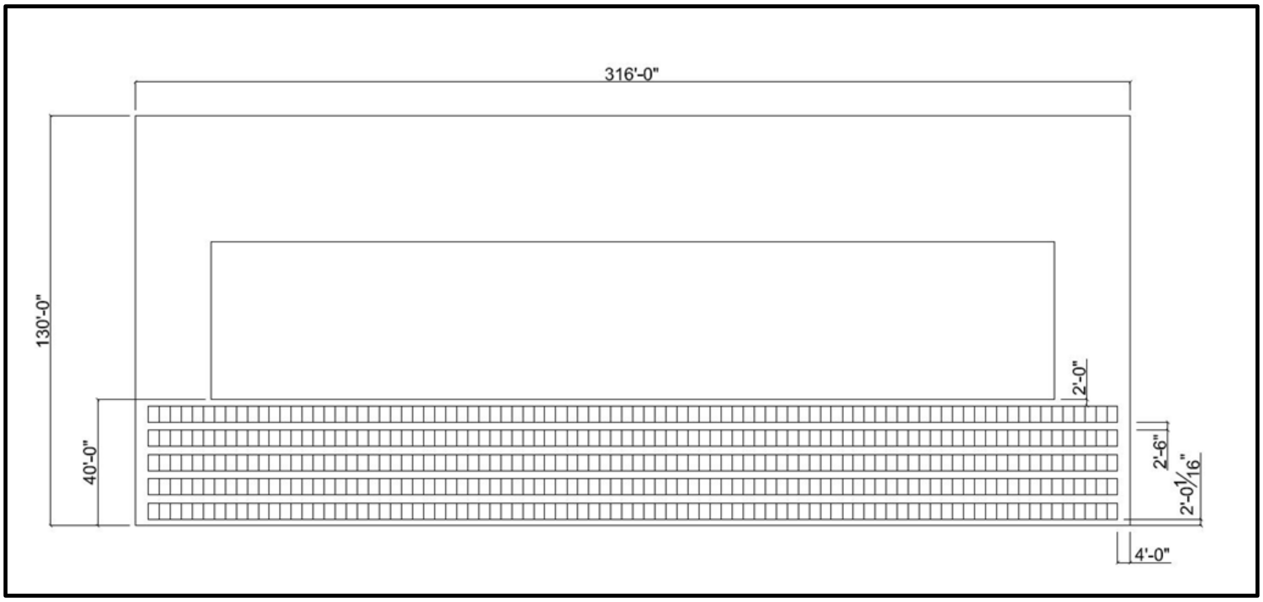


Figure 18 shows the proposed layout for maximum electricity production for the PV array.

For this particular array a 255W TPS105 solar panel from Topray Solar was chosen. The proposed system contains 440 photovoltaic panels capable of generating up to 4.41A at 41.67V a piece. Specific information on the chosen panels can be found in the panel specifications in **Appendix E.** Extrapolating this out over the entire system, a total of about 81kW of power could be produced by the system. Prime solar generating hours are between 9AM and 3PM on average throughout the year. This translates to about 5 hours of generating time per day. Given the latitude of the array and referencing the Solar Radiation chart from *Photovoltaic Systems* it is estimated that the 8,008 square foot system will be capable of producing 405kWh of electricity per day. The calculations behind these numbers can be found in **Appendix F.**

Assuming the average office building uses .0517kWh/sqft/day Westinghouse Building 4 would need a supply of approximately 6,300kWh of electricity each day to sustain itself. Since total building supply is not possible, a consumption study was done to try to isolate one building system that consumes approximately as much energy as the PV array will output. Figure 19 shows the average usage of power amongst the different systems in an office building. Lighting is by far the largest consumer of power and will be provided 24 hours a day in Westinghouse Building 4. Office equipment such as computers, printers, and phones are the next largest electricity loads consuming about 24% of the buildings total power. These loads are less because modern office equipment can put itself into "sleep mode" when it is not being used and thus will consume much less energy.

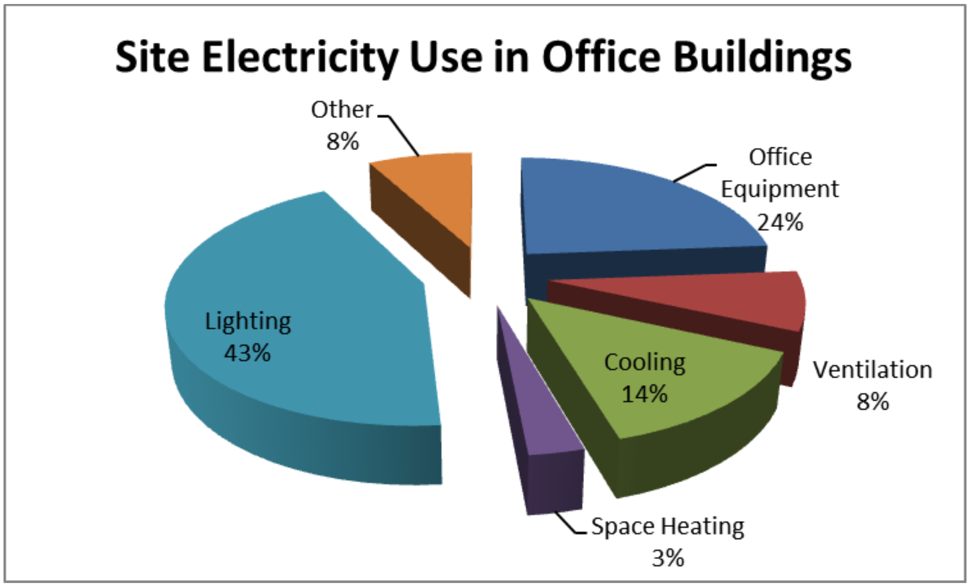


Figure 19 shows the breakdown of how office buildings use electricity.

Given these quantities and the hours of day that the array will be producing power, it is most practical to say the array will be able to substantially assist the building's ventilation load throughout the day. During normal work hours are when the most electricity can be produced by the panels and when the highest ventilation loads will occur. In the particular case of Building 4, the ventilation load would be about 500kWh and with the array producing 405kWh this is a fair assumption. However, as mentioned above, the power generated by the array will be tied directly into the main bus panel and thus will not be directed into any system in particular. Covering the ventilation system loads during the day is just meant to put usage and generation into perspective.

5.11 Electricity Generation and Utility Savings

Solar paterns and daylight hours changes throughout the year so a study needed to be done to determine how much electricity could be produced over the course of the year. Table 10 shows the results of the analysis. The prime solar months are during the summer around the summer solstice. During these months the PV array will be able to generate approximately 38% more electricity than it can during an average month. Decmber has the lowest generating potential with only 2.2kWh/m^2/day of solar radiation. During this month the array will only be capable of generating about half of its average output power. Although this is significantly less, December is also a large holiday month among Westinghouse

Table 10 shows the expected power output per day of the PV array during the different months of the year.

Average PV Electrity Produced in One Day			
Month	Solar Raiation	DC Energy (kWh)	AC Energy (kWh)
Jan	2.7	249	234
Feb	3.5	322	303
Mar	4.1	377	355
April	5.0	460	433
May	5.8	534	502
June	6.1	561	528
July	6.1	561	528
Aug	5.7	525	493
Sept	4.9	451	424
Oct	3.9	359	337
Nov	2.5	230	216
Dec	2.2	203	190
Average	4.4	403	379

employees and thus loads in the building will be less.

Allegheny Power will be the utility that supplies Westinghouse Building 4 with electricity. The commercial power rate in Cranberry, PA is $0.06/kWh of electricity. Over the course of one year the array would generate just under $8,400 assuming normal solar exposure throughout the year. Table 11 shows the expected savings per month from the electricity generated by the PV array. Westinghouse could use this information to forecast monthly overhead costs for their headquarters. Assuming the building uses a total of 6,300kWh of electricity a day, Westinghouse's average monthly total electric bill would be around $11,340. During the peak months of June and July the array would pay for approximately 8.4% of the overall electric bill of the building.

Table 11 shows the electricity savings over the course of one year due to the PV array.

Electricty Savings			
Month	AC Power (kWh/month)	Utility Electricity Cost	Savings
Jan	7,254	$0.06/kWh	$435.24
Feb	8,484	$0.06/kWh	$509.04
Mar	11,005	$0.06/kWh	$660.30
April	12,990	$0.06/kWh	$779.40
May	15,562	$0.06/kWh	$933.72
June	15,840	$0.06/kWh	$950.40
July	16,368	$0.06/kWh	$982.08
Aug	15,283	$0.06/kWh	$916.98
Sept	12,720	$0.06/kWh	$763.20
Oct	10,447	$0.06/kWh	$626.82
Nov	6,480	$0.06/kWh	$388.80
Dec	5,890	$0.06/kWh	$353.40
Total	138,323	$0.06/kWh	$8,299.38

5.12 Pay Back Period

The calculated annual savings can be assumed to continue over the 25 year expected lifespan of the system. Allegheny Power increases their utility rate by about 3.78% annually, so throughtout the lifespan of the system it will save more and more money each year. As mentioned above there are 3 types of financial aid to help pay for the high up-front cost of these systems. For this system in particular the payback period would be between 11 and 12 years of service. An addition area of cost savings is writing the system depreciation off in the company's taxes. For this particular system the write off would be a couple hundred thousand dollars, but the exact calculation of that value would be very complex.

With the Federal Government covering 30% of the up front cost and the PA State Government picking up another 6% the first month cost of the system falls from $834,000 to only $534,000. Unfortunitely, the full $834,000 would still have to be covered by Westinghouse during the system's installation. Solar Renewable Energy Credits (SREC) are credits paid by the utility company based on the output of your system. These credits start paying out in the fist year after the utility company can measure the amount of electricity being produced by the array. Allegheny Power generally pays about $300 per MegaWatt that your system produces. This helps them reach their requirement of 1.5% of their power generation being from renewable methods. The results of all of the savings types and generated electrical costs of the system can be seen in Table 12**.** Figure 20 displays this information as a bar gragh for quicker understanding of the payback period.

Table 12 shows the costs, returns, and financial aid information used to calculate the payback period of the system.

PV Array Payback Period						
Year	Utility Electric Cost (per kWh)	Savings	Fed. Gov. Funding (30% of Up front cost)	PA State Funding (6% of up front cost)	SREC Credit Money ($300 per MW for 10 years)	System Cost to Date
0	$0.06	$0.00	$0.00	$0.00	$0.00	-$834,000.00
1	$0.06	$8,299.38	$250,200.00	$50,040.00	$41,696.00	-$483,764.62
2	$0.06	$8,613.10	$0.00	$0.00	$41,696.00	-$433,455.52
3	$0.06	$8,938.67	$0.00	$0.00	$41,696.00	-$382,820.85
4	$0.07	$9,276.55	$0.00	$0.00	$41,696.00	-$331,848.30
5	$0.07	$9,627.21	$0.00	$0.00	$41,696.00	-$280,525.09
6	$0.07	$9,991.12	$0.00	$0.00	$41,696.00	-$228,837.98
7	$0.07	$10,368.78	$0.00	$0.00	$41,696.00	-$176,773.20
8	$0.08	$10,760.72	$0.00	$0.00	$41,696.00	-$124,316.48
9	$0.08	$11,167.47	$0.00	$0.00	$41,696.00	-$71,453.00
10	$0.08	$11,589.61	$0.00	$0.00	$41,696.00	-$18,167.40
11	$0.09	$12,027.69	$0.00	$0.00	$0.00	-$6,139.70
12	$0.09	$12,482.34	$0.00	$0.00	$0.00	$6,342.64
13	$0.09	$12,954.17	$0.00	$0.00	$0.00	$19,296.81
14	$0.10	$13,443.84	$0.00	$0.00	$0.00	$32,740.65
15	$0.10	$13,952.02	$0.00	$0.00	$0.00	$46,692.66
16	$0.10	$14,479.40	$0.00	$0.00	$0.00	$61,172.07
17	$0.11	$15,026.72	$0.00	$0.00	$0.00	$76,198.79
18	$0.11	$15,594.73	$0.00	$0.00	$0.00	$91,793.52
19	$0.12	$16,184.22	$0.00	$0.00	$0.00	$107,977.74
20	$0.12	$16,795.98	$0.00	$0.00	$0.00	$124,773.72
21	$0.13	$17,430.87	$0.00	$0.00	$0.00	$142,204.58
22	$0.13	$18,089.75	$0.00	$0.00	$0.00	$160,294.34
23	$0.14	$18,773.55	$0.00	$0.00	$0.00	$179,067.88
24	$0.14	$19,483.19	$0.00	$0.00	$0.00	$198,551.07
25	$0.15	$20,219.65	$0.00	$0.00	$0.00	$218,770.72
Total		$335,570.72				

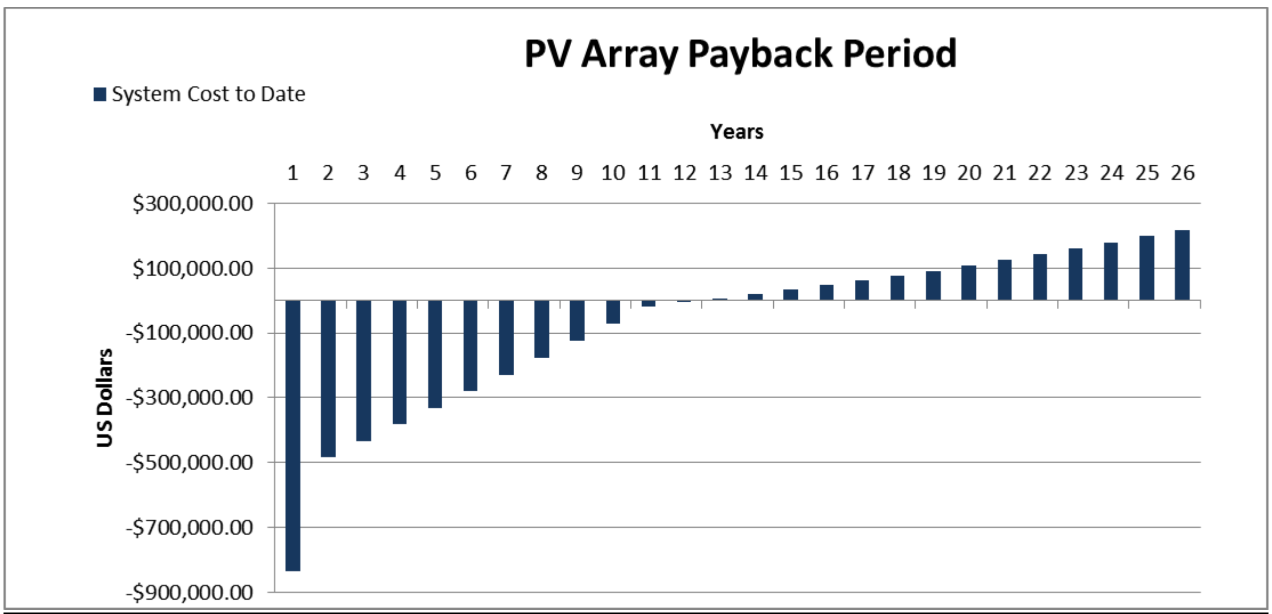


Figure 20 is a graph of the expected payback period of the PV array. These quantities are based on the values shown in Table 12.

5.12 Integration into Electrical System

Photovoltaic panels output DC power that must be converted into AC power through the use of inverters before it can be integrated into the building's electrical system. A Sunny Island 4280 inverter was chosen for this system. Each inverter can handle 4,200 watts of electricity, but for safety purposes only 3,680 watts will run to each inverter from the 20 panels that will feed into it. The calculations to support this can be found in **Appendix F**. Twenty two inverters handling 20 panels a piece will be required for the anticipated inversion of the electricity. The specifications for the selected inverters can be found in **Appendix E.** Three #12 AWG wires in ¾" EMT conduit will run from the panels, across the roof, down through the ceiling and into the 3rd floor electrical room where the inverters will be held. Once in the 3rd floor electrical room, the AC power can be connected directly into the 3rd floor distribution panel via the main panel bus. Three #10 AWG wires in ¾" EMT conduit will be used to transport this electricity from the inverter to the electrical bus. The calculations to support the wire and conduit sizes can be found in **Appendix F**. The 2008 National Electric Code was used for wire and conduit sizing. The array is only producing about 8% of the building's power so only connecting to the 3rd floor distribution panel would not be a problem. Figure 21 below shows how the wiring will be run from the panels to the 3rd floor electrical room.

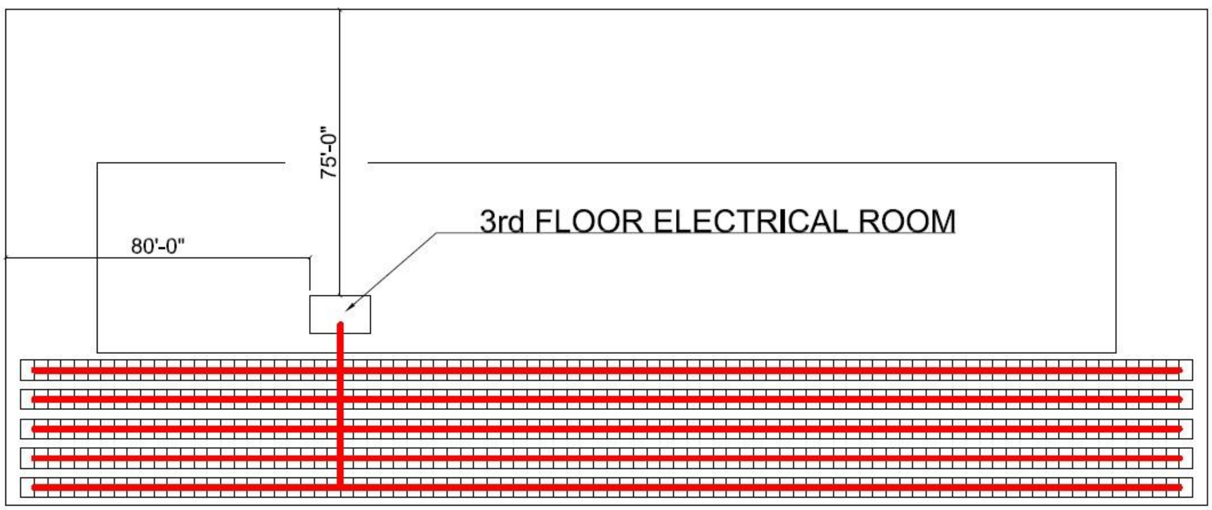


Figure 21 shows the wiring layout and location of the 3rd floor electrical room. Electrical wiring carrying the DC current will run into the 3rd floor electrical room where the inverters will be stored.

5.13 Conclusion and Recommendations

In conclusion, a photovoltaic array on the rooftop of Westinghouse Building 4 would be a great investment for the company to make. Through interviews with Westinghouse employees it is clear that the gains from a solar array would stretch far beyond just the financial aspects of the system. By displaying themselves as a "green" company in multiple fashions, the company could truly market themselves as a leader in utilizing sustainable technologies and zero carbon emission energy production. As mentioned in the interview analysis, if Westinghouse were to gain a more in depth knowledge of PV arrays and their capabilities, this technology could be integrated into the company's nuclear power plant systems to produce even more power.

The financial aspects of a PV array can be staggering due to the high upfront costs. However, with funding from the government and utility company these costs can be cut to a fraction of what they would be otherwise. Gains from the array would come over time and for a company like Westinghouse that plans to occupy this building for many years the system would pay for itself and potentially save the company more than $215,000 over its lifetime. Therefore, from a financial aspect this system would also be a wise investment.

After looking into PV arrays it was recognized that they do carry negative aspects as well. There are only a handful of suppliers and tradesman that have installed PV arrays. These systems need to be installed by experienced people to ensure the system output is maximized. Also, the panels and inverters can be very expensive and may need period replacing. These expenses should be covered in the system warrantee, but not always are. Also, after the 25 years of expected life PV array's output usually falls dramatically. After weighing the positive and negative aspects of a PV array it is clear that the system's pros would outweigh the cons.

6.0 Depth Analysis: Short Interval Production Schedule Development

6.1 Problem Identification

While their building was being completed, the Westinghouse Electric Company had to lease office space in another building a couple miles from their headquarters. This made it very inconvenient to gather employees and hold meeting. Westinghouse Building 4 sits right next to the headquarters, so moving into the building offers more than just financial gain for the company.

6.2 Proposed Solution

By using a Short Interval Production Schedule (SIPS schedule) for the finishes on the project, Westinghouse will be able to relocate their employees into the new building sooner rather than later. Since Westinghouse Building 4 is an office building, the building finishes are repetitive in nature and a SIPS schedule capitalizes on this attribute.

6.3 Solution Method

- Break down and analyze the original finishes schedule
- Section the building into smaller segments with similar finishes
- Set up a SIPS schedule for one area of the building
- Determine all materials, equipment and workers involved
- Calculate a reasonable amount of time per section and extrapolate
- Maintain a level resource schedule to achieve constant productivity
- Compare duration of SIPS schedule to the original duration
- Identify costs and benefits of implementing a SIPS schedule

6.4 Resources

- ✓ Original Project Schedule
- ✓ Westinghouse Building 4 Project Manager with Turner Construction
- ✓ Penn State AE Faculty
- ✓ Professor Craig Dubler
- ✓ AE 473: Building Construction Management & Control
- ✓ IHS 420: Fire Protection Engineering
- ✓ RS Means Cost Estimate Data

6.5 Expected Outcome

By using a Short Interval Production Schedule (SIPS schedule) the project duration will be reduced and allow the owner to move in earlier rather than later. It is important to Westinghouse to be able to move into their new building as soon as possible because they are currently leasing office space in another building while Westinghouse Building 4 is being completed. Turner Construction is the General Contractor on the project and would also be able to see financial gains from using a SIPS schedule because their general conditions costs would be reduced on the project.

6.6 Short Interval Production Schedule Overview

Short Interval Production Schedules (SIPS schedules) take advantage repetition to decrease the overall length of a project's schedule. This particular type of schedule usually only involves one trade, but in the case of Westinghouse Building 4 a "parade of trades" approach was taken for the schedule. A "parade of trades" is the use of a SIPS schedule across all of the trades involved in a project. SIPS scheduling techniques are usually used on projects such as office buildings, hotels, apartments, and even jails. Westinghouse Building 4 is an office building with similar areas and finishes throughout the entire building so it fits this bill perfectly.

As stated above a SIPS schedule utilizes the repetition of materials and layouts on projects, but it also takes advantage of workers becoming more efficient at the specific task that they are completing over and over. Workers become very familiar with their responsibilities they complete more sections of the building. This makes for fewer mistakes and sometimes even allows subcontractors to move on to re-works or punch-list items early, which further reduces the project schedule. SIPS schedules are also set up to give a subcontractor the entire area of the building to themselves. This eliminates "trade stacking" and subcontractor interference with one another and their different materials, tools, and equipment.

Creating a SIPS schedule requires an overall knowledge of the building and the different systems within it because the first thing that must be done is breaking the building into smaller sections. These sections must keep their repetitive spirit in order for the SIPS schedule to be effective. In the case of Westinghouse Building 4, the open office space of each floor was separated into 4 quadrants. These four areas were replicated on all three floors of the building creating a total of 12 building sections. The "core" of the building consists of small conference rooms, kitchenettes, and bathrooms that differ per floor so it was a slight concern in the creation of the SIPS schedule. However, the same crews will still be doing the same portions of the building so the work will still be repetitive in nature.

The next step in the process was doing a material takeoff for the quadrants. These material quantities were obtained by hand by closely following the building drawing set. However, the sprinkler branch and sprinkler head layout had to be assumed using general requirements for office building fire protection systems. Besides the fire protection system, material quantities were determined for: Gypsum wall board, ductwork, interior framing, plumbing and electrical rough-ins, acoustic ceiling tiles, paint, lighting, and flooring. These were the major finishing entities with the drywall being the SIPS schedule driver.

Finally, the SIPS schedule itself must be produced. This stage requires an in depth knowledge of the original project schedule as well as manpower and materials required to keep the project moving at the required pace. RS Means Cost Estimating Data can be used to help foresee production rates and adjust crew sizes as needed. The original project durations per trade were kept to a similar length to that of the original schedule. This ensures that the durations were reasonable and practical. The SIPS schedule developed for one zone of the building is then extrapolated out over all of the other zones to reveal the overall duration for the finishes of the entire building.

6.7 Project Constraints

Westinghouse Building 4 had to be completed by September 13, 2010 or Turner Construction would have to pay liquidated damages in Westinghouse for their continued leasing of other buildings and inconvenience charges for the delay of moving into their new building. Also, the finishes could not be put in until after the "Building Dry-in" milestone on the project. This would ensure that none of the interior finishes were damaged by moisture after being placed. Finally, extra will be left at the end of each week in order to facilitate any inspections that are required for items such as: in-wall checks, sprinkler system inspections, and electrical inspections.

6.8 SIPS Schedule Development

Each of the three floors in Westinghouse Building 4 was sectioned off into 4 quadrants for a total of 12 sections as shown in Figure 22. Zone 1 on the second floor was used to create the original SIPS schedule for the project. This quadrant had the fewest anomalies and could safely be used to give a

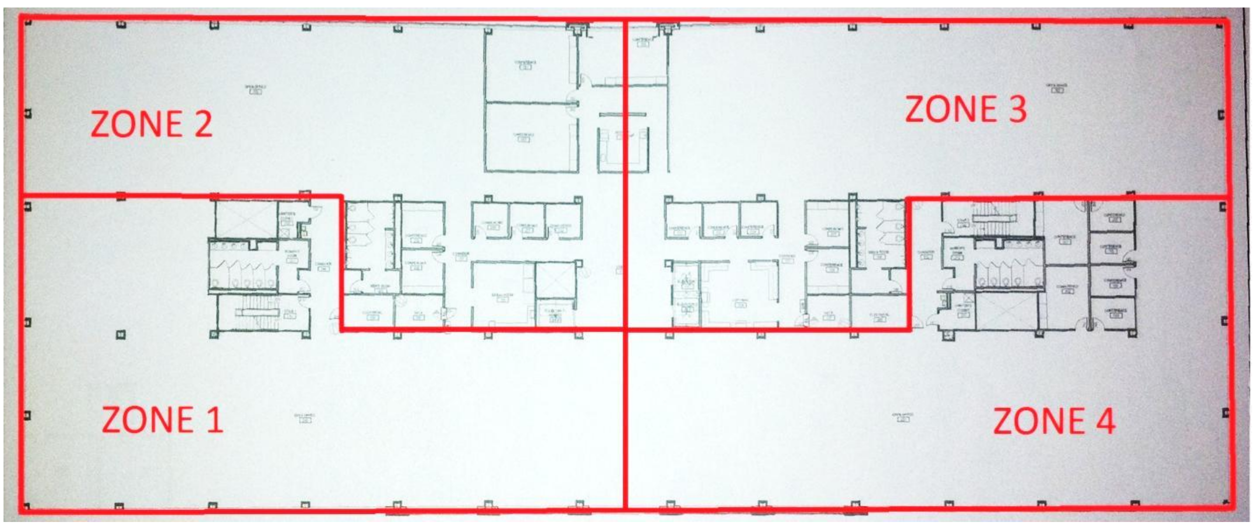


Figure 22 shows the layout of how the quadrants of each floor are laid out. All four zones are of comparable size with just slightly different orientations. The center or "core" of the building will not be completed using a SIPS schedule.

fair representation of the other areas. However, only zones 2 and 4 contain bathrooms so extra plumbing and casework will be required in these areas.

Table 13 shows a quantity takeoff and an associated manpower and process duration. These quantities were used and adjusted to mimic the durations of the original schedule. The calculations for these takeoffs can be found in **Appendix G.** This was a precautionary measure that was taken to ensure the schedule was actually possible and would still safely finish before the Building Turnover Milestone. In addition, RS Means Cost Estimating Data was utilized to calculate the crew size and daily output of the different tradesman. After speaking with the Project Manager on the site, it was determined that crew sizes had been adjust slightly to achieve the desired durations. This table also displays the matrix durations that will be assigned to each activity despite their calculated actual duration. This was done to

Table 13 shows the different entities that were required to successfully develop the associated SIPS schedule.

Material Takeoff for 1 Section								
Material	Material Description	Quantity	Units	Crew	Dainly Output	Crew Mult.	Total Duration	Matrix Duration
5/8" GWB	4'X8'X5/8" Gypsum Wall Board	5,133	sqft	6	360 sqft	2	7.1 days	10 days
Ductwork	Varying Sizes	727	LF	3	55 LF	3	3.8 days	5 days
Spinkler Branches	Branches	699	LF	2	53 LF	3	4.4 days	5 days
Sprinkler Heads	Consealed Overhead Sprinklers	57	Sprinklers	4	16 Sprin. Heads	1	3.6 days	5 days
Interior Framing	3 5/8" metal studs at 16"O.C.	336	LF	2	66 LF	1	5 days	5 days
Plumbing electrical rough in	Complete Necesssary Rough-ins	688	LF	4	70 LF	2	4.5 days	5 days
Ceilings	2'X4' Accoustic Ceiling Tiles	10,008	sqft	1	380 sqft	6	4.4 days	5 days
Painting	PPG 'Heavy Cream 314-2' Eggshell Finish	5,133	sqft	1	2750 sqft	1	1.9 days	4 days
Lighting	Direct/Indirect Pendant Lighting	146	Lights	1	5 lights	6	4.9 days	5 days
Flooring	Mohawk Commercial Floor tiles	10,008	sqft	1	720 sqft	3	4.6 days	5 days

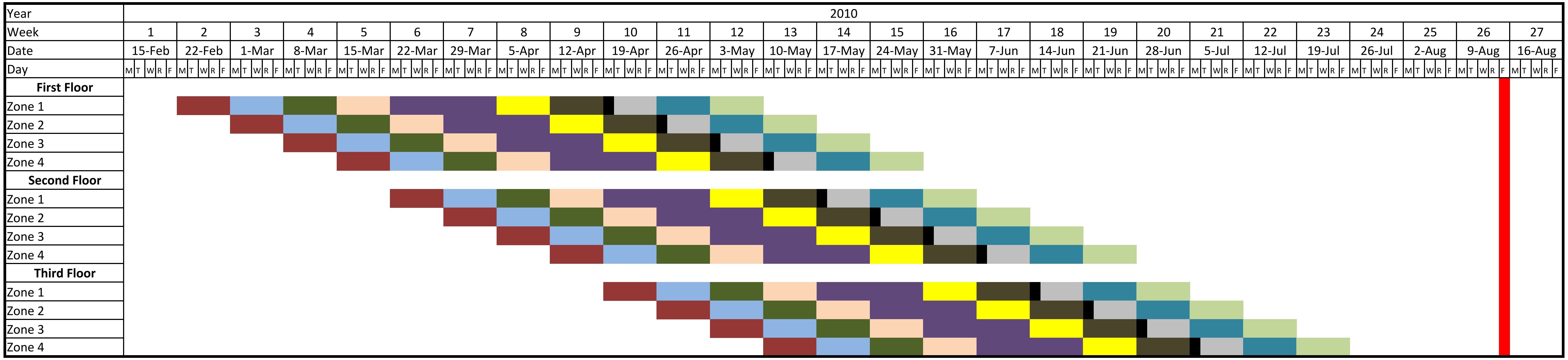
ensure enough time for any mistakes, re-works, or additional effort that was required for each trade. One area this was especially evident was in the painters duration. The 1.2 days allotted for the painting does not include prepping the area, touch-up, trim painting, or time allotted for the area to air out before the next crew come in. The additional time was added into the matrix to ensure that none of the issues became an imperative problem to the schedule.

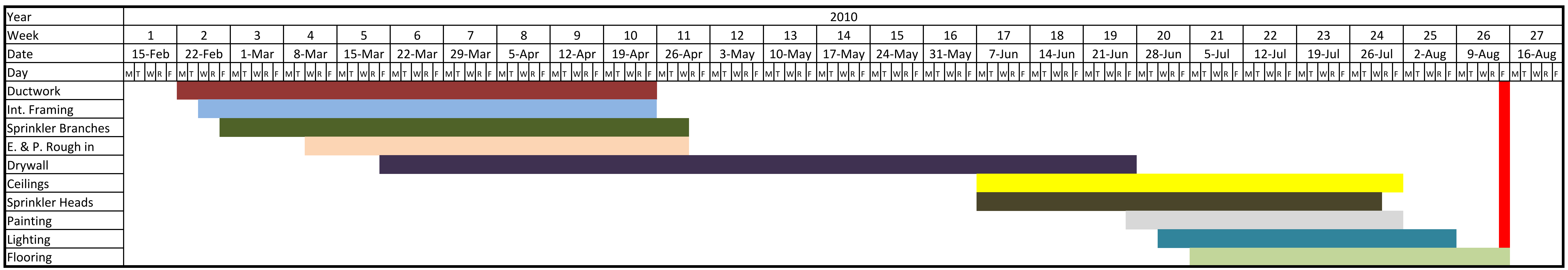
After establishing the matrix durations, the sequence and matrix schedule were produced. The sequence used closely followed that of the original schedule to be sure that the sequence was possible and practical. Figure 23 below shows the sequence and color coding of the different operations that are to be performed.

The side-by-side comparison of the original schedule and the SIPS schedule on the next page clearly illustrates the gains from using this type of schedule. The thick red line indicates the original interior finishes completion date.

SIPS Schedule Key		
Order	Color	Activity
1		Ductwork
2		Interior Framing
3		Sprinkler Branches
4		Elec. & Plumbing Rough In
5		Drywall
6		Ceilings
7		Sprinkler Heads
8		Painting
9		Lighting
10		Flooring
11		Unforeseen Delays

Figure 23 shows the sequence and color coding that will be used in the SIPS matrix.


Year
2010
Week
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27
Date
15-Feb 22-Feb 1-Mar 8-Mar 15-Mar 22-Mar 29-Mar 5-Apr 12-Apr 19-Apr 26-Apr 3-May 10-May 17-May 24-May 31-May 7-Jun 14-Jun 21-Jun 28-Jun 5-Jul 12-Jul 19-Jul 26-Jul 2-Aug 9-Aug 16-Aug
Day
M T W R F
First Floor
Zone 1
Zone 2
Zone 3
Zone 4
Second Floor
Zone 1
Zone 2
Zone 3
Zone 4
Third Floor
Zone 1
Zone 2
Zone 3
Zone 4


Year
2010
Week
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27
Date
15-Feb 22-Feb 1-Mar 8-Mar 15-Mar 22-Mar 29-Mar 5-Apr 12-Apr 19-Apr 26-Apr 3-May 10-May 17-May 24-May 31-May 7-Jun 14-Jun 21-Jun 28-Jun 5-Jul 12-Jul 19-Jul 26-Jul 2-Aug 9-Aug 16-Aug
Day
M T W R F
Ductwork
Int. Framing
Sprinkler Branches
E. & P. Rough in
Drywall
Ceilings
Sprinkler Heads
Painting
Lighting
Flooring

6.10 Costs and Schedule Impacts

After constructing and analyzing the SIPS schedule and comparing to the original duration it was determined that the finishes schedule could be cut from 25 weeks down to 22 weeks. An earlier report indicated that general conditions costs for Turner Construction for this project would be around $26,000 per week. This means the company could potentially save around $78,000 in general conditions costs by opting to go with a SIPS schedule on the finishes. However, it was also noted in creating this schedule that the individual trades will be required at the job for a longer time than what was stated in the original contract. Also, the value of having these extra 3 weeks would be of great value to Westinghouse because it would enable them to move their employees that much sooner.

6.11 Conclusion and Recommendation

In conclusion, the benefits of using a SIPS schedule on the finishes of the building would be an overall benefit to the owner and the constructor. The repetitive nature of the finishes would allow the utmost in productivity and greatly reduce the number of unforeseen errors. However, because the building in only 3 stories tall and the core of the building varies per floor, there would not be as much room for a learning curve in the processes. The variations per floor in the core could cause confusion and cost extra time on the project if complications arise.

In this analysis there was time saved on the project. The time saved by using this schedule would also allow for 3 weeks of overall project float. These three weeks would ensure that the project team had ample time to deal with delays, finish punch list items, or force majeure events that could have happened earlier in the project. Considering the emphasis put on the Turn-Over date this extra time would ensure that there was no overtime or last minute crunching involved on the project.

As stated above, the largest benefit to the early completion of the building would be the ability for the tenant, Westinghouse Electric Company, to enter the building early. The company is currently paying $5,000 per day to rent office space in another building for its employees. This matter is both expensive and inconvenient for the company and having an early move in would be of great value.

Finally, there are great benefits to be had for both Turner Construction as the constructor and the Westinghouse Electric Company as the building in owner in using a SIPS schedule to complete the finishes on the Westinghouse Building 4 project. There would be challenges with using the “parade of trades” technique of completing the project but having a detailed schedule laid out with help the trades work through these challenges. The benefits in using a SIPS schedule are both monetary and none monetary and are outlined in Table 14 below.

Table 14 shows the basic breakdown of why a SIPS schedule would be a great advantage if it were used on the Westinghouse Building 4 project.

Short Interval Production Schedule Results		
Results of using SIPS schedule	**Entity Effected**	**Effect**
Decrease the finish schedule by 3 weeks	Turner Construction	Turner can subtract 3 weeks of general conditions costs (around $78,000) from the project cost and report that as extra profit. This also takes away some of the fear of incurring liquidated damages from Tuner as they will have 3 extra weeks to deal with any short-comings.
Decrease overall project by 3 weeks	Westinghouse	Westinghouse will be able to move its employees into their new building 3 weeks earlier. This will save them $5,000 days in rent and be much more convenient for the employees
Stretch out individual trades	Subcontractors	By using a SIPS schedule some of the contractors will be on this job longer than originally planned. In tough times when work is hard to come by this is seen as a good thing to hard working subcontractors.
Predictability of SIPS schedule	All	SIPS schedule make a job very predictable. The subcontractors know exactly where in the building they will be working and when. By the same token this also makes the subcontractors very easy for the project manager to find should the need to meet with them arise. And for the customer is provides a very confident look into when the project will be completed.

7.0 Resources

Weniger, Mike. (2011, March 20)"Westinghouse Building 4." Turner Construction Company. (Interview by Jonathan M. Fisher)

Stoehr, Bob. (2011, February 12)"Solar Power." Solar Powered Industries. (Interview by Jonathan M. Fisher)

Woody, Bill. (2011, March 15)"Precast Construction." Shockey Precast Concrete. (Interview by Jonathan M. Fisher)

Nowicki, Tim. (2011, March 22)"Westinghouse Building 4 and Solar Power." Westinghouse Electric Company. (Interview by Jonathan M. Fisher)

Smith, Stephanie. (2011, March 5)"Westinghouse Building 4 and Solar Power." Westinghouse Electric Company. (Interview by Jonathan M. Fisher)

Greco, Phil. (2011, March 8)"Westinghouse Building 4 and Solar Power." Westinghouse Electric Company. (Interview by Jonathan M. Fisher)

Jackson, Frank. *Photovoltaic Systems*. Second ed. Vol. One. London: Earthscan, 2008. Print.

Dunlop, Jim. *Photovoltaic Systems*. Homewood: American Technical, 2007. Print.

"Solar Estimator Solar Energy Calculator Free Solar Power Estimate Calculations and Analysis. Estimate Solar Panel Cost Solar Power Production: Incentives Rebates Tax Credits Energy Bill Savings Energy Efficiency Estimate." *Find Solar Installers Solar Contractors: Solar Cost Estimate. Solar Energy Solar Power Analysis. Customer Reviews of Solar Professionals Pros. Local Directory for Solar Electric Water Pool Heat Contractor. Findsolar*. Energy Matters LLC, 10 Feb. 2000. Web. 23 Feb. 2011. <http://www.solar-estimate.org/?page=solar-calculator>.

Google SketchUp 7. (2010). USA: Google

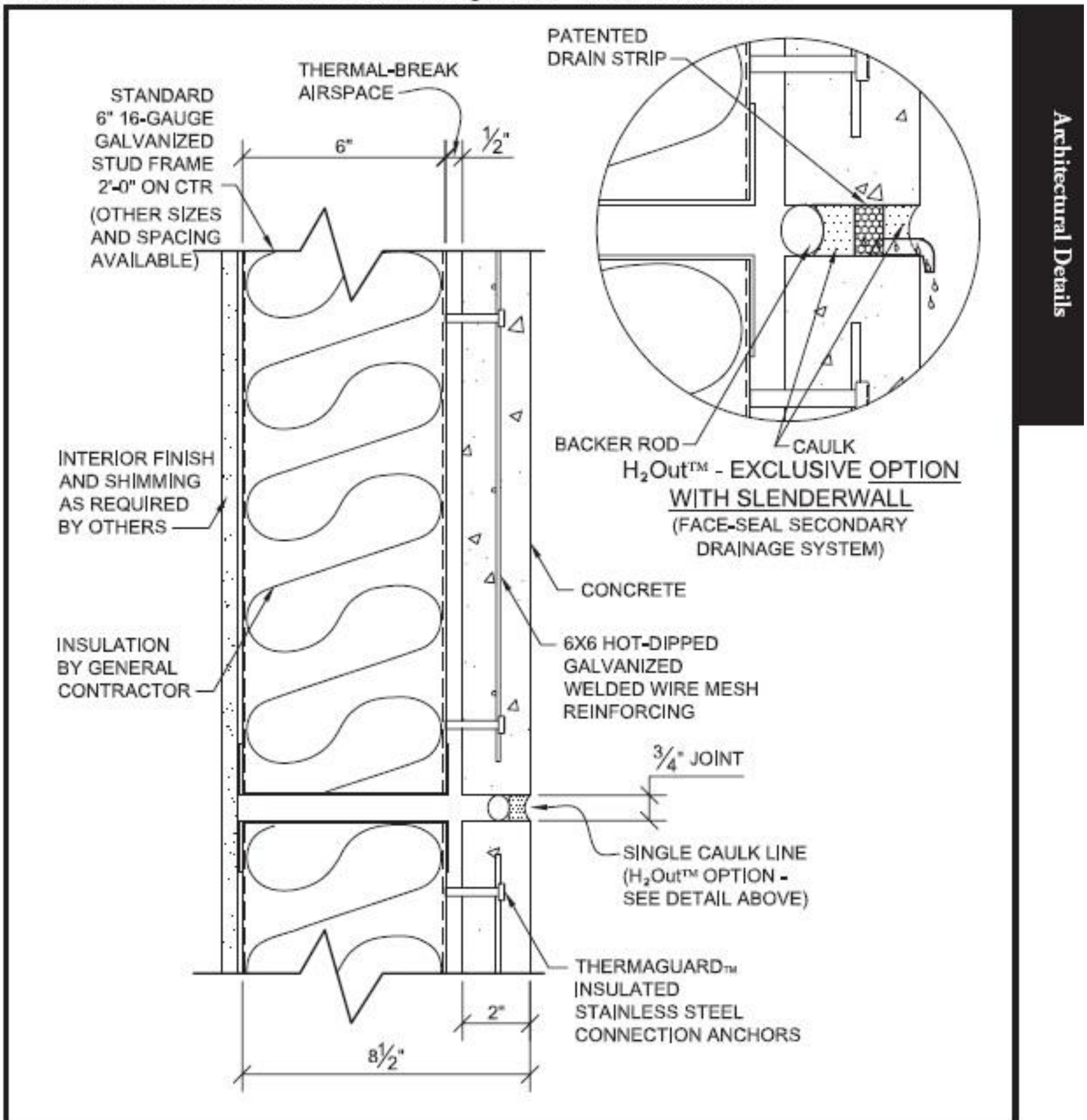
RISA-2D 10.0. (2010). Foothill Ranch, CA, USA: RISA Technologies, LLC

8.0 Appendix A

Appendix A contains the specifications for the proposed precast SlenderWall systems. The various drawings show how the panels will be connected and supported once in place.

SLENDERWALL®

Architectural Precast Concrete/Steel Stud Building Panels www.slenderwall.com



TYPICAL SLENDERWALL SECTION

EASI-SET® INDUSTRIES
New Dimensions in Concrete
PO Box 400 • Midland, VA 22728
phone: 540-439-8911
fax: 540-439-2541

These details are provided solely as an example and should not be relied on for use in architectural or engineering drawings unless approved by a qualified professional based on project requirements.

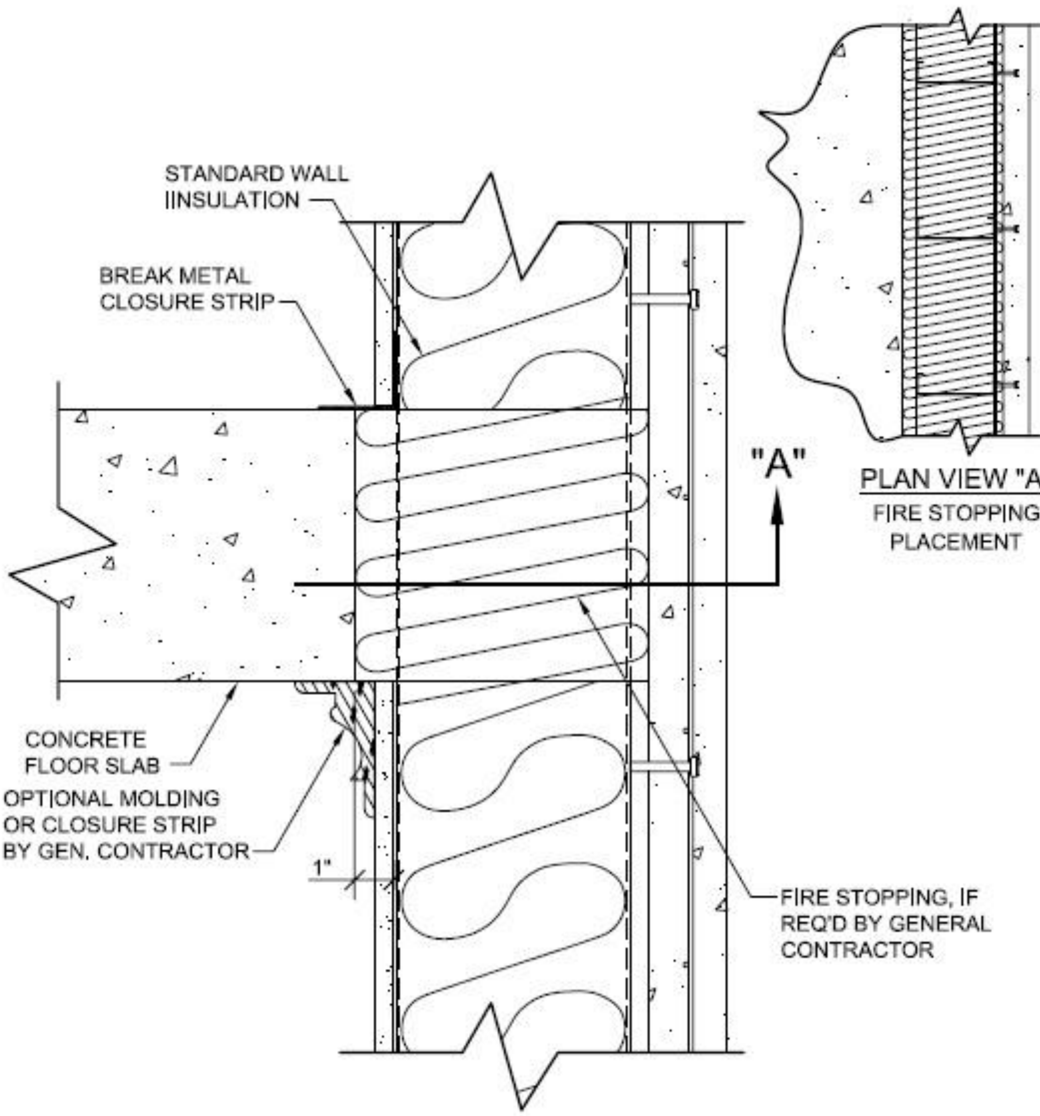
A-1		
SCALE	DN.BY	DATE
NTS	CEK	5/1/08

07/08 EASI-SET Industries, Licensor of Precast Concrete Products Worldwide 800-547-4045 www.easiset.com A-1

SLENDERWALL®

Architectural Precast Concrete/Steel Stud Building Panels www.slenderwall.com

Architectural Details



SEE DETAIL A-1 FOR ADDITIONAL INFORMATION

TYPICAL FLOOR DETAIL

EASI-SET® INDUSTRIES
New Dimensions in Concrete
PO Box 400 • Midland, VA 22728
phone: 540-439-8911
fax: 540-439-2541

These details are provided solely as an example and should not be relied on for use in architectural or engineering drawings unless approved by a qualified professional based on project requirements.

A-3

SCALE	DN.BY	DATE
NTS	CEK	5/1/06

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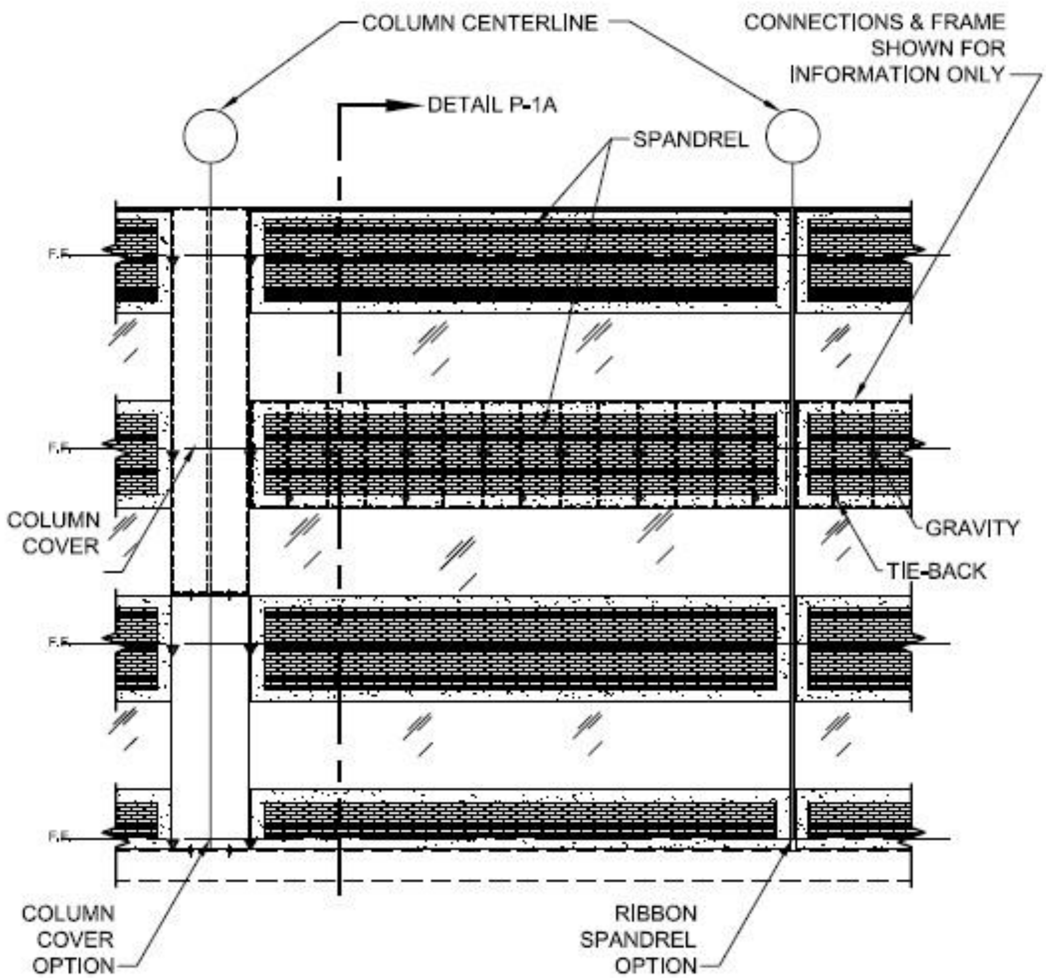
SLENDERWALL®

Architectural Precast Concrete/Steel Stud Building Panels www.slenderwall.com



NOTES:

1. SEE A-9 & A-10 FOR BRICK COURSING OPTIONS.
2. MAXIMUM PANEL WIDTH 13'-0".
3. MAXIMUM PANEL LENGTH 40'-0".
4. FOR MAXIMUM ECONOMY, LIMIT PANEL SIZE TO 10'-0" X 35'-0".
5. SEE CONNECTION DETAILS FOR MORE INFORMATION.

CONNECTION DETAIL LEGEND:

▼GRAVITY CONNECTION

●TIE-BACK CONNECTION

OPTION 1 – SPANDRELS AND COLUMN COVERS

EASI-SET® INDUSTRIES
New Dimensions in Concrete
PO Box 400 • Midland, VA 22728
phone: 540-439-8911
fax: 540-439-2541

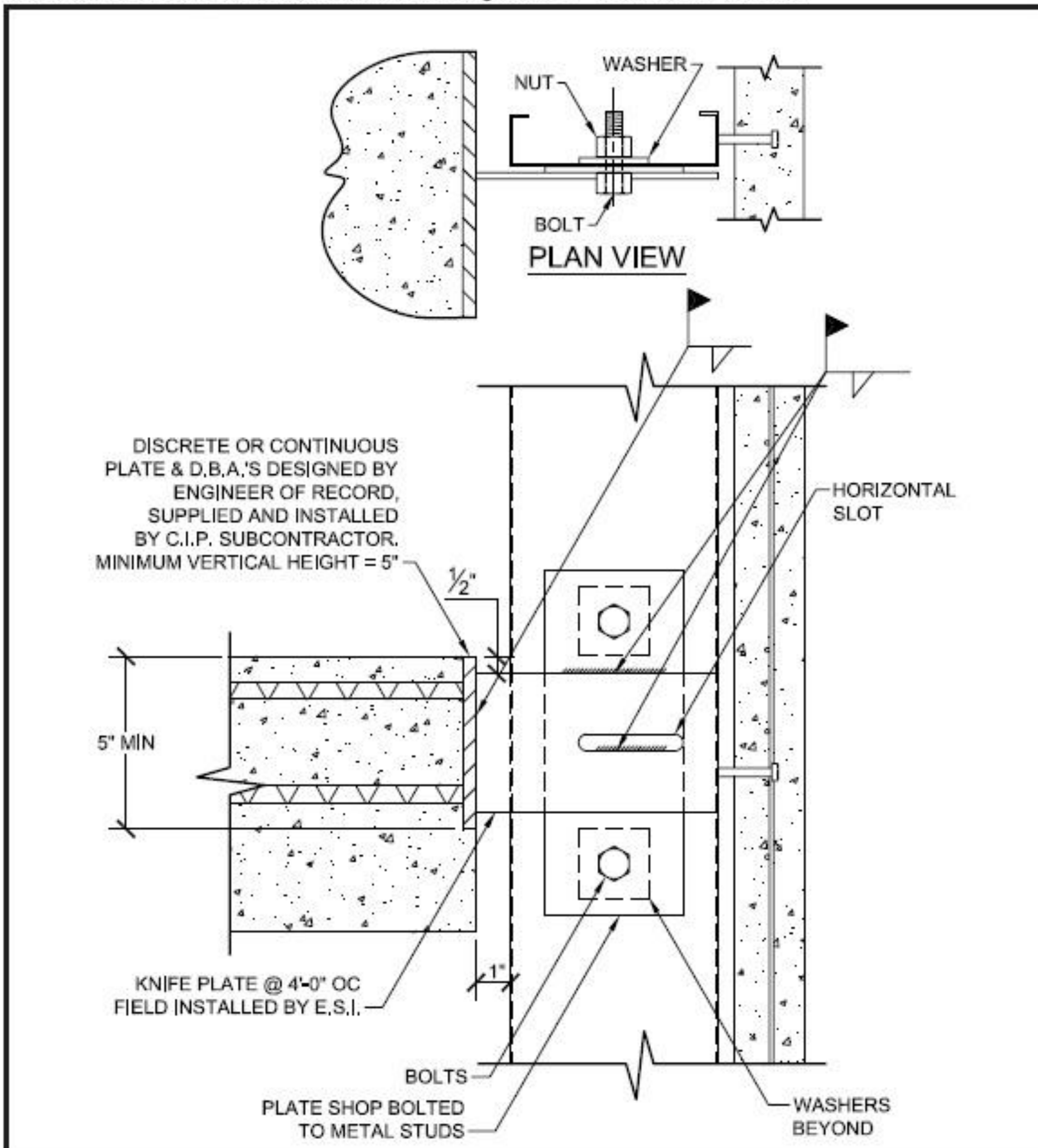
P-1

SCALE	DN,BY	DATE
1/8" = 1'-0"	CEK	5/1/06

07/08 EASI-SET Industries, Licensor of Precast Concrete Products Worldwide 800-547-4045 www.easiset.com P-1

Panelization Options

SLENDERWALL®
Architectural Precast Concrete/Steel Stud Building Panels www.slenderwall.com



GRAVITY CONNECTION @ CAST-IN-PLACE SLAB

EASI-SET® INDUSTRIES
New Dimensions in Concrete
PO Box 400 • Midland, VA 22728
phone: 540-439-8911
fax: 540-439-2541

These details are provided solely as an example and should not be relied on for use in architectural or engineering drawings unless approved by a qualified professional based on project requirements.

S-1

SCALE	DN.BY	DATE
3" = 1'-0"	CEK	8/1/06

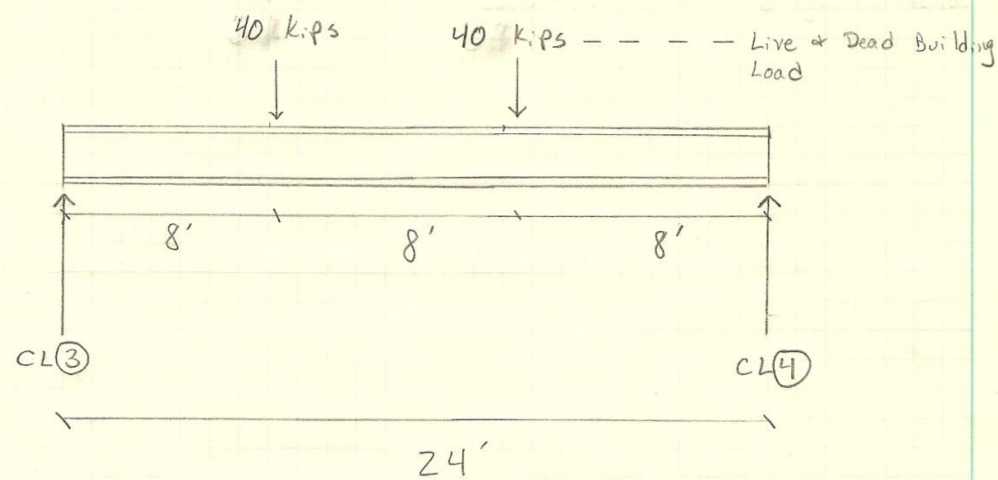
Structural/Connection Details

07/08 EASI-SET Industries, Licensor of Precast Concrete Products Worldwide 800-547-4045 www.easiset.com S-1

9.0 Appendix B

Appendix B contains the hand calculations of the exterior spandrel beam that will support the weight of the proposed precast system. The calculations ensure that the maximum moment and deflection of the beam will not exceed that of the original system or that which is allowed by industry standards.

Spandral Beam W 24 x 55 areforum.org



Dead Loads	Concrete	65 psf	5" thick
	Steel Deck	3 psf	
		68 psf	

Live Loads	Live Load	80 psf	office building
	movable partitions	20 psf	
		100 psf	

$$\boxed{L = L_o\left(.25 + \frac{15}{\sqrt{K_{LL} A_T}}\right)}$$

$$L = 100\left(.25 + \frac{15}{\sqrt{(2)(384)}}\right)$$

$$L = 79.13 \text{ psf}$$

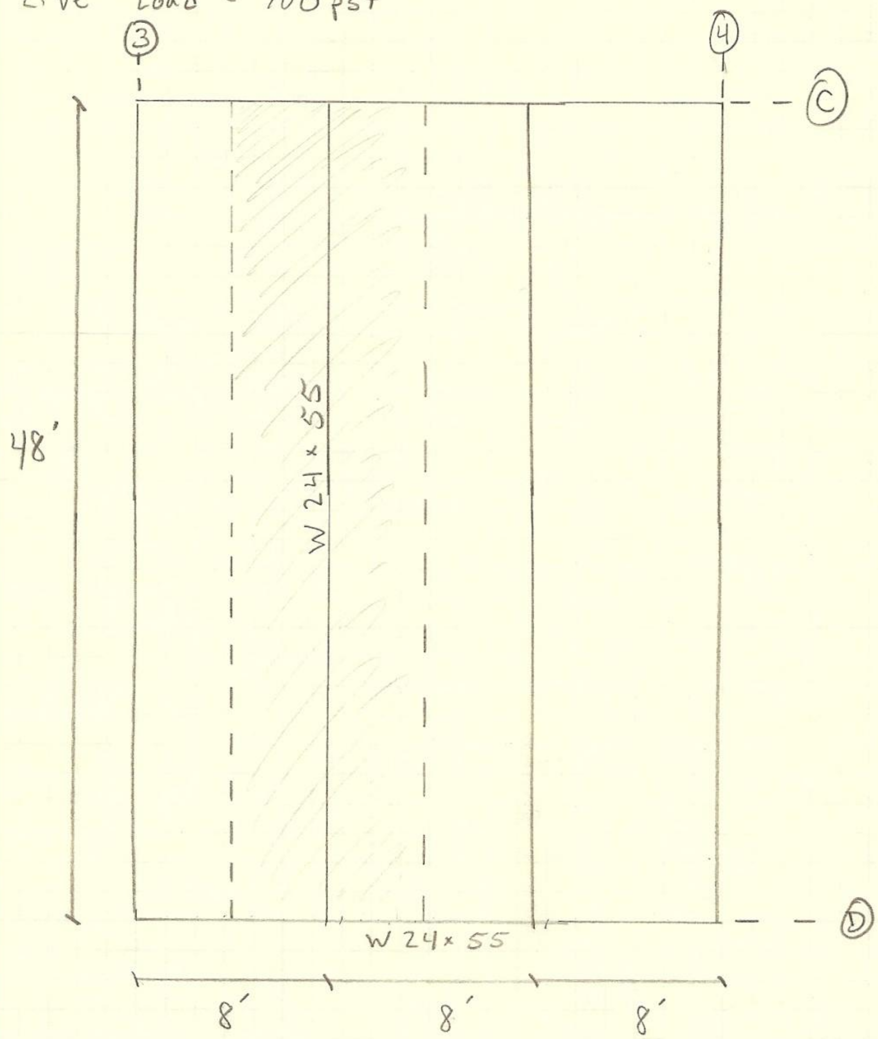
Factored Loads

$$W_u = 1.2(68) + 1.6(79.13) = 208.2 \text{ psf}$$

$$P_u = \frac{208.2}{1000} \times \left(8 \times \frac{48}{2}\right) = 39.97 \approx 40 \text{ kips}$$

Dead Load = 68 psF   1 Bay

Live Load = 100 psF

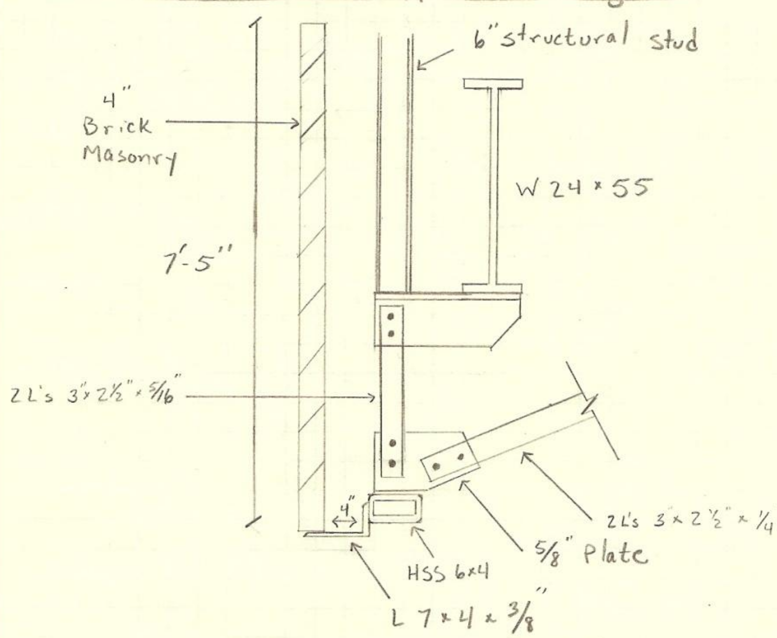


Beam Load = 1399 plf

L = Beam Length
P = Beam Load

Point Load $= \frac{1}{2}(L)(P)$
$= \frac{1}{2}(48')(1399 \text{ plf})$
$= 33,576 \text{ lbs} \approx 34 \text{ kips}$

Curtain Wall Support Diagram



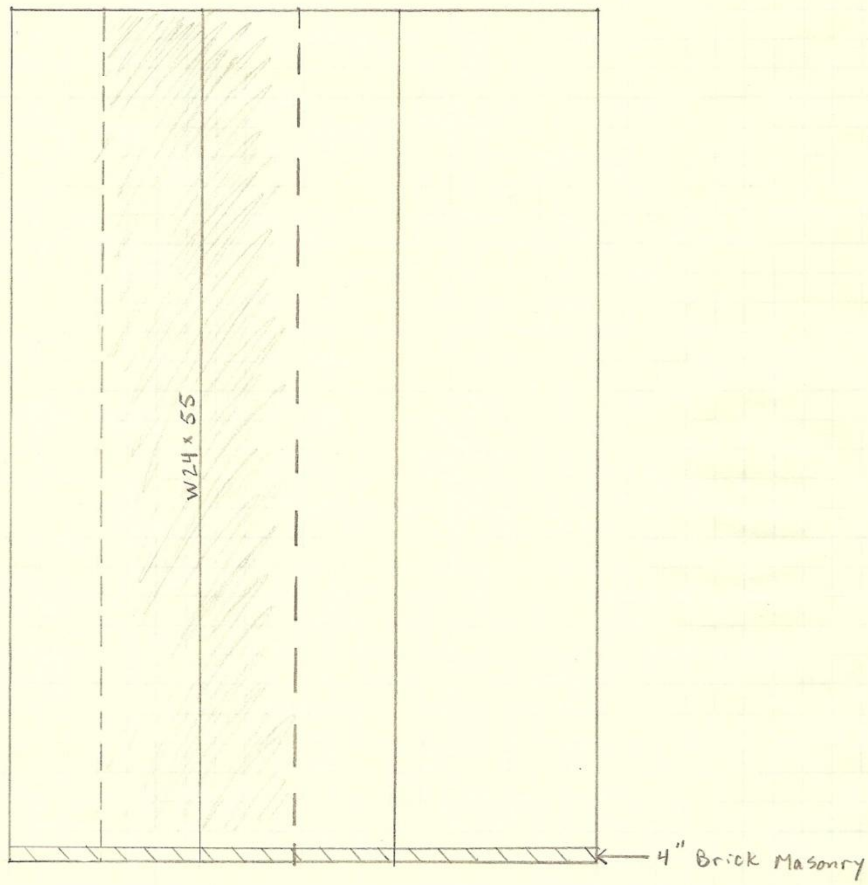
Brick Veneer Load

4" Brick Masonry = 42 psf
weight per linear foot
$= (42 \text{ psf})(7.46')$
$= 313.32 \text{ plf}$

Glass Storefront Load

1" insulated storefront glass
¼" over ¼" w/ ½" air space
Weight per linear foot
$= (6.25 \text{ lb/sqft})(6.67')$
$= 41.7 \text{ plf}$

7'-5" tall Brick veneer is supported by a 3/8" L Bracket that spans the length of the Building. This 3/8" L Bracket is supported by 5/16" L Brackets spaced @ 8' max.



$L_T = 8'$

$L = 314\ plf$

$P = (L_T)(L)$

$P = (8')(314\ plf)$

$P = 2{,}512\ lbs \approx 2.5\ kips$

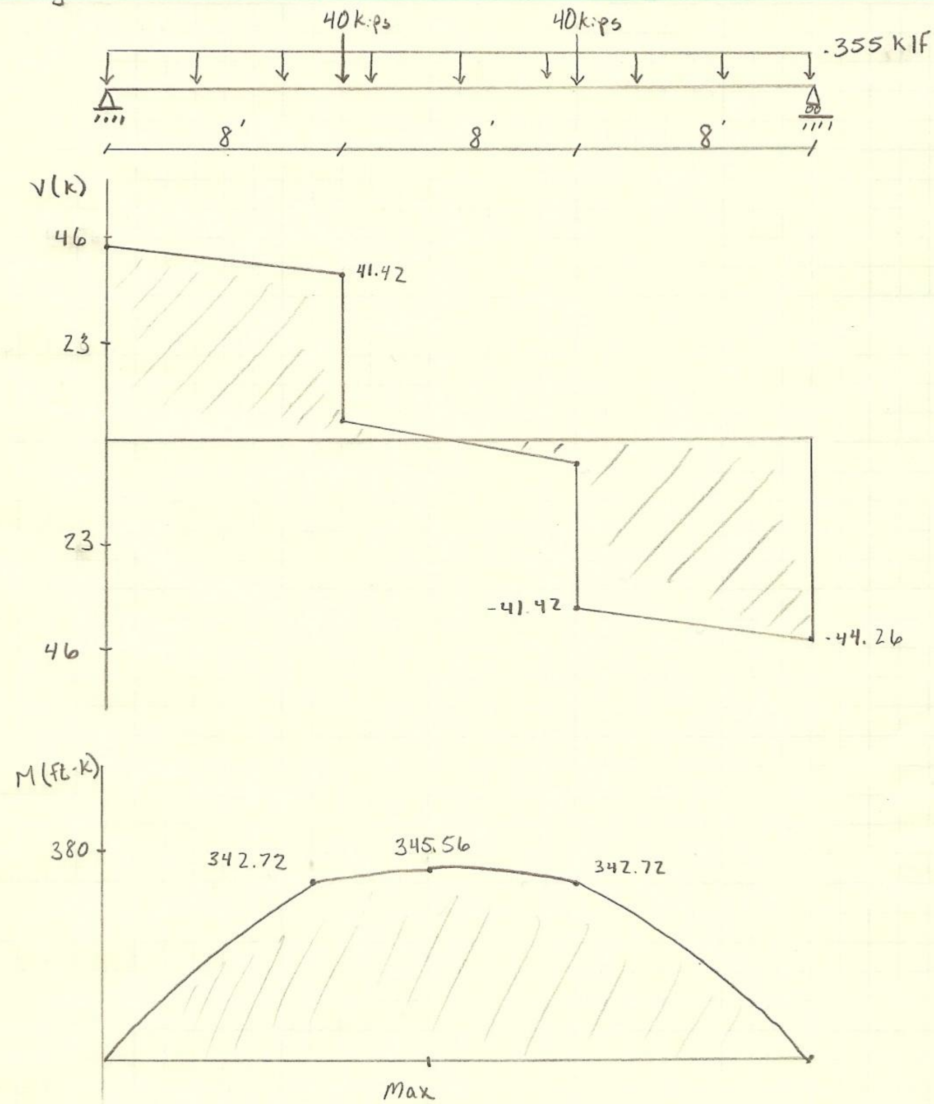
glass storfront

$P = (L_T)(L)$

$= (41.7\ plf)(8')$

$= 333.5\ lbs. \approx .333\ kips$

Original Facade



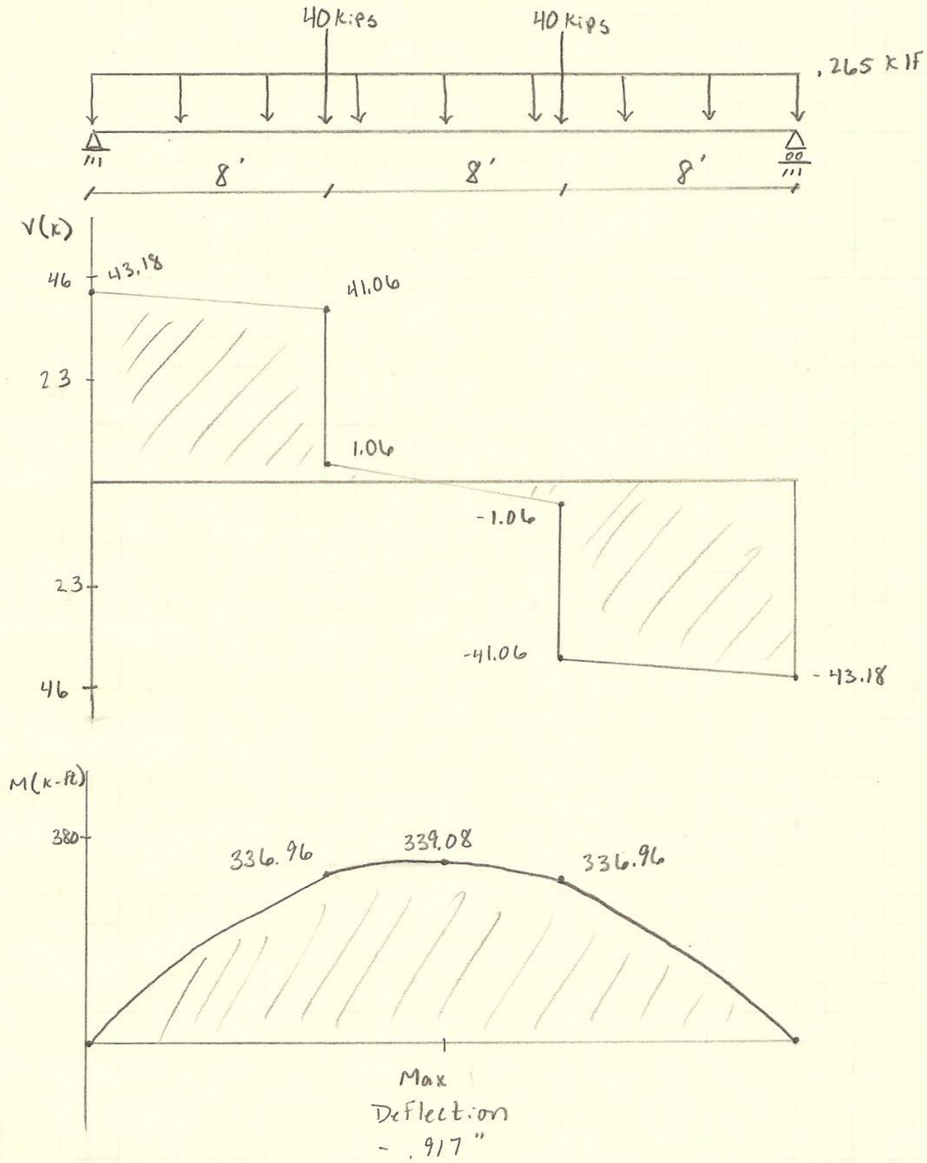
Max
Deflection
- .934"

<u>Check</u>

$\Delta_{TL} = \frac{L}{240} = \frac{(24')(12)}{240} = 1.2" \therefore$ OK ✓

$\Delta_{LL} = \frac{L}{360} = \frac{(24')(12)}{360} = .8 \therefore$ No

Precast Facade



Check

$\Delta_{TL} = \frac{L}{240} = \frac{24'(12)}{240} = 1.2'' \therefore$ Ok ✓

$\Delta_{LL} = \frac{L}{360} = \frac{24'(12)}{360} = .8'' \therefore$ No

However Deflection is less with New System

10.0 Appendix C

Appendix C contains shows the questionnaire that was distributed to several Westinghouse employees. The purpose of the questionnaire was to determine the none-monetary benefits that Westinghouse would reap from a solar array.

Westinghouse [WESTINGHOUSE EMPLOYEE QUESTIONNAIRE] February 18, 2011

Jonathan Fisher's Thesis pertaining to the Westinghouse Building 4 Project

Westinghouse Employee Questionnaire

Westinghouse portrays itself as a "green" company. What do you feel are some of the company's primary "green" goals?

What are some of the non-monetary benefits you feel Westinghouse would experience through installing a Photovoltaic Array on the roof of Building 4?

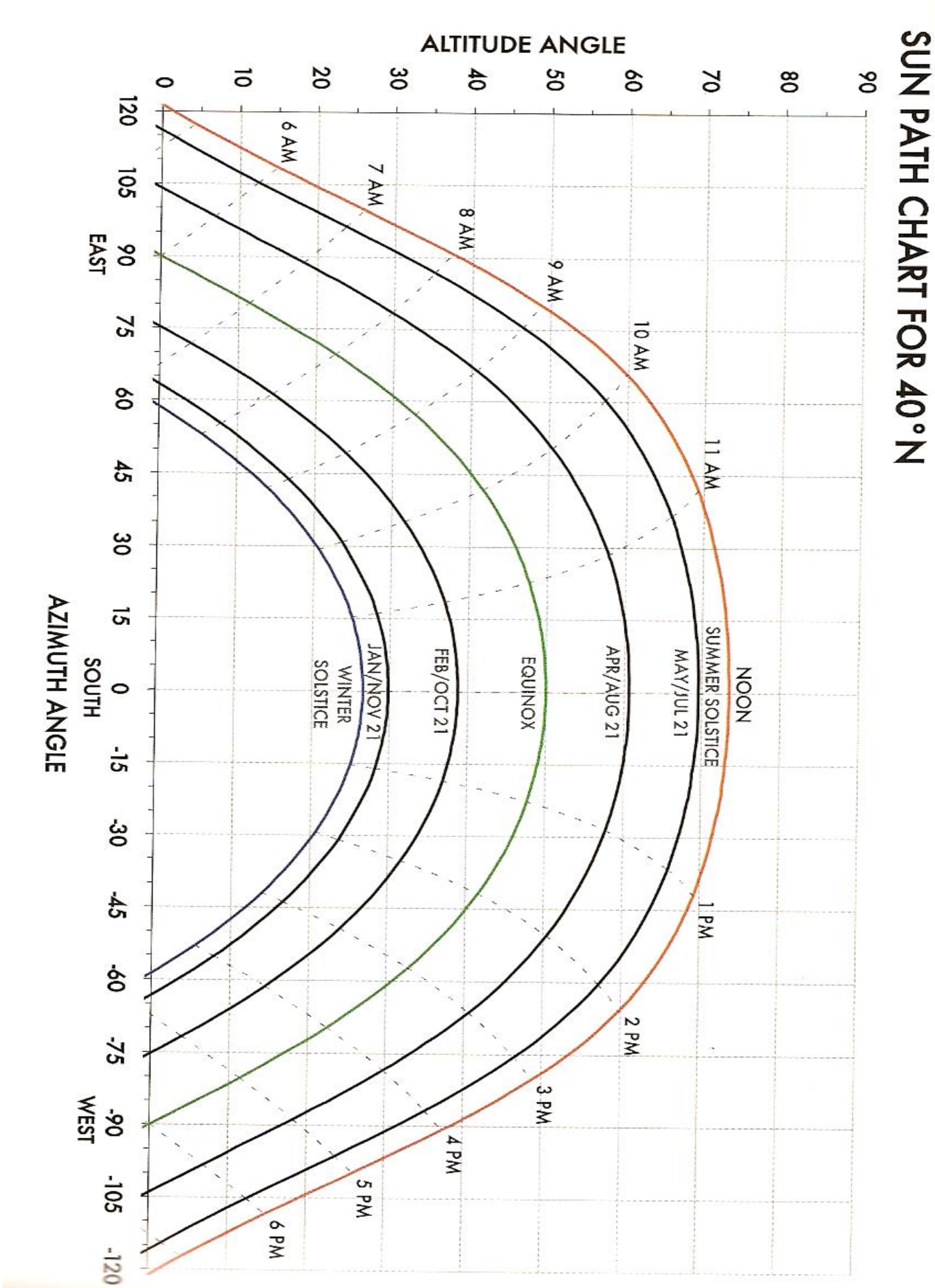
Considering Westinghouse is a Nuclear Power Plant designer, how would knowing more about solar technologies and sustainable practices benefit the company?

The world energy crisis is only getting worse and fossil fuels are getting harder and more costly to produce. Do you think nuclear technologies and fuel supplies will able to keep up with demand as fossil fuels fade away and more of the world is wired to a grid? Please give a brief explanation.

Some people feel that smaller independent substation would be more efficient than large, wide spread power plants. Do you agree or disagree with this notion? And do you think photovoltaic arrays would be the most viable small scale power supply stations? Please give a brief explanation.

11.0 APPENDIX D

Appendix D contains the sun path diagram that was used to deduce the optimum angle of the panels. This chart was also used to determine the total time that the panels would be in sunlight each day.


SUN PATH CHART FOR 40°N
ALTITUDE ANGLE
0 10 20 30 40 50 60 70 80 90
AZIMUTH ANGLE
120 105 90 75 60 45 30 15 0 -15 -30 -45 -60 -75 -90 -105 -120
EAST
SOUTH
WEST
6 AM
7 AM
8 AM
9 AM
10 AM
11 AM
NOON
1 PM
2 PM
3 PM
4 PM
5 PM
6 PM
SUMMER SOLSTICE
MAY/JUL 21
APR/AUG 21
EQUINOX
FEB/OCT 21
JAN/NOV 21
WINTER SOLSTICE

12.0 Appendix E

Appendix E contains the specifications for the solar panels and inverters that will be used in the proposed solar array. The specifications were used to calculate the output of the array in both DC and AC power.

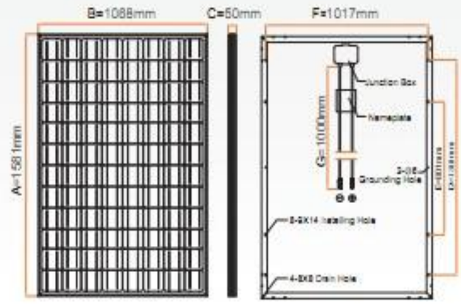
TPS105 230W/235W/240W/245W/250W/255W Photovoltaic Module

TOPRAY Solar

MECHANICAL SPECIFICATION

Cell Type	Monocrystalline 125×125 mm (5 inches)
Number of cells	96 (8×12)
Dimensions (A×B×C)	1581×1068×50mm
Weight	20kg
Front Glass	3.2 mm Low iron tempered glass
Frame	Anodized aluminum alloy
Junction Box	IP 65, with bypass diodes
Connector	Renhe (compatible with MC4)
Output Cables	Renhe, ±length 1000mm, 4.0mm²

MECHANICAL DRAWINGS



ELECTRICAL CHARACTERISTICS

PERFORMANCE AT STANDARD TEST CONDITIONS (STC: 1000 W/m², 25 °C, AM 1.5)

Maximum Power at STC (Pmax)	230W	235W	240W	245W	250W	255W
Short Circuit Current (Isc)	5.38A	5.40A	5.45A	5.50A	5.59A	5.68A
Open Circuit Voltage (Voc)	58.00V	58.20V	58.20V	58.20V	58.40V	58.40V
Maximum Power Current (Impp)	4.96A	5.04A	5.12A	5.23A	5.32A	5.39A
Maximum Power Voltage (Vmpp)	46.40V	46.60V	46.80V	46.80V	47.00V	47.30V
Encapsulated Cell Efficiency	16.00%	16.40%	16.80%	17.10%	17.40%	17.70%
Module Efficiency	13.50%	13.80%	14.10%	14.40%	14.70%	15.00%
Power Tolerance	0/+3%	0/+3%	0/+3%	0/+3%	0/+3%	0/+3%

PERFORMANCE AT NORMAL OPERATING CELL TEMPERATURE (NOCT: 800W/m², 47±3 °C, AM 1.5)

Maximum Power (Pmax)	230W	235W	240W	245W	250W	255W
Short Circuit Current (Isc)	4.54A	4.55A	4.60A	4.64A	4.71A	4.79A
Open Circuit Voltage (Voc)	53.79V	53.97V	53.97V	53.97V	54.16V	54.16V
Maximum Power Current (Impp)	4.05A	4.12A	4.19A	4.28A	4.35A	4.41A
Maximum Power Voltage (Vmpp)	40.88V	41.06V	41.23V	41.23V	41.41V	41.67V

The typical relative change in module efficiency at an irradiance of 200W/m² in relation to 1000W/m² (both at 25°C and AM 1.5 spectrum) is less than 6%.

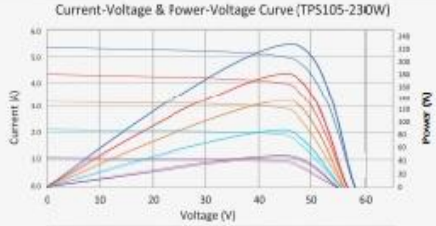
TEMPERATURE CHARACTERISTICS

Nominal Operating Cell Temperature (NOCT)	47±3°C
Temperature Coefficient of Pmax (γ)	-0.47%/K
Temperature Coefficient of Voc (β)	-0.36%/K
Temperature Coefficient of Isc (α)	0.05%/K

PACKING CONFIGURATION

Container	20' GP	40' HC
Pieces per pallet	20	20
Pallets per container	6	28
Pieces per container	120	560

Current-Voltage & Power-Voltage Curve (TPS105-230W)

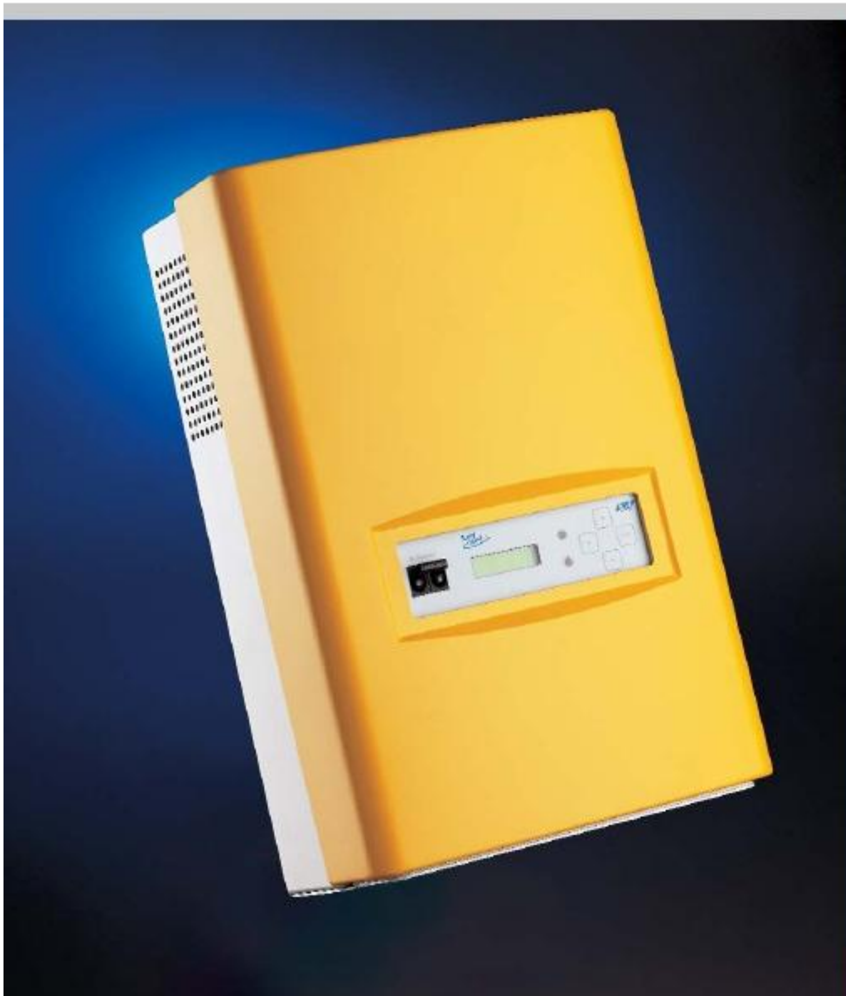


SYSTEM INTEGRATION PARAMETERS

Maximum system voltage	DC 1000V
Maximum Series Fuse	10A
Maximum reverse current	13.5A
Increased snowload acc. to IEC 61215	5400Pa/m²
Operating Temperature	-40~+85°C
Number of bypass diodes	4

Sunny Island 4248U

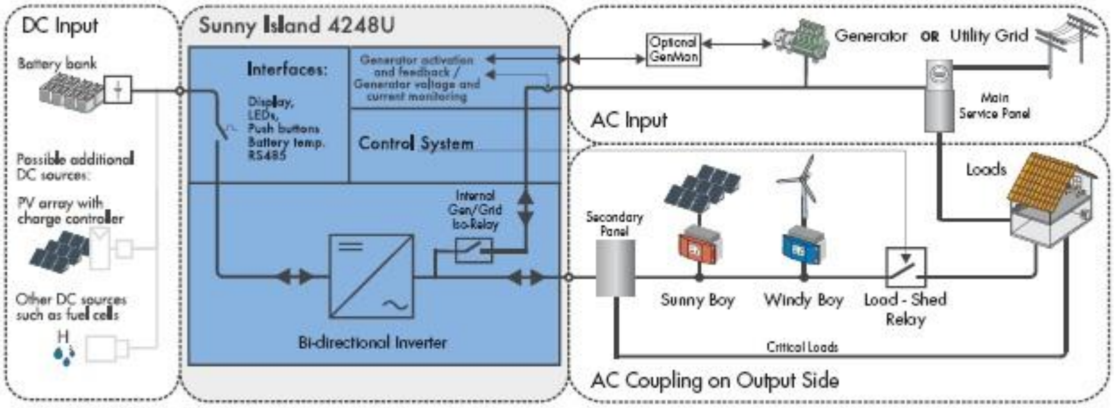
SMA's new off grid inverter - A technological leap into the future



- Optimized for high ambient temperatures
- Very high overload capability
- High efficiency
- Integrated DC breaker
- Intuitive user interface
- Output load shedding
- DC and AC coupling of energy sources
- Nearly silent operation
- Automatic generator start
- Battery protection
- Insect proof
- Easy installation and commissioning
- Non volatile parameter settings
- Compatible with the Sunny Family of products

The new Sunny Island 4248U battery based inverter is the first off-grid inverter from SMA for use in the U.S. Perfect sine wave off-grid electricity is now available with high efficiency, robust power and outstanding reliability. Simple to install and use, yet loaded with powerful and advanced features, the Sunny Island 4248U is designed to meet the needs of off-grid as well as back-up power system applications.

Whenever and wherever electric power is needed, the new Sunny Island 4248U will perform!



The Sunny Island 4248U provides a continuous power output of 4200 watts at 25°C and 3400 watts even at scorching temperatures up to 45°C. That's enough power to comfortably energize most household appliances with power to spare. Large critical loads such as water pumps and refrigerators can be easily powered by the Sunny Island 4248U. This inverter operates silently and can be powered from multiple sources: wind, utility grid (for back-up power), hydro, solar electric and is even compatible with fuel cells. A number of communication options provide flexible remote system monitoring. The optional SMA "GenMan" (Generator Management Box) provides advanced control of even the most basic generators. The Sunny Island 4248U also works in conjunction with grid tied Sunny Boy solar systems to provide a powerful and efficient back up power solution.

The internal battery charger can supply up to 100A to the battery when in charge mode. Transition from charge to invert mode is a lightning fast 20ms, so even your computers will stay on-line. A pass-through relay with a rating of 60A at 120V is also included. Two Sunny Island 4248's may be paralled to support 240VAC split-phase load centers. Once installed, the Sunny Island 4248U will run with basically no maintenance for years to come. With its state-of-the-art software and non-volatile memory, just set it and forget it.

Technical Data

Electrical / Mechanical data

Nom. Battery Voltage:	$V_{DC,nom}$	48 V
Battery Voltage Range:	V_{DC}	41 - 63 V
Nom. AC Voltage:	$V_{AC,nom}$	120 V
AC Voltage Range:	V_{AC}	105 - 132 V
Nom. AC Frequency:	$f_{AC,nom}$	60 Hz
AC Input Charge Current:	$I_{AC,chrg}$	40A @ 25°C
		28A @ 45°C
Max. AC pass through current (transfer relay):		60 A
Consumption (no load operation):		<22 W
Consumption (standby):		<4 W
Total harmonic distortion:		<3 %

Temperature Range
-20°C to +45°C / -4.0°F to +113.0°F

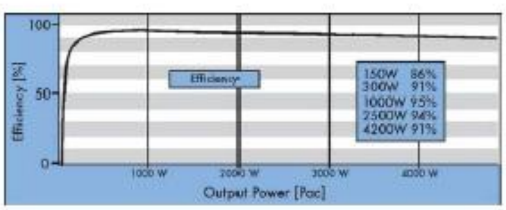
Enclosure: IP30

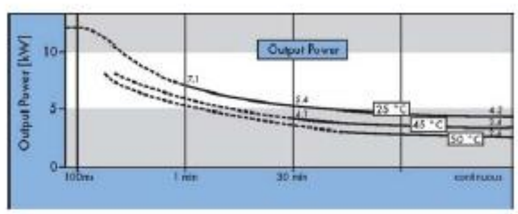
Weight: 39 kg / 86 lbs

Size: W 390 x L 590 x H 245 millimeters
W 15.35 x L 23.22 x H 9.64 inches

Interfaces
- 2 LEDs; 2-line LCD; 4 push buttons
- 1 dry contact output for load shedding
- 1 dry contact for generator start
- 1 generator-ready opto isolated input

Accessories
- Remote battery temperature sensor (included)
- Generator Management Box (optional)
- 1 RS232/485 galvanic isolated for communication(optional)





SMA America, Inc.
12438 Loma Rica Drive
Grass Valley, CA 95945
phone: 530.273.4895
email: info@sma-america.com
www.sma-america.com

Solar Today ...
Energy Tomorrow

13.0 Appendix F

Appendix F contains the hand calculations that were done to determine the electrical output of the array. Hand calculations were also done to determine the square footage of roof that is available for the array.

Photovoltaic calculation

16,000 sq. ft. available Area

1 panel = 1581 × 1068 × 50mm

Area = 1,688,508 mm^2

$\approx$ 18.2 sq. ft

# of Panels = $\frac{8,008 \text{ sq. ft}}{18.2 \text{ sqft/Panel}}$

= 440 panels

max output current = 4.41 A/panel

max output voltage = 41.67 V/panel

(4.41A)(41.67V)

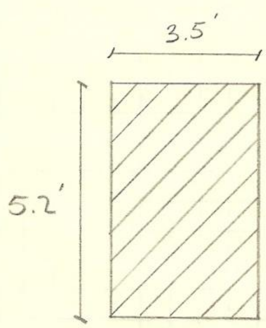
= 184 VA

× 440 panels

80,960 VA

$\approx$ 81 KVA output

= 81 KW



prime solar hours = 9AM - 3PM

= 5 hours (Avg)

Annual output

Daily output = (81kw)(5 hours/Day)

= (405 kwh/Day)(365 Days/Year)

= (148,000 kwh)(.94)

inverter efficiency

= 139,000 kwh Annually

Inverter Calculation

1 inverter = 4,200 watts for 4248U sunny island inverter
1 panel ÷ 184 VA
22.82 panels/inverter ≈ 20 panels/inverter

Inverter

20 panels × 184 VA = 3,680 VA Demand load

Wiring (Distribution Panel to inverter) Table 310.16

Size to 4,200 watts @ 120 Volts

$\frac{4{,}200 \text{ watts}}{120 \text{ Volts}} = 30.7$ Amps

Table 250.122

2(#10 AWG wire) + 1(#10 AWG GRD wire)

Conduit Sizing (Annex C Table C1)

3(#10 AWG) = 3/4" EMT conduit

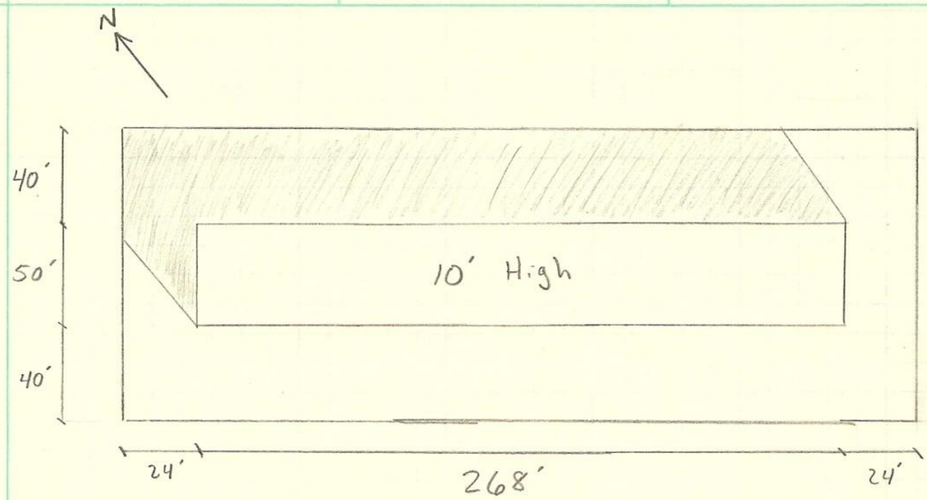
Wiring (PV to inverter)

$\frac{184 VA}{120 V} = 1.53$ Amps

2(#12 AWG wire) + 1(#12 AWG GRD)

Conduit sizing

3/4" EMT Conduit



Panel Area

(40)(316) = 12,640 sqFt

.5(50)(24) = 600 sqFt

(90)(24) = 2,160 sqFt

.5(30)(40) = 600 sqFt

Total 16,000 sqFt

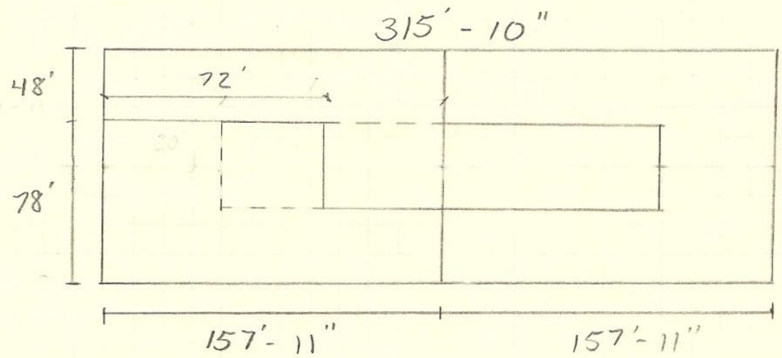
14.0 Appendix G

Appendix G contains the quantity takeoff figures required to produce the SIPS schedule. These quantities were taken from the building drawing set and the durations were calculated from the original project schedule.

Quantity Takeoff Calculations

GWB

3'-2½" high all the way around outside walls
9'-6" high on all interior walls
9'-6" high on all interior columns



Ceiling tiles

31 tiles along short side
40 tiles along long side
40 x 31 = 1240 tiles per zone

Floor tiles

Total Floor Area = (158')(65') = 10,270 sqft
Floor Area in Core = (108')(20') = 2,160 sqft
Carpeted open office Area = 8,110 sqft

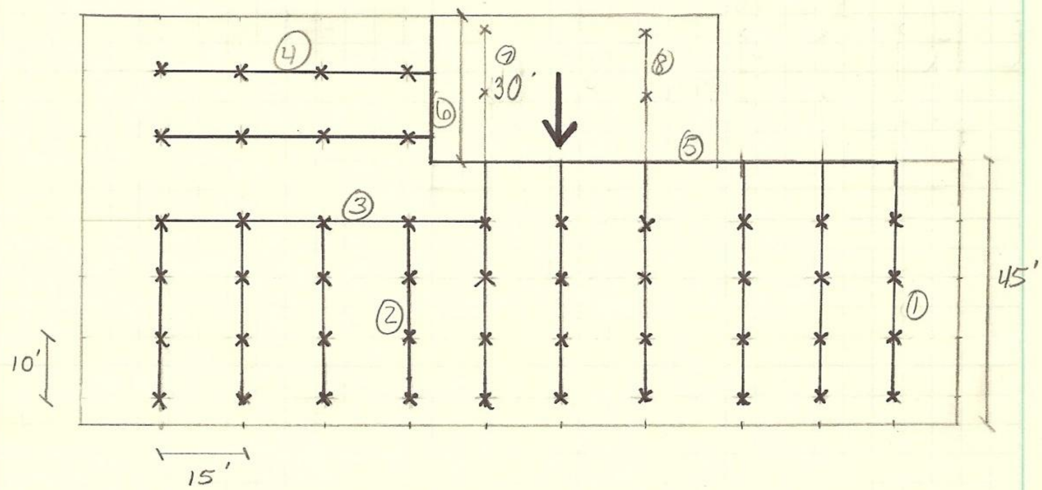
Light Count

per 24' section starting at project west

See spread sheet

Light Hazard - Office Building

Sprinkler Calculation



maximum spacing = 15'

maximum Area per head = 200'

Total sprinkler line

① (6)(40) = 240'

② (4)(35) = 140'

③ = 45'

④ (2)(35) = 70'

⑤ 105'

⑥ 15'

Total 615'

Sprinkler Heads

48 heads

archtoolbox.com

Schedule Break Down

		Week/Zone	Day/Zone
Ductwork	9 weeks	.75	3.75
Int. Framing	8.5 weeks	.71	3.55
Sprinkler Branches	9 weeks	.75	3.75
Rough In	7.5 weeks	.625	3.125
Drywall	13 weeks	1.08	5.4
Ceilings	8 weeks	.667	3.335
Sprinkler Heads	7.5 weeks	.625	3.125
Painting	5 weeks	.417	2.09
Lighting	6 weeks	.5	2.5
Flooring	6 weeks	.5	2.5
Quality in wall check	3 weeks	.25	1.25
		Total Days	34.375
		Total weeks	6.875

Lighting Count			
Starting Column Line	Ending Column Line	Type	Qty
1	2	Direct/Indirect Penant Light Fixture	21
2	3	Direct/Indirect Penant Light Fixture	24
3	4	Direct/Indirect Penant Light Fixture	20
4	5	Direct/Indirect Penant Light Fixture	23
5	6	Direct/Indirect Penant Light Fixture	23
6	7	Direct/Indirect Penant Light Fixture	28
7	7.5	Direct/Indirect Penant Light Fixture	7
		Total Light Fixtures	146

Sprinkler Branches					
Branch	Length (ft)	No. of sprinkler heads	Quantity	Total Length	Total Sprinkler heads
1	40	4	6	240	24
2	35	4	4	140	16
3	45	0	1	45	0
4	35	4	2	70	8
5	105	0	1	105	0
6	15	0	1	15	0
7	28	3	3	84	9
		Totals		699	57

Gypsum Board Quantity Calculation			
Entity	Height (ft)	Length (LF)	Total sqft
Exterior Walls	3.21	223	715.83
Interior Walls	9.5	113	1073.5
Columns	9.5	10	95
Core	9.5	342	3249
	Grand total	688	5,133.33

Mechanical System Takeoff			
N/S Col. Line	E/W Col. Line	Size	Length (LF)
1-2	D-C	10" ϕ	20
1-2	D-C	16X12	30
1-2	D-C	20X12	5
1-2	D-C	12" ϕ	5
1-2	D-C	8" ϕ	5
1-2	C-B	20X12	8
1-2	C-B	20X14	10
1-2	C-B	12" ϕ	5
2-3	D-C	12" ϕ	7
2-3	D-C	16X14	17
2-3	D-C	10X10	24
2-3	D-C	14X10	18
2-3	D-C	36X14	33
2-3	D-C	20X14	10
2-3	D-C	18X10	5
2-3	D-C	26X16	8
2-3	D-C	12ϕ	4
2-3	D-C	14ϕ	4
2-3	C-B	45X14	34
2-3	C-B	12" ϕ	8
2-3	C-B	6" ϕ	11
2-3	C-B	6X8	10
2-3	C-B	42X14	6
3-4	D-C	16X14	24
3-4	D-C	25X14	24
3-4	D-C	14X10	8
3-4	D-C	10X10	18
3-4	D-C	8" ϕ	12
3-4	D-C	8" ϕ	14
3-4	D-C	10X10	5
3-4	C-B	10X8	40
3-4	C-B	12X8	10
4-5	C-B	12X10	8
4-5	C-B	10X8	12
4-5	D-C	12" ϕ	10
4-5	D-C	12" ϕ	8
4-5	D-C	25X14	24
5-6	D-C	10X10	24
5-6	D-C	10X12	30

5-6	D-C	25X14	24
5-6	D-C	8" ϕ	4
5-6	D-C	12" ϕ	6
5-6	D-C	16X14	18
5-6	D-C	14" ϕ	5
5-6	D-C	14X10	6
5-6	D-C	10X10	6
5-6	D-C	18X14	8
6-7	D-C	16X14	22
6-7	D-C	26X16	6
6-7	D-C	10X10	30
6-7	D-C	14X10	6
6-7	D-C	8" ϕ	20
7-8	D-C	12" ϕ	8
Total			727

Metal Studs	
	Length of Wall being framed (LF)
Exterior Walls	223
Interior Walls	113
Core Walls	342
Grand Total	678