THESIS REPORT

LAFAYETTE TOWER
WASHINGTON, DC

JUSTIN WINGENFIELD
CONSTRUCTION MANAGEMENT

DR. DAVID RILEY

SPRING 2009

Lafayette Tower
Washington D.C.

The Players

General Contractor: Clark Construction Group, LLC
Owner: Louis Dreyfus Property Group
Architect: Kevin Roche John Dinkeloo & Associates, LCC
Structural Engineer: Tadjer-Cohen-Edelson & Associates, Inc.
MEP Engineer: Tolk, Inc.
Civil Engineer: Edwards & Kelcey

Statistics

Size: 328,00 SF; 11 stories
Function: office / corporate
Cost: $47 million
Schedule: August 2006 - December 2008
Contract Type: GMP
Location: 801 17th St. NW, Washington D.C.

MEP Systems

AHU's on each floor with 2 rooptop cooling towers
2 Main Switchboards (3 phase, 3000A, 265/469V)
250 gallon diesel generator
Building utilizes both wet and dry sprinkler systems

Structural

Cast-in-place concrete structure with 10" and 12" thick post-tensioned concrete slabs above grade, 8 1/2" and 10 1/2" thick concrete slabs below grade
Sits atop existing foundation consisting of slab on grade with spread footings

Special Features

Column-free perimeter
Floor to floor glass curtain wall skin
LEED Gold design
Green roof terrace with views of The White Hosue and The Washington Monument
Located just 3 Blocks from The White House
3 Levels of below grade parking

Justin Wingenfield
Construction Management
http://www.engr.psu.edu/ae/thesis/portfolios/2009/jew5006/

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Executive Summary

This senior thesis is an in depth study pertaining to 801 17th Street NW, Washington DC, the site of Lafayette Tower. After a brief background on the project, three topic areas will be explored include a critique of the buildings column-free perimeters from both a construction management and structural point of view and the implementation of solar design.

Depth Study - *Column-Free Perimeter Analysis (Construction Management)*

This analysis assess the actual value of having column-free perimeters on three sides of the building, compared to including them on only one side, and determines which brings more value to the project with the big picture in mind. I feel that this architectural feature was overused in unnecessary areas and therefore cost the project time, money, and energy that could have been used elsewhere. This analysis is somewhat subjective but I remained as unbiased as possible throughout so that a concrete solution could be reached. In the end, the partial removal of the column-free exterior was recommended but the analysis was not completely one sided by any means.

Analysis I - *Column-Free Perimeter Structural Redesign (Structural Breadth)*

This analysis included developing a typical floor plan with the column-free perimeter only incorporated on the South face of the building and evaluating it structurally to determine the necessary reinforcement and prove the new design is structurally stable. To test the design, a Portland Cement Association (PCA) two-way post-tension design guide was followed to determine if the materials and reinforcement currently used for Lafayette Tower will support the structure with the new column layout. The new column layout worked structurally with the reinforcement designated by the PCA guide and the same thickness slab was used in the original design and the floor plan is now more open for the tenants to fit out as they please.

Analysis II - *Solar implementation (Electrical Breadth/Critical Industry Issue)*

This analysis looked the affects of incorporating solar design into the building systems in an effort to make the building more self sustaining. With one of today's critical construction issues being energy and the economy, incorporating solar power into the design of a building addresses both. Solar implementation will not only reduce the life cycle costs of Lafayette Tower but also make it more sustainable which is important with the nations push for going green. Even though economically this analysis did not end up as promising as I had hoped, I still believe that implementing solar, or any other form of green energy systems, would be beneficial for Lafayette Tower and every other building for that matter.

Acknowledgements

I would have never been able to complete this project without the help of many people. At this point, I would like to recognize the various people that aided me during this process.

Penn State Faculty
Dr. David Riley
Dr. Robert Holland
Dr. Moses Ling

Clark Construction Team
Jamie Hart
Justin Tobias
Dustin Carey
Richard Wagner

Louis Dreyfus Group
Sean Cahill

My Family
Father - John
Mother - Linda
Sister - Emily
Dogs - Lilly & Sophie

My Friends & Fellow AEs

Project Background

General Information

Lafayette Tower is an 11 story core & shell office building in downtown Washington, DC owned by Louis Dreyfus Property Group. The design team consists of design architect, Kevin Roche John Dinkeloo & Associates, LLC, structural engineer, Tadjer Cohen Edelson & Associates, Inc. and MEP engineers, TOLK, Inc.

The project includes demolition of the Existing building that housed the FDIC Headquarters. Demolition began in August 2006 under an early start agreement and was completed in August 2007. The existing foundations and foundation walls were salvaged and support three tiers of rakers and tiebacks during demolition. The project team utilized a 3D scale model to plan the exact placement of the rakers and corner bracing to minimize the number of conflicts in the demolition of the existing and construction of the new structure. Construction of the new building started in August 2007 and will be completed in December 2008.

Lafayette Tower is designed to LEED Gold standard and will comprise 327,688 square feet of mixed use space, with the ground floor dedicated to retail. The combination of column-free perimeter and floor-to-floor glass curtain wall skin will offer spectacular views of the city specifically The White House and The Washington Monument. Lastly, the penthouse level will have a green roof terrace and there will be three levels of underground parking available for tenant use.

Figure 1 - Renderings of Lafayette Tower

Client Information

Principal activities of the Louis Dreyfus Group consist of worldwide processing, trading and merchandising of various agricultural and energy commodities. The Group is also significantly involved in the ownership and management of ocean vessels; in the development and operation of telecommunications infrastructures; and in real estate development, management and ownership.

Since it was organized in 1971, Louis Dreyfus Property Group has acquired and developed over eight million square feet of office space in North America and Europe. Current office buildings and development sites in the portfolio, some of which are held in joint ventures with other parties, are located in Washington, DC; suburban New York; Portland (Oregon); and Paris. Louis Dreyfus is also building and developing for ownership a number of hotels in partnership with Four Seasons Hotels and Resorts, including the Four Seasons Resort in Jackson Hole, Wyoming, and the Four Seasons Hotel Silicon Valley.

The main goal of this project for Louis Dreyfus was simply to make money. They expected this property to be a cash cow for a couple of reasons and the foremost of those being its close proximity and views of The White House and The Washington Monument.

As far as their cost, quality, schedule and safety expectations for this project, as of right now the only one that is not being stressed is schedule due to the fact that they have only been able to procure one tenant (John Deere) for a project that is supposed to be finished in around three months. Safety is always the number one concern in any type of construction matter due to how dangerous it is compared to other professions. Both Louis Dreyfus and Clark always make it their highest priority to send workers home the same way they came.

The only sequencing concerns of L.D. is that critical path items don’t get delayed and the project keeps moving forward. There are no dual or phase occupancy requirements for the project. And the keys to completing the project to the owner’s satisfaction would be that the project comes in on or under budget and it is of excellent quality.

After the building is completed, Louis Dreyfus will use it as its new headquarters until the building becomes entirely leased or they complete a new project that would suite them better.

Project Delivery Method

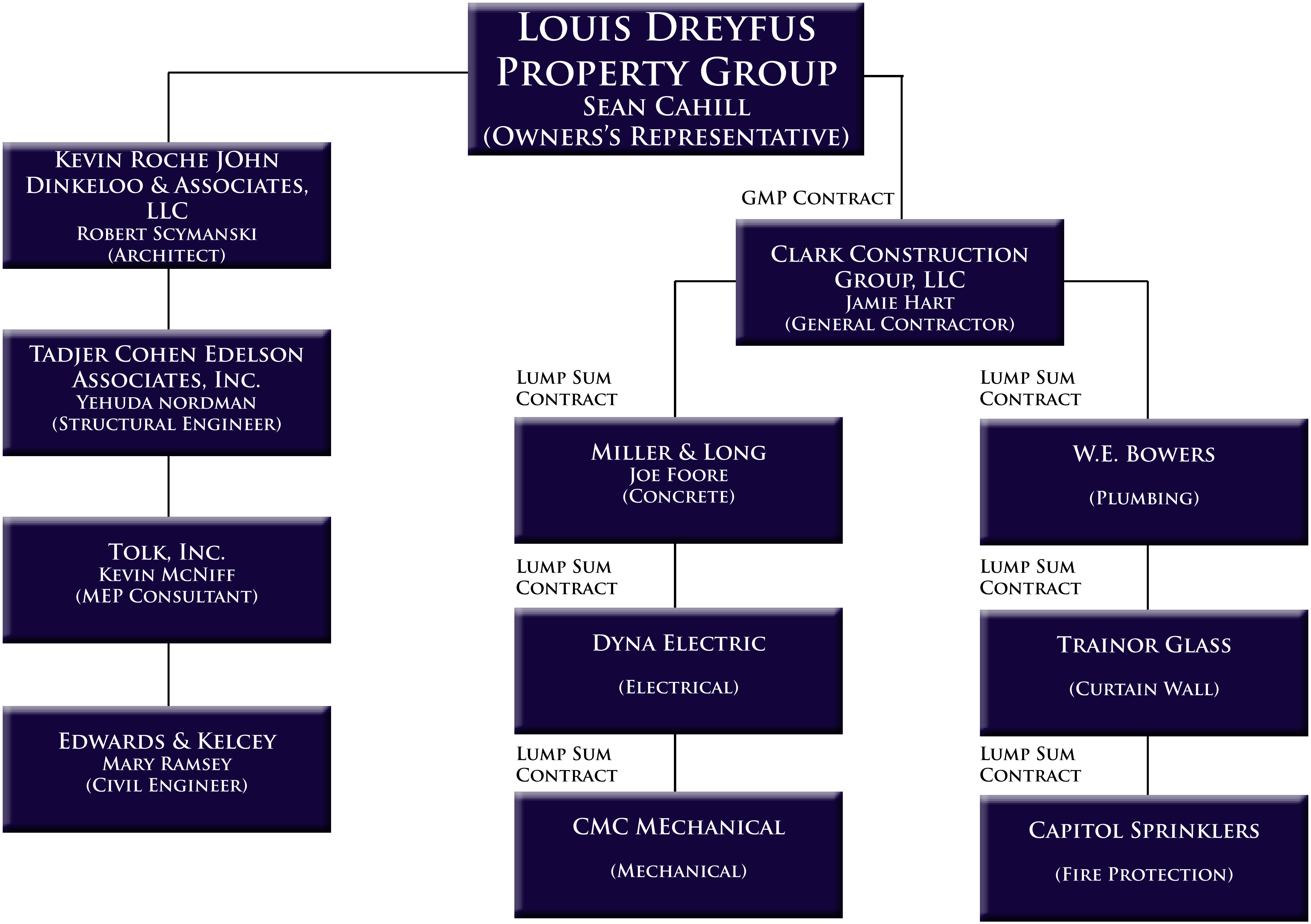
Clark Construction is acting as the general contractor for Lafayette Tower. A GMP contract was used between Clark and Louis Dreyfus because upon the negotiation of the contract, the drawings were well underway but not yet complete and a GMP would make it easy to changes things later.

All of the contracts held between Clark and the subcontractors are lump sum. This is a typical contract agreement and allows for change orders later on. Clark also has a CCIP with most of the subcontractors which includes worker's compensation and general liability insurance. Payment and performance bonds are also covered in the CCIP. So minor subcontractors, the insulator for example, don't hold contracts directly with Clark but through larger subcontractors in which the 1st sub is responsible for the 2nd tier sub's bonding and insurance.

The owner would not disclose the types of contracts held between themselves and their hired consultants.

The organization chart for Lafayette Tower is displayed on the next page.

Organization Chart - Lafayette Tower



Staffing Plan

The project management and field supervision staff work hand-in-hand on this project and even share a site trailer. Therefore the project manager and the superintendent were considered equals in the construction hierarchy. Below the project manager, there is a project engineer, office engineer and an intern. Recently another project engineer was added to help with the dilemmas the curtain wall causing the job.

The field side consisted of the superintendent, an assistant superintendent and a party chief engineer (one of the different levels Clark has for field engineers). Both sides also had a college intern and there were also two labor foreman on the field side.

The staffing plan for Lafayette Tower is displayed on the next page.

Staffing Plan - Lafayette Tower

Louis Dreyfus Property Group
Sean Cahill
(Owners's Representative)

Kevin Roche John Dinkeloo & Associates, LLC
Robert Scymanski
(Architect)

Tadjer Cohen Edelson Associates, Inc.
Yehuda Nordman
(Structural Engineer)

Tolk, Inc.
Kevin McNiff
(MEP Consultant)

Edwards & Kelcey
Mary Ramsey
(Civil Engineer)

Brian Apt
(Division President)

Mike Hartman
(Project Executive)

Jamie Hart
(Senior PM)

Justin Tobias
(Project Engineer)

Tainika Taylor
(Office Engineer)

Richard Wagner
(Construction Executive)

Jim Keefer
(Assitant Superintendent)

Dustin Carey
(Field Engineer)

Louis Dreyfus Corporate Executive Management

Jeffery Susssman, President
Robert Braunholer, Regional

Clark Corporate Support

Estimating: Brad Trent
Purchasing: Larry Stovicek
Scheduling: Patrick Stethem
Cost Engineering: Mike Parrino
Risk Management: Jessica Gray
Safety: Rick Bowers
Quality control: Joe Conover

Site Planning

Lafayette Tower is located at 801 17th Street N.W. which is a mere 3 blocks from The White House and tended to complicate things.

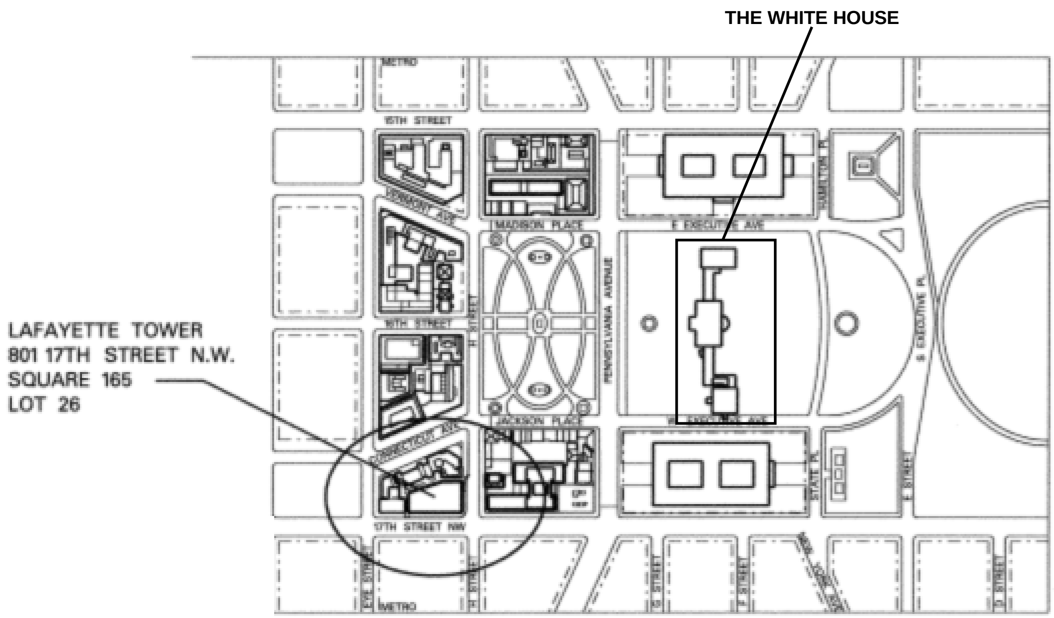


Figure 2 - Local Map

In the District of Columbia there is height restriction that prohibits buildings from being taller than the capital building. This being said, the primary type of construction used in D.C. is cast-in-place to maximize the floor to ceiling heights and sometimes sneak an extra floor in that you wouldn't be able to have if you used steel. Post-tensioning is also often utilized so that thinner slabs or larger spans between columns can be used.

Parking for your workers is always a concern while working in downtown D.C. There are two public lots located on the site's block but they are not cheap. Fortunate for many of the workers, the site is located a block from the Farragut West metro stop. After the parking levels were finished, there was some on-site parking available but it was very limited and only foreman were allowed to park there.

There were three critical phases of the project that needed to be analyzed for the site layout of Lafayette Tower: demolition, superstructure and finishes. On the whole, the layouts are fairly similar for all three phases but there are some differences that will be explained below.

Demolition

The first phase that took place was the demolition of the existing building. The picture below illustrates what the site looked like once the demolition was complete. It gives a great view of all of the support of the foundation walls in place. You can also see Clark's site trailer, storage sheds, and various pieces of equipment around the site.

Figure 3 - Demolition Site Picture

The only problems that I noticed with Clark's site layout is that the south-west corner of the site was extremely congested which would make it hard for equipment and materials to be moved around in that area and also occasionally when materials were being hauled from site, extra lanes of traffic had to be shut down. This could potentially cause some problems with the local authorities especially considering the White House is a few blocks away.

Superstructure

The second key phase to be analyzed was the layout while the superstructure was being constructed. Below, you can see what the site looked like while concrete was being placed. In the picture, you can see the pump truck distributing concrete for 4th floor deck. Along with that, you can see three concrete trucks either fueling or waiting to fuel the pump truck and the crane which won't be used for placing concrete until the building reaches its upper floors.

Figure 4 - Superstructure Site Picture

I think Clark's site layout is very functional for this stage of construction. Site cleanliness is somewhat of an issue in the above picture and needs to be kept under control better.

Finishes

The final phase examined was the finishes layout which shows what the site will look like after the building becomes water tight and interiors are the main concern. This is presently the current phase the project is in. As you can see in the picture below, the façade is entirely erected and there is a very minimal amount of activity going on outside of the building. Once the superstructure reached about the 8th or 9th floor, Clark's office was moved inside so there was no need for a trailer outside.

Figure 5 - Finishes Site Picture

The only thing that surprises me about the current state of the site is that there is still a lift and a concrete truck on the premise in this picture. Other than that, everything seems to be in order.

Project Schedule Summary

As the schedule below shows, the project is broken up into two main parts; First, the demolition of the existing structure and second, the construction of the new building. Demolition started in September of 2006 where the building was systematically stripped from top to bottom removing everything that was non-structural. After about two months, the interior demolition was completed and the demolition heads back to the top of the building to start on the structural system.

To take down the structural system, they started by using skid steer with a hydraulic demolition hammer attachment to deconstruct the upper floors. The process they followed was to crush up the decks of the floor that they had the skid steer on then move down to the next floor to knock out the columns. This repeated until they could get in reach of the excavators with hydraulic shears.

To get down to the existing foundation, it took about 9 months with a good portion of that time being once they got below grade. This is because as they removed each level, they installed tiebacks, corner bracing and rakers to keep the surrounding soil from caving into the hole. Extra support was provided along the alley because of the additional weight from the nearby buildings. Demolition wrapped up in August of 2007.

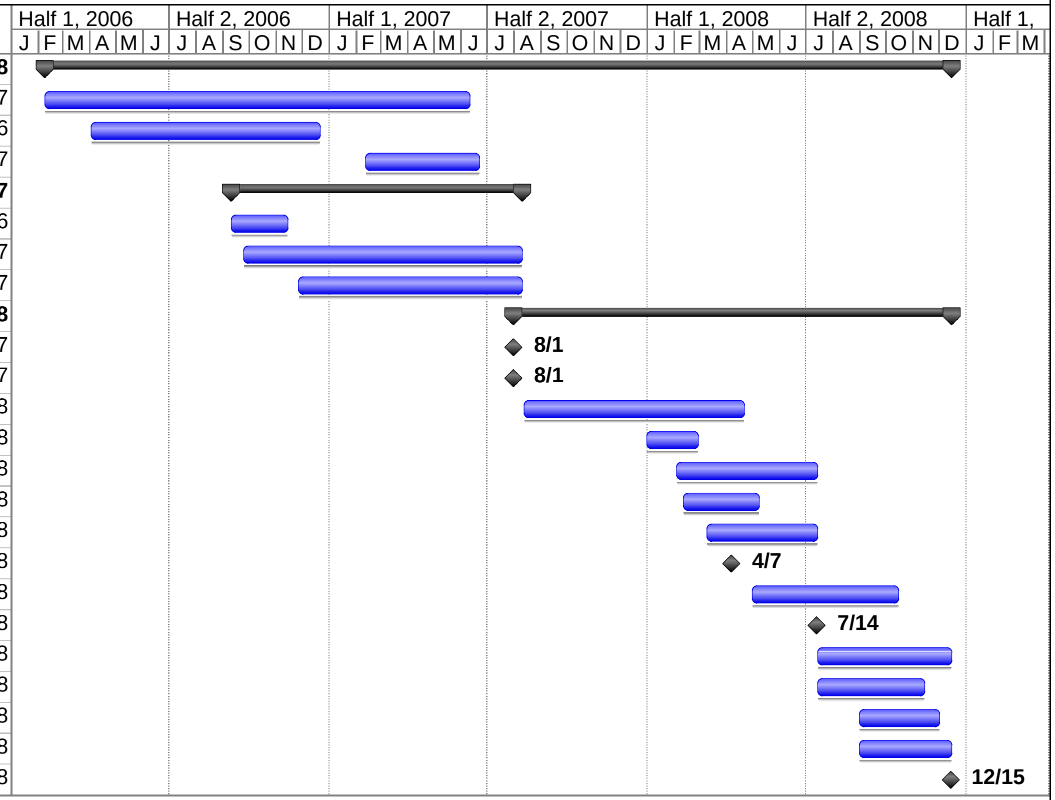
After demolition was finished, the critical path of the project moved onto the concrete as it came up and out of the hole. The existing foundation and foundation walls were kept but additional concrete was added to support the extra weight of the new building. It took a little under 4 months to get the project out of the hole and up to grade. Once the building was above grade, it took roughly two weeks per floor. The building topped out in April of 2008.

Before the concrete was finished, the curtain wall and MEP work was already underway. The curtain wall construction is not broken up by floors in the schedule because it was not constructed by floors on site. The original plan was to wrap the floors in a counter-clockwise fashion and move up the building uniformly but due to problems with fabrication and shipping, a different approach that took slightly more time had to be adopted. This led to the façade being several floors higher in some places than in others. The curtain wall finished up and the building became watertight in July of 2008.

Once the building was watertight, the finishes started in and are currently taking about 2 weeks per floor as they move up through the building. The reason that they can move so fast is because the scope only includes the core, which means little more than the bathrooms and elevator lobbies of the building where the tenants are responsible to fit-out of the majority of the floor themselves.

Basic Project Schedule for Lafayatte Tower (Washington DC)

ID		Task Name	Duration	Start	Finish
1		**Lafayette Tower**	**736 days**	**Thu 2/9/06**	**Mon 12/15/08**
2		Permitting	341 days	Thu 2/9/06	Mon 6/11/07
3		Bid Packages	184 days	Mon 4/3/06	Thu 12/21/06
4		Project Purchasing	95 days	Mon 2/12/07	Fri 6/22/07
5		**Demolition**	**236 days**	**Mon 9/11/06**	**Fri 8/10/07**
6		Interior Demolition	47 days	Mon 9/11/06	Tue 11/14/06
7		Sheeting and Shoring	226 days	Mon 9/25/06	Fri 8/10/07
8		Structural Demolition	183 days	Mon 11/27/06	Fri 8/10/07
9		**Construction**	**359 days**	**Wed 8/1/07**	**Mon 12/15/08**
10		Notice to Proceed Co	0 days	Wed 8/1/07	Wed 8/1/07
11		Site Mobilization	0 days	Wed 8/1/07	Wed 8/1/07
12		Concrete	181 days	Mon 8/13/07	Mon 4/21/08
13		Utilities	43 days	Tue 1/1/08	Thu 2/28/08
14		Glass and Glazing	116 days	Mon 2/4/08	Mon 7/14/08
15		M/E/P	63 days	Tue 2/12/08	Thu 5/8/08
16		Curtainwall	91 days	Mon 3/10/08	Mon 7/14/08
17		Topping Out	0 days	Mon 4/7/08	Mon 4/7/08
18		Elevators	120 days	Thu 5/1/08	Wed 10/15/08
19		Building Watertight	0 days	Mon 7/14/08	Mon 7/14/08
20		Interior Finishes	110 days	Tue 7/15/08	Mon 12/15/08
21		Framing/Draywall	89 days	Tue 7/15/08	Fri 11/14/08
22		Applied Finishes	66 days	Mon 9/1/08	Mon 12/1/08
23		Test & Start Mech.	76 days	Mon 9/1/08	Mon 12/15/08
24		Substantial Completio	0 days	Mon 12/15/08	Mon 12/15/08



Project: Lafayette Tower
Date: Mon 4/6/09

Task	Milestone	External Tasks
Split	Summary	External Milestone
Progress	Project Summary	Deadline

Building Systems Summary

Demolition

Before September 2006, the site was home to the Federal Deposit Insurance Corporation or the FDIC who has now moved to 550 17^{th} Street NW. Demolition began September 11^{th} 2006. Clark started by completely gutting the interior of the building, removing anything that wasn't linked to the structural system. That was completed November 14^{th} of the same year and which time they started the structural demolition.

To take down the structural system, they started by using skid steer with a hydraulic demolition hammer attachment to deconstruct the upper floors. The process they followed was to crush up the decks of the floor that they had the skid steer on then move down to the next floor to knock out the columns. This repeated until they could get in reach of the excavators with hydraulic shears.

Once in reach of the excavators, the demolition process sped up significantly. The sequencing went from basically going floor by floor to taking out sections of the building from top to bottom.

Figure 6- Excavators w/ hydraulic shears

After the demolition got below grade, tiebacks and rakers were used to help support the existing foundation walls until the walls were thickened with 14" of additional concrete for extra support.

Cast-in-Place Concrete

The structure of the building is made up entirely of cast-in-place concrete.
All of the slabs below grade are 8 ½" or 10 ½" thick where as all of the slabs above grade are 10" or 12" thick and also utilize post tensioning to allow for larger spans between columns and provide support for the cantilevered slabs that extend out past the exterior row of columns. The concrete for the slabs was put in place by a pump truck.

The columns were put in place by using vertical formwork and the crane and bucket method. The sizes of columns range from 24x40 to 24x12. Slanted columns were used 13 cases all below grade on either the P1 or Concourse level. Slanted columns allow you to stray from typical bays throughout your entire build but still transfer the load down from above.

Mechanical System

Although there are small mechanical rooms on each of the above ground floors (each floor has its own AHU because each floor will host a different tenant), the main mechanical room is located on the P2 Parking level. The key system components that it houses are (2) water chilling units, (2) condenser water pumps, (1) chilled water pump, (1) heat exchanger. The only other major pieces of equipment in the building are (2) cooling towers that are located on the roof.

For fire suppression, both wet and dry systems are used. Wet is the primary system but a dry system is used in the spaces that aren't heated such as the parking levels and parts of the concourse level. Quick response heads are used throughout the building.

Electrical System

Lafayette Tower's electrical service is supplied by Pepco, a regulated electric utility that provides transmission and distribution services. The main feed is brought into the building and stepped down to 3Φ, 3000A, 265/460V before it goes into either of the 2 main switchboards that provide power for the rest of the building.

An emergency generator is located just north of the loading dock on the first floor. It is a 500KW/625KVA diesel generator with a 250 gallon tank. This generator would not be able to support the building running at full capacity for more than a couple of hours without being refueled during the outage.

Masonry

All of the masonry used on this job is non load bearing. It is mainly used in the stair wells and the exterior walls for the first two floors on parts of alley and the alley is the only place where scaffolding was used. It is also used as partitions for parts of the first floor and all the below grade levels.

The brick used in the alley is tied back into the building after every two layers by masonry wall ties. There is also a curtain wall stack joint with continuous masonry cap flashing that ties the bricks into the curtain wall coming down from above.

Curtain Wall

An elaborate curtain wall system is used for almost the entirety of the building. There are many box-ins and outs to make the building appear that it is made of glass Legos. There are two main materials used for construction which are aluminum and glass. The assemble involves two layers of glass with an air gap in-between with a coating on the inside of the outer piece of glass to promote heat transfer and it is held together with the aluminum. The design and assembly is the responsibility of Trainor Glass Company.

The individual piece of curtain wall are manufactured in Trainor's shop where they are then packaged up and shipped to site ready to be installed as soon as they arrive. This process is called unitized glazing which allows for the glass to be set faster and cheaper. To get the glass into place, Trainor uses a crane to lift the panels to the floor above where the panel will actually be set then they use a mobile floor crane to lower them into place and attach them to the rest of the system.

The major benefits of this system is that it not only lowers energy costs and looks cool architecturally but it also does not impose loads on the structural system of the building and it is flexible so that it can move with the wind or expansion from heat.

Depth Study – Column-Free Perimeter Analysis

Problem

The column-free perimeters are an exciting feature to potential tenants because of the increased square footage of window space they provide on the North, West, and South faces of the building but they greatly increase the difficulty of construction due to the incorporation of detailed fall protection plans and cantilevered slabs.

Solution

I agree that the views to the South side of the building are worthwhile due to the fact that they overlook The White House. However, I don't feel the views to the West and North are worthy of the extra time, money and energy needed to incorporate this feature. I would like to analyze the effects of only incorporating them South face and come to my own conclusion whether or not they are worth including.

Methodology

The dollar value gained from removing this feature will be hard to determine. One of the items I'll have to examine and estimate is the cost differential between the current cantilevered slab to a normal PT slab. Along with that, I will have to ballpark a figure on how much additional time and money was lost due to implementing the atypical fall protection plan. And finally, I will have to determine how the change will affect the $/SF rental price for the building if at all.

Resources

In order to obtain the necessary information, I will rely on the contacts I have made in the construction industry and attempt to obtain $/SF rental costs from with my owner's representative or a realtor. Any other needed facts or values will be found through research online or through contacts found from that research.

Concluding Remarks

I feel that the gains from limiting the column-free perimeter to only the South face of the building will prove to be worthwhile. But also, I recognize that this analysis will be highly subjective. I will do my best to keep this analysis as unbiased as possible in order to determine if this architectural feature should have been included in this project.

Background

Upon completion, Lafayette Tower became one of Washington's most advanced trophy offices. Along with its proximity to the White House, Lafayette tower is marketed for its innovative design by Kevin Roche, rooftop terrace, green roof, digital controlled HVAC system, LEED Gold certification, and of course its column-free perimeter glass exterior. All of these features add to the laundry list of reasons why a possible tenant would pay top dollar to call this building home.

All of the aforementioned items make Lafayette Tower seem like a spectacular place to work but with the addition of each amenity, the rental price continues to go up. This might not be a big deal with a strong economy but with today's recession, possible tenants are forced to cut back on luxuries in order to stay afloat.

With all of this being said, the builder needs to consider what can be changed without taking away from the prestige of their trophy office building. The answer that I have come up with is the partial removal of the column-free perimeter. The views that are highly coveted are solely to the South and therefore should be kept, whereas the views to the West and North aren't nearly as valuable and should be removed. The following images utilized Google Earth to demonstrate my point.

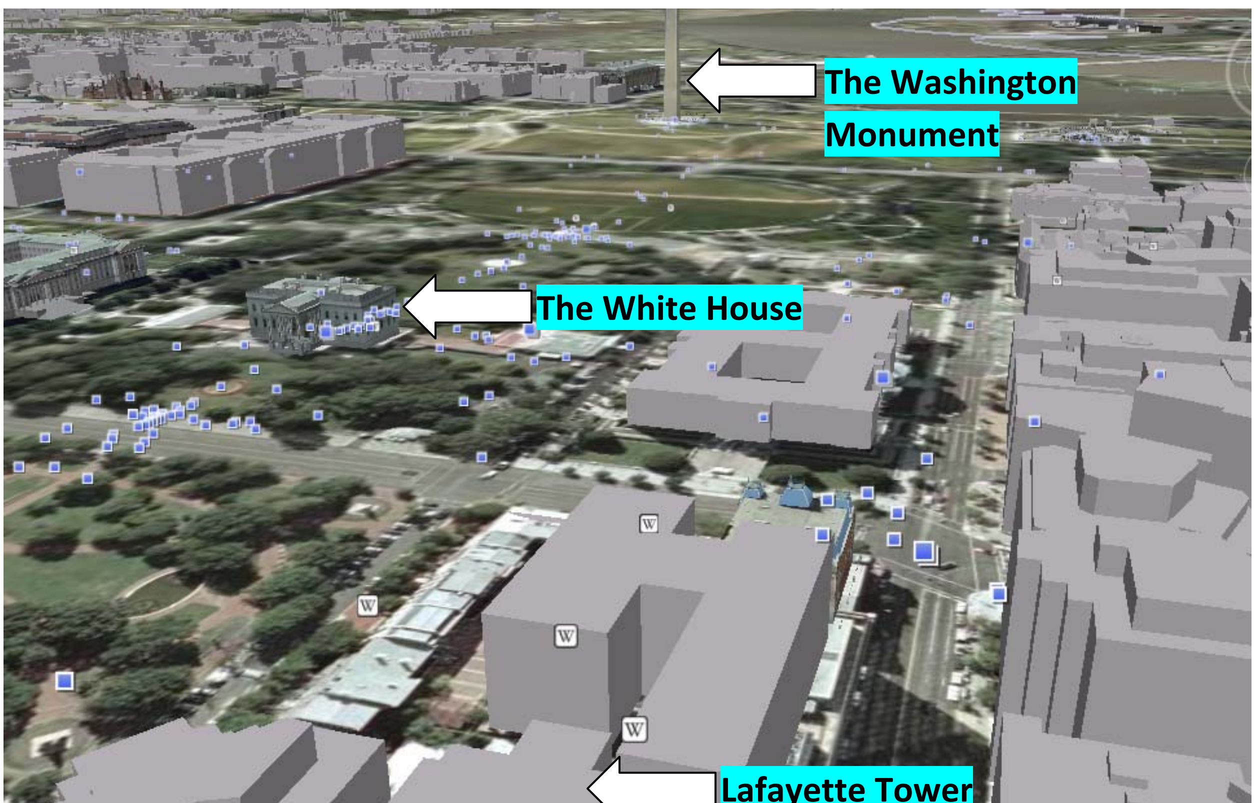


Figure 7 – The South view from above Lafayette Tower

Although not every building is modeled, this gives a fairly accurate illustration of the buildings in this area. The White House can be seen with an unobstructed view from the 7th floor and up and a few of the upper floors can see the top of The Washington Monument. These views are clearly worthwhile and add a great amount of value to the building.

Now let's take a look at the views of the other two sides of the building that also incorporate the column-free perimeter.

Figure 8 - The West view from above Lafayette Tower

The view to the West gives the tenants a scene that includes the buildings across the street and down H Street if you're in the southern corner. Neither of which are overly impressive, especially if it is being used to justify the time, money, and effort needed to include a cantilever that stretches over 200 feet along the length of building.

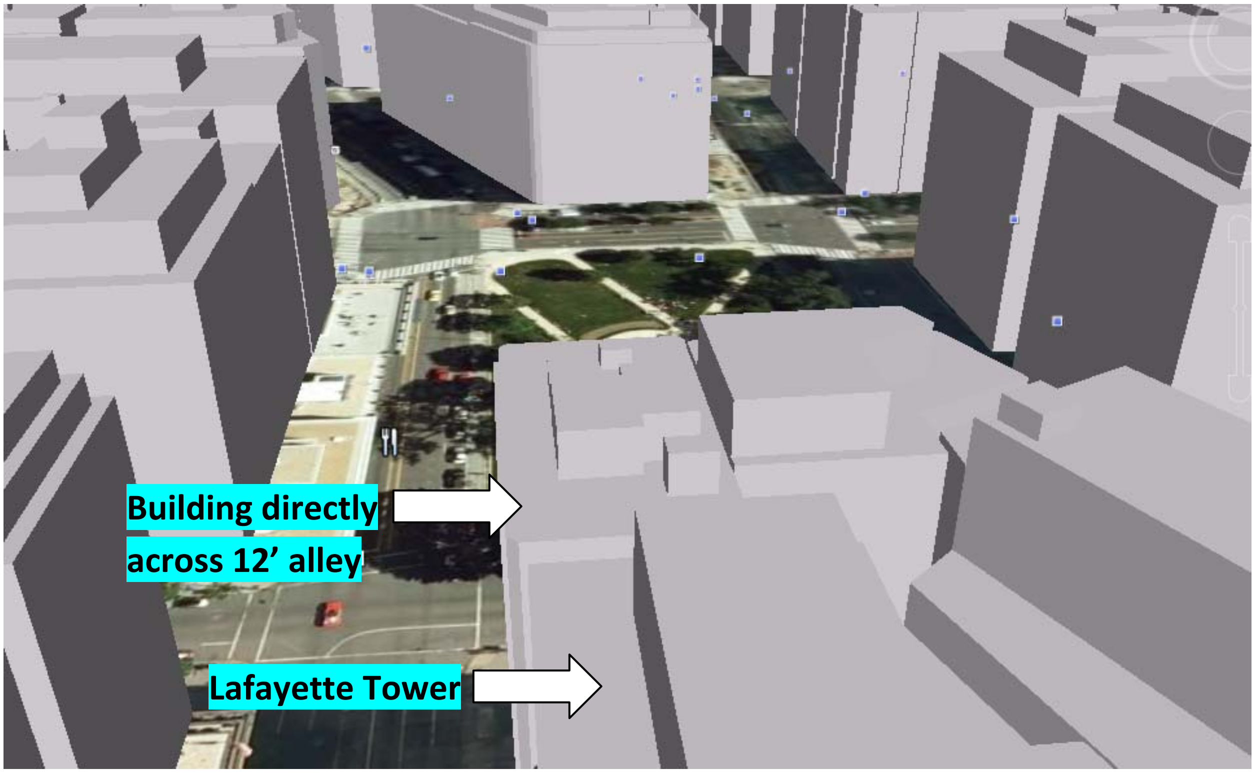


Figure 9 - The North view from above Lafayette Tower

Without going into too much detail, this view brings nothing to the table. All that can really be seen is the building directly across the 12' alley whose façade is nothing special. The building across the alley is also a hotel. Providing tenants with an unobstructed view of the hotels guests seems somewhat intrusive.

Analysis

Three keys things need to be considered to determine if the partial removal of the column-free perimeter is beneficial. They are cost implications, schedule impacts and constructability variances between the two scenarios. All three need to be looked at simultaneously because they are so closely intertwined. To analyze them, my process was as follows:

- Consult my owners representative in an effort to determine how much extra it cost him to include the cantilevered slabs/column-free exterior and how much he expected to gain from them in terms of rental prices
- Consult my representative from Clark Construction to determine home much extra time, effort and money was spent to accommodate the cantilevered slabs/column-free exterior. This also includes what was needed for safety purposes and how those precautions affected both the Clark and Trainor Glass Employee's labor production.
- Redesign the column layout, which was done for a structural breadth and will be discussed in great detail in the next section, so that applicable proportions could be assigned to the provided values. (i.e., If I plan on removing x% of the column-free perimeter, then I expect to see a drop of x% in the increased rental value it brings to the building)
- Weigh the pros verse the cons and determine which scenario came out on top.

Information from Owner's Representative:

After consulting my owner's representative, I received the following information:

The cost for the cantilever to me was about $1.00/gsf of building area. What we get out of it in rent that is directly attributable is very hard but I would say conservatively, that it adds $0.25 to $0.50/rsf. Put that in a lease for 15 years and you are talking about a little bit of money…

The important things in that I got from this are that:

1. The cantilever cost him $1.00/gsf. With the building sitting at around 328,000 SF, the addition of the cantilever cost approximately <u>$328,000</u>.
2. The column-free perimeter increases the value of the rental space somewhere between $0.25 and $0.50 per square foot.
3. The typical lease period is 15 years.

With the information from #2 and #3, the following table was created.

Cantilever Value Calculator								
Floor	**Floor Area (SF)**	**Low $/SF**	**High $/SF**	**Value Range**		**Typical Lease**	**Value Range**	
2nd	17,482	$0.25	$0.50	$4,370.50	$8,741.00	15 years	$65,557.50	$131,115.00
3rd	21,156	$0.25	$0.50	$5,289.00	$10,578.00	15 years	$79,335.00	$158,670.00
4th	20,556	$0.25	$0.50	$5,139.00	$10,278.00	15 years	$77,085.00	$154,170.00
5th	21,006	$0.25	$0.50	$5,251.50	$10,503.00	15 years	$78,772.50	$157,545.00
6th	21,006	$0.25	$0.50	$5,251.50	$10,503.00	15 years	$78,772.50	$157,545.00
7th	21,006	$0.25	$0.50	$5,251.50	$10,503.00	15 years	$78,772.50	$157,545.00
8th	21,006	$0.25	$0.50	$5,251.50	$10,503.00	15 years	$78,772.50	$157,545.00
9th	21,006	$0.25	$0.50	$5,251.50	$10,503.00	15 years	$78,772.50	$157,545.00
10th	20,856	$0.25	$0.50	$5,214.00	$10,428.00	15 years	$78,210.00	$156,420.00
11th	21,156	$0.25	$0.50	$5,289.00	$10,578.00	15 years	$79,335.00	$158,670.00
						Total	$773,385.00	$1,546,770.00

Table 1 - Cantilever Value Calculator spreadsheet from Excel

This chart tells us that if all 10 of the floors are being leased, Louis Dreyfus expects to receive somewhere between $773,385.00 and $1,546,770.00 at the cost of $328,000.00. At first glance, this seems like an extremely easy decision with even the low end expectations bringing in almost $450,000 over cost. But other factors need to be considered.

First and foremost, with the economy in a recession spending extra money to all the amenities of Lafayette Tower may not be considered a necessity for companies. Even though the building is finished, many of the floors still remain unrented. The following chart shows how much the cantilever can be expected to bring in depending on how many floors are occupied. For this, the value of each floor was summed and an averaged determined due to the fact that any combination of floors could be occupied at once.

Cantilever Value / Floors Leased					
Floors Leased	**Value Range/ Floor**		**Low Total**	**Ave. Total**	**High Total**
1	$77,338.50	$154,677.00	$77,338.50	$116,007.75	$154,677.00
2	$77,338.50	$154,677.00	$154,677.00	$232,015.50	$309,354.00
3	$77,338.50	$154,677.00	$232,015.50	$348,023.25	$464,031.00
4	$77,338.50	$154,677.00	$309,354.00	$464,031.00	$618,708.00
5	$77,338.50	$154,677.00	$386,692.50	$580,038.75	$773,385.00
6	$77,338.50	$154,677.00	$464,031.00	$696,046.50	$928,062.00
7	$77,338.50	$154,677.00	$541,369.50	$812,054.25	$1,082,739.00
8	$77,338.50	$154,677.00	$618,708.00	$928,062.00	$1,237,416.00
9	$77,338.50	$154,677.00	$696,046.50	$1,044,069.75	$1,392,093.00
10	$77,338.50	$154,677.00	$773,385.00	$1,160,077.50	$1,546,770.00

Table 2 - Cantilever Value / Floor Leased spreadsheet from Excel

This graph demonstrates that:

- The low value requires over 4 floors to be leased for the cantilever to pay for itself in the first 15 years
- The average value requires at least 3 floors to be leased for the cantilever to pay for itself in the first 15 years
- The high value requires over 2 floors to be leased for the cantilever to pay for itself in the first 15 years

*note: engineering economics was ignored because the figures are already highly subjective and could just lead to the analysis becoming even more skewed in the wrong direction. This will just make the analysis more conservative.

Information from Clark Construction Representative:

The first aspect we discussed was the cost difference for furnishing and installing the cantilevered slabs verse a more traditional design. But as mentioned previously, it is nearly impossible to discuss cost without also including schedule impacts and constructability issues.

For the installation, almost everything is similar between installing a cantilevered slab verse a traditional slab. All of the same scaffolding and formwork is used for both scenarios. There is also no real difference between the skill level of the crew needed to install both slabs. So as far as installation costs, schedule and constructability, both slabs are very similar and no further analysis is necessary.

The concrete specified by the drawings was 6,000psi normal weight concrete. After consulting my Clark Representative, I found out that 10,000 psi concrete was actually used. He did not specify why, but I'm assuming that Clark felt more comfortable with the higher strength concrete when spanning such lengthy distances. Clark's material cost for concrete is approximately $325 dollars per cubic yard of 10,000 psi concrete. He also informed me that the material cost for 2,500 psi is around $135 per cubic yard.

Originally, I had planned on interpolating and coming up with a cost for 5,000 psi concrete, which was used in for my structural redesign and will be discussed later, but after further thought, I determined that there must be a reason that I either don't realize or am not being told for the selection of 10,000 psi concrete. It may be as simple as 10,000 psi concrete was the highest strength needed on the building and Clark wanted to keep things simple for the concrete subcontractor, Miller & Long, but I find that unlikely with the cost differences between different strengths. There also could have been concerns with the structural integrity of the original design so a stronger concrete was chosen to prevent possible failures which would be extremely expensive to fix. I find this a lot more likely. Because of this, I will not deviate from the path Clark followed and I will also assume 10,000 psi concrete is used in my cost review of my structural analysis.

Next, we discussed what type of time impacts came from using a cantilevered slab verse a traditional slab. These are the important issues we discussed:

- For safety purposes, the poor breaks are more stringent and need to be monitored closely. This creates extra work for the GC, Clark. Also, to compensate for elevated breaking strengths, an accelerator was added to the concrete. This allowed construction to progress at a normal rate but also increased the cost of concrete by $50 per cubic yard.
- The entire process takes longer because it is much harder to maintain precision throughout construction. The elevation of the deck needs to be shot at multiple times to ensure it hasn't moved (it's normally shot once after being poured). If it moved more than ¼" up or down, it would affect the installation of the curtain wall. It takes 5x more time to check a cantilevered deck as opposed to a normal deck. It is shot:
    - Before the concrete is poured, on the formwork
    - After the concrete is poured, on top of concrete
    - After post-tension stressing, on top of concrete
    - After 28 days of post-tensioning, on top of concrete
    - Both curtain wall installation, on top of concrete

The last thing we discussed were the effects of including a detailed fall protection plan. The difference between a typical safety plan and the one utilized at Lafayette Tower, to accommodate the cantilevered slabs, is that normally the columns are at the very exterior of the building and have cables running into them to prevent people from falling over the sides. This is enough because people will not be working outside of the cables. At Lafayette Tower, a lot of work needed to be performed outside of the column line. For people to be allowed outside of the column line at Lafayette Tower, they had to be wearing a personal fall arrest system. This system involves a full body harness which is attached to a retractable lifeline cable which is then attached to anchor straps that are imbedded (2) into each column along the exterior.

The workers that primary used this system were the Clark Construction engineers and the Trainor Glass installers. The impact on the GC will be analyzed first followed by the affect on the installation of the curtain wall. The exact cost to incorporate this system is somewhat unclear due to the fact that the Clark representative was not allowed to disclose actual costs. Here is a combination of what I was able to obtain from him and my experiences on-site this past summer.

In Column Anchor Strap:

Figure 10 - 5' Nylon Anchorage Connector Strap with D-Ring on One End and Sewn Loop on the Other

Vender Price: $25.09

Clark's Price: $19.00

(2) Anchors / Column * (16) Columns / Floor * (10) Floors with Anchors = (320) Anchors

(320) Anchors * $19.00 / Anchor = $6,080

Full Body Harness:

Figure 11 - Harness with Back D-Ring and Quick Connect Buckles

Vender Price: $198.00

Clark's Price: $150.00

(5) Harnesses * $150.00 / Harness = $750

Retractable Lifeline Cable:

Figure 12 - 50' Sealed Self Retracting Lifeline with 3/16" Galvanized Steel Wire Rope

Vender Price: $1,385.50

Clark's Price: $1000.00

(5) Retractables * $1000.00 = $5000.00

Total Cost = $11,830

With a total cost of around $12,000, the extra materials needed to incorporate the unique fall protection plan don't amount to much. The major drawback of this plan is the additional time caused for people who are affected by it. Something that would take an hour would take approximately an hour and a half if it had to be done outside of the cables.

The first step in estimating the amount of extra man hours the personal fall arrest system caused is to determine the time period between when the elevated decks were constructed and when the curtain wall was put in place. The significance of this is that once the curtain wall was up, the cables were taken down because they were no longer necessary.

The second floor, which is the first floor that needed fall protection, was completed being poured on February 11th, 2008. The concrete reached the roof, which was the last floor needing fall protection, on April 28th, 2008 at which time the curtain wall was already being put in place. The curtain wall ran behind schedule and was finally finished on August 11th, 2008. This means that there was approximately 131 days during which the fall protection plan hindered the work of the Clark Engineers.

The next step is to consider the amount of hours the engineer and his helper would be working on the exterior of the building. While the building is still going up, this will be a considerable number do to quality control for the cantilevered slabs. The estimate myself and Clark's engineer came up with was at least 6 hours per day. This is over a period of 56 days. After all the decks are in place, we estimated that the engineer spent 4 hours per day between either checking elevations or helping the curtain wall subcontractor with layout. This is for the remaining 75 days. These hours need to be multiplied by 1/3 due to the fact that this cost is based off the statement that something that would normally take 1 hour now takes 1.5 hours.

The final step is to determine the total cost of the necessary labor. For this, a wage rate of $32 per hour will be assumed for the engineer and $23 per hour for the helper. Also, a 25% increase in the total cost will be included to compensate for any other employees that needed to complete tasks outside of the secure area. The following chart shows the total increased cost in labor.

Fall Protection Labor Cost					
Employee Classification	**Hours/Day**	**Multi-plier**	**Duration (days)**	**Wage ($/hr)**	**Cost ($)**
Engineer	6	0.33	56	32	$3,548.16
Helper	6	0.33	56	23	$2,550.24
Engineer	4	0.33	75	32	$3,168.00
Helper	4	0.33	75	23	$2,277.00
				Sub-Total	$11,543.40
				25% increase	$2,885.85
				Total	$14,429.25

Table 3 - Increased Labor Cost from Fall Protection spreadsheet from Excel

This table shows that approximately $14,429.25 was spent to accommodate the extra time that was needed to complete work with the elevated deck fall protection plan that was put in place. This figure is not 100% accurate because it is impossible to determine the actual amount of additional time that was needed but it is a reasonable approximate.

The final piece of information we discussed was the financial impacts on the curtain wall installation by the safety plan. In order to determine a monetary value for this, a total labor cost needs to be determined and a modified version of the labor loss rate proportion from above can be applied to it to come up with a cost differential. The exact cost could not be released but the general range was that the curtain wall cost around $4 million and labor was 15% of the total cost. This equates to $600,000.

The fall protection plan wouldn't affect the curtain wall installers as much as any other trade because they would have to be tied off working that close to the edge of the building anyway. It was reasoned that the safety setup at Lafayette Tower reduced their production by 20% which means something that would normally take them an hour would take them 1.2 hours or 1 hour and 12 minutes. They way this information is tied into the analysis is that the extra time from working around the fall protection apparatuses is added to the original estimate. The 20% increase in labor time causes a difference of $120,000 that would be saved with the partial removal of the cantilevered slab.

Figure 13 - Curtain Wall Being Hung at Lafayette Tower

Information from Structural Redesign:

The third part of this study involved redesigning the column layout in order to create an optimal plan that kept the column-free design on the South face of the building but incorporated a more typical layout for the columns on the West and North faces while keeping it as close to the original design as possible. The specifics will be discussed later in the report in the structural breadth section, but a brief overview will be discussed here.

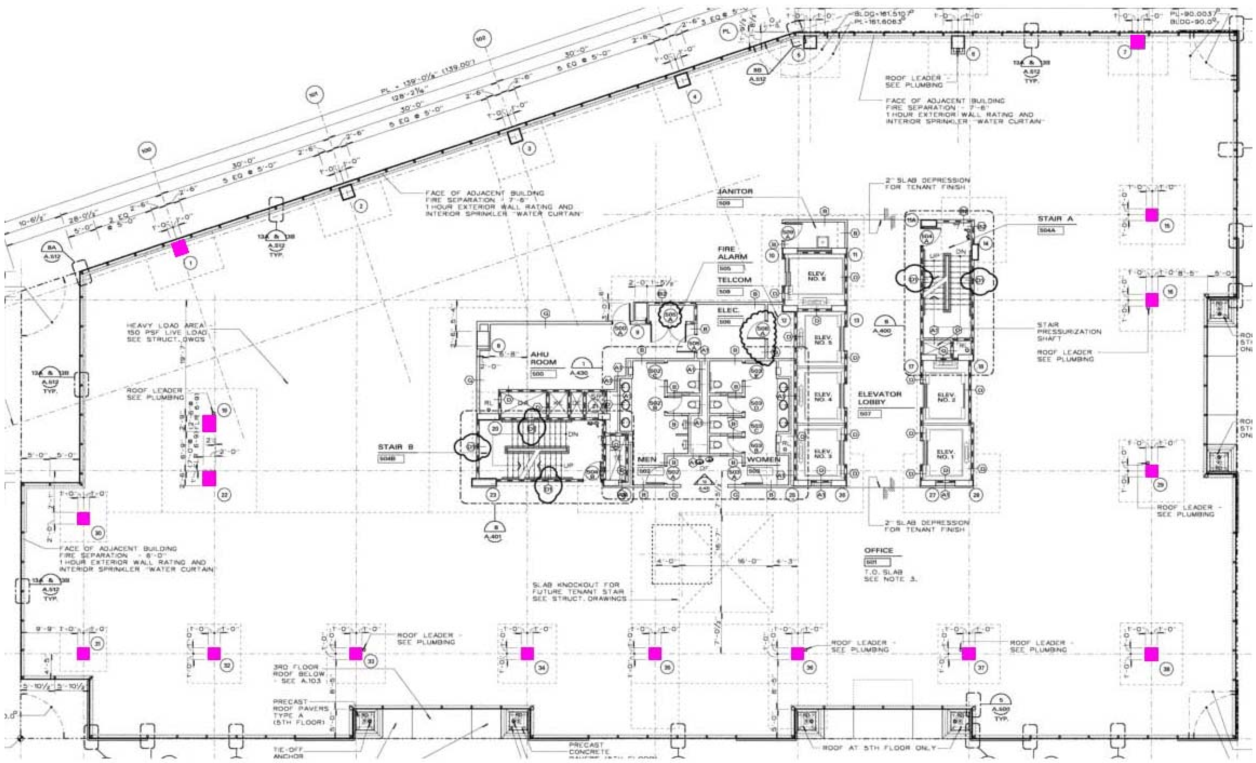


Figure 14 - Floor Plan with Cantilever Supporting Columns Highlighted

This image shows the plan for a typical floor in Lafayette Tower. Highlighted in pink are the columns that support the cantilevered slabs in the original design. In my structural redesign, which can be seen on the next page, I eliminated the 12 columns along the West and North sides of the building that supported the cantilevered slabs and added 12 new columns along the perimeter of the building.

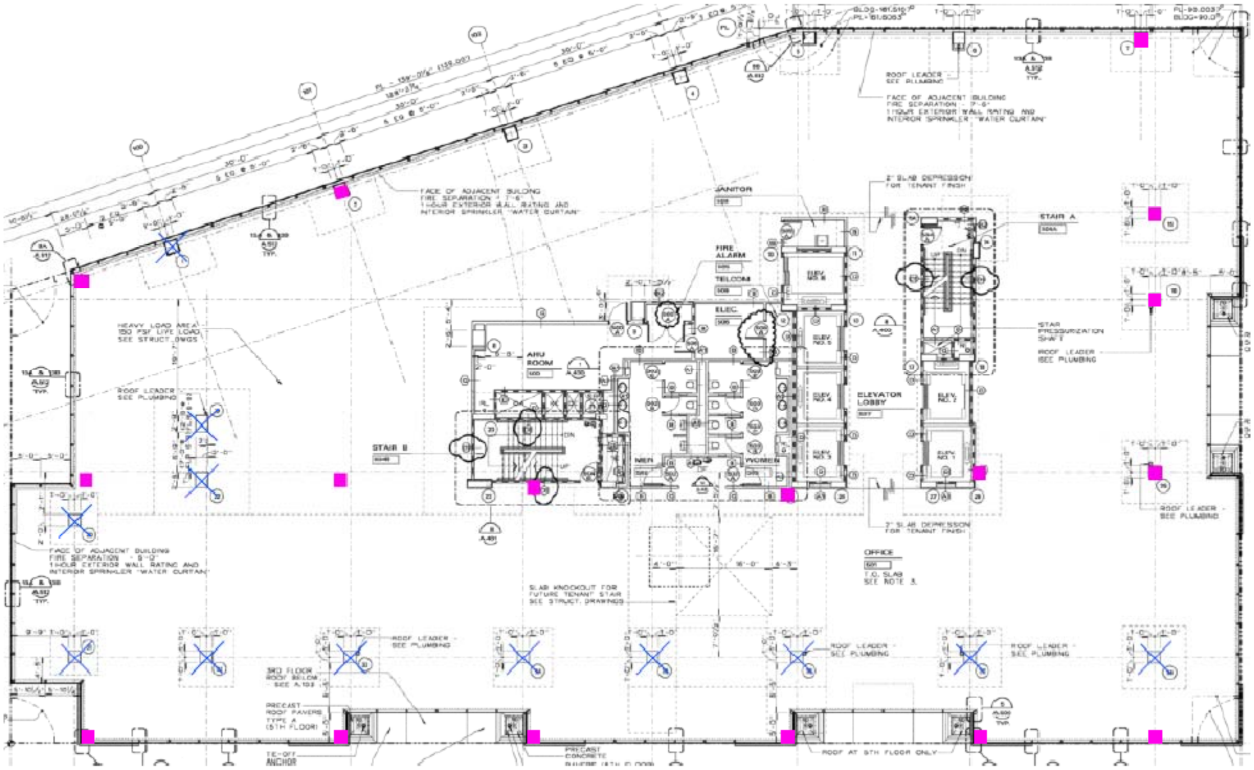


Figure 15 - New Column Layout for Typical Floor

The original design incorporated 403 LF of column-free perimeters along the exterior of the building whereas the new design only includes 120 LF of column-free perimeters. This equates to a 70% removal of the cantilevered slabs. I'm assuming that I can relate that directly to relate that to the cost of adding the cantilevered slabs. If that's the case, it takes the original cost of $328,000 and reduces it by $229,600 to $98,400 for just the cantilever on the South face of the building.

The final factor to include is how will removing the column-free perimeters affect the increase in lease rates. This is probably the most subjective part of this analysis without a question. The recommendations I've obtained from others puts me anywhere from a 70% reduction in rental value (the proportion of building changed) to a mere 10% reduction in the rental value. Clearly both are extremes and shouldn't be included. After taking everything into consideration, I have determined that the new design will retain somewhere between approximately 50-66% of its original value. This will be pursued farther in the pros vs. cons section on the following page.

Pros vs. Cons:

This section of the report will evaluate the pros and the cons of the partial removal of the column free exterior of Lafayette Tower. It is the summation of the first three parts of this analysis and will included all of the items discussed previously. The way that I am going to tabulate the data is as follows:

Original Design:

- The total value of the scenario can be found by taking the average value the column-free exterior brings to the building per floor and subtract the cost of the cantilever. This was all calculated and is displayed above.
- There will be a different value for depending on the number of floors being leased.

New Design:

- All of the benefits (money saved from fall protection materials and extra labor for both the GC and curtain wall company) will be compiled.
- The average value per floor of the column-free exterior brings to each floor will be adjusted by the percentage determined by the cantilever's partial removal analysis.
- The cantilever cost will be adjusted to correspond with the percentage of cantilevered slab remaining in the new design

All of the inputs for each scenario will be summed and the highest value for each number of floors being leased will be indicated.

New Design Benefits:

	Material	Labor	Total $$
Safety Plan	$11,830	$14,430	$26,260

	Original Value	Multiplier	New Cost
Cantilever	$328,000	30%	$98,400
Curtain Wall Labor Savings	$600,000	20%	$120,000
New Value / Floor	$116,008	58%	$67,285

Table 4 - Column-Free Exterior Value Calculator for Original Design

Cantilever Value / Floors Leased				
	Original Design			
Floors Leased	Value/ Floor	Ave. Total	Cantilever Cost	Total Value
1	$116,007.80	$116,007.80	$328,000	-$211,992.20
2	$116,007.80	$232,015.60	$328,000	-$95,984.40
3	$116,007.80	$348,023.40	$328,000	$20,023.40
4	$116,007.80	$464,031.20	$328,000	$136,031.20
5	$116,007.80	$580,039.00	$328,000	$252,039.00
6	$116,007.80	$696,046.80	$328,000	$368,046.80
7	$116,007.80	$812,054.60	$328,000	$484,054.60
8	$116,007.80	$928,062.40	$328,000	**$600,062.40**
9	$116,007.80	$1,044,070.20	$328,000	**$716,070.20**
10	$116,007.80	$1,160,078.00	$328,000	**$832,078.00**

This table indicates that if 8 are more of the floors are in a 15 year lease, then the original design is more valuable.

Table 5 - Column-Free Exterior Value Calculator for New Design

Cantilever Value / Floors Leased					
	New Design				
Floors Leased	Value/ Floor	Ave. Total	Benefits	Cantilever Cost	Total Value
1	$67,284.52	$67,284.52	$146,260	$98,400	**$115,144.52**
2	$67,284.52	$134,569.05	$146,260	$98,400	**$182,429.05**
3	$67,284.52	$201,853.57	$146,260	$98,400	**$249,713.57**
4	$67,284.52	$269,138.10	$146,260	$98,400	**$316,998.10**
5	$67,284.52	$336,422.62	$146,260	$98,400	**$384,282.62**
6	$67,284.52	$403,707.14	$146,260	$98,400	**$451,567.14**
7	$67,284.52	$470,991.67	$146,260	$98,400	**$518,851.67**
8	$67,284.52	$538,276.19	$146,260	$98,400	$586,136.19
9	$67,284.52	$605,560.72	$146,260	$98,400	$653,420.72
10	$67,284.52	$672,845.24	$146,260	$98,400	$720,705.24

This table indicates that if less than 8 floors are leased for the first 15 years, than the new design is more valuable.

Conclusion and Recommendations

The first thing that needs to be said about this analysis is that a good portion of the items that values were found for are subjective and almost, if not, impossible to obtain a 100% value for. That being said, I feel that a fair representation for each has been selected and used to help determine a solution.

This analysis was to prove if the original design, column-free exteriors along the South, West and North face of the building, could be replaced by a more simplistic version of itself that played on its strengths, keeping the cantilever on the South face. The analysis was based on a 15 year time period which is the length of a typical lease. After everything was summed up, the answer is yes and no. If less than 8 floors are being leased, then the new design bests the old but if 8 or more are leased during the first 15 years of operation, then the old design wins out.

I do not feel that this analysis covers everything that should contribute when making this decision. Things such as the column-free exteriors bringing prestige to the building or the amount of frustration caused by cantilevered slabs that never seem to be at the same elevation or continually having to step over a cable to do your job are not taken into account because a monetary value cannot be placed on them. Regardless, I feel that the evaluation was fair to both sides of the argument and as unbiased as possible.

My recommendation would be to construct the building with the partial removal of the column-free exterior. I feel that the view to the South with The White House and The Washington Monument is a major selling point for the realtor but the other views are not worthwhile and for the amount of time, money and aggravation they cause, they should be cut from the building. I also think that with today's economy in a downturn, it will be hard to fill 8 or more floors with tenants and that saving money is a priority to a lot of people. And in this scenario, the partial removal wins out.

Analysis I – Column-Free Perimeter Structural Redesign (Structural Breadth)

Problem

In order to eliminate the column-free perimeters and cantilevered slabs, a new structural plan needs to be devised.

Solution

To solve this problem, the columns need to be relocated to the exterior of the building on a typical floor. The current sizes and strengths of the columns and slabs will also need to be evaluated to establish if they will support the new plan.

Methodology

My first step in the structural redesign will be to consult a few contacts from industry along with classmates in order to obtain some general knowledge about how a building is designed. During this process, I hope to come across a couple different options to consider for the new plan.

From there, I will select a new layout and begin analyzing it for structural integrity. I plan on trying to use the same typical strengths of concrete and sizes of rebar that are used throughout the building to keep things more simple for the subcontractors.

I will primarily use hand calculations in order to analyze the building. To do so, I plan on utilizing a PCA design guide and Excel spreadsheets.

Resources

In order to obtain the necessary information, I will rely on the contacts that I've have made in the construction industry, knowledge gained through the courses I have taken here at The Pennsylvania State University, and my peers.

Concluding Remarks

The somewhat odd geometry of the building may make redesign difficult. I will try to keep bay sizes as consistent as possible. Also, this breadth will be tied very closely to the aforementioned construction depth and parts from each will be tied in with one another. This analysis will give me a much greater understanding of structural systems and their design techniques which will be very valuable to me as a new engineer.

Background

Through research and reasoning with peers, I determined that the best way to attempt to redesign the structural system of a building with little experience would be to change only what needs to be changed in order to keep things as simple as possible. That being said, the new design will still be a two-way post-tensioned slab. The only real differences will be the placement of the columns and the amount of reinforcing needed to meet original loads. Also, deck and column sizes will be kept as typical as possible.

Below is an image of the original and in place design of a typical floor in Lafayette Tower. All of the columns associated with the cantilevered slabs are highlighted in pink. From left to right, the plan goes from North to South.

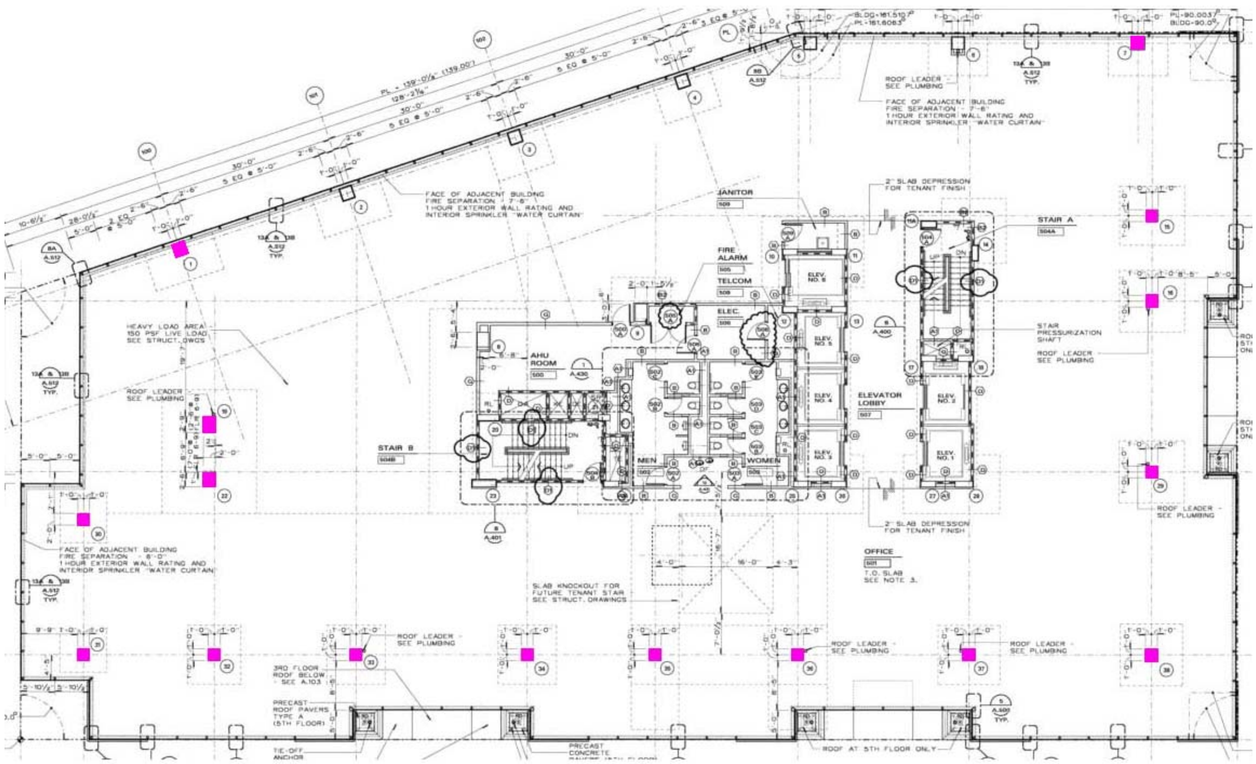


Figure 16 - Floor Plan with Cantilever Supporting Columns Highlighted

The purpose of the new design is to extend the columns on the North and West out to the exterior of the building to remove the cantilevered slabs. The columns on the South face will remain in place.

For the new design, similar sized bays will be created in order allow for the calculation to be run only once. The system will therefore be designed to accommodate the largest bay. This will result in an over design of the other bays but guarantee that they will be structurally sound. This is a conservative approach but safer and easier then attempting to design each individual bay.

This will also make the building easier to construct. A repetitive pattern will be easy to follow for the concrete subcontractor which will speed up their production and hopefully prevent them from making mistakes. Quality control will also be easier to check/maintain. Cantilevered slabs need to be monitored much closer than a normal two-way slab because of the lack of support. Also, curtain wall installation will be more simplistic due to the removal of the fall protection plan associated with the cantilevered slabs.

I do not expect severe differences in terms of cost and schedule. If the goal of keeping the building as similar as possible is achieved, there shouldn't be much of a variance between the two designs.

Analysis

After creating a few different options for the new column layout, the image below pictures the design selected.

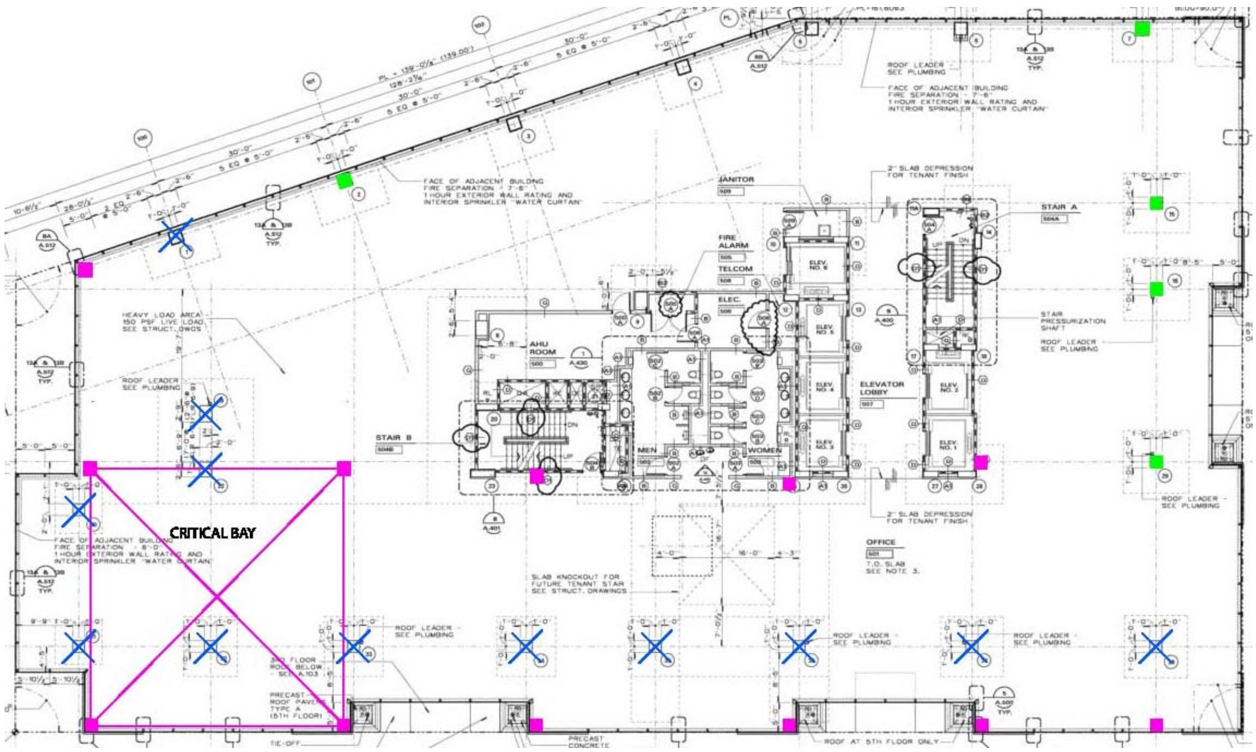


Figure 17 - New Column Layout for Typical Floor

In the figure above, the blue X's indicate the columns that are being removed from the original design, the green boxes indicated the columns from the old design that are remaining in place and the pink poxes indicate the placement of the new columns. The large X-ed out box is showing the largest bay in the design which will be considered the critical bay. The new design removes 12 of the old columns and adds 12 new ones.

To test the design, a Portland Cement Association (PCA) two-way post-tension design guide will be followed to determine if the materials and reinforcement currently used for Lafayette Tower will support the structure with the new column layout. Extra reinforcement may need to be added because the spans have increased from the old design to the new one.

The following pages will step through the design guide to determine the necessary reinforcement and assure the structure's stability.

Two-Way Post-Tensioned Design Walkthrough

*This example illustrates the design methods presented in ACI 318-05 and IBC 2003 for Two-Way Post-Tension Design

Loads:

Framing - Selfweight (psf)	150
Superimposed Dead Load (psf)	20
Live Load (psf)	80
K_{LL}	1
A_T (ft^2)	2115.75
Reduced Live Load (psf)	46

The loads were taken from the structural specifications for Lafayette Tower

A_T = area of critical bay

$R_{LL} = K_{LL} (0.25 + (15/\sqrt{(K_{LL} * A_T)}))$

Materials:

Normal Weight Concrete (pcf)	150
f'_c (psi)	6000
f'_{ci} (psi)	3000
slab thickness - h (in)	12
Reinforcement	
f_y (psi)	60000
Unbonded PT Tendons	
Diameter (in)	0.5
Wire Strands	7
Area (in2)	0.153
f_{pu} (ksi)	270
Estimated Prestress Losses (ksi)	15
f_{se} (ksi)	174
P_{eff} (k/tendon)	26.6

The material values were taken from the structural specifications for Lafayette Tower

$f_{se} = (0.7 * f_{pu}) - 15$

P_{eff} = Tendon Area * f_{se}

Calculate Section Properties:

Class	**U**
A=bh (in2)	6552
S=bh^2/6 (in3)	13104.00

Two-way slabs must be designed as Class U (ACI 18.3.3), Gross cross-sectional properties allowed (ACI 18.3.4)

Set Design Parameters:

Allowable Stress @ Jacking	**ACI 18.4.1**	
f'_{ci} (psi)	3000	
Compression (psi)	1800	Compression = $0.6*f'_{ci}$
Tension (psi)	164	Tension = $3\sqrt{f'_{ci}}$
Allowable Stress @ Service Loads	**ACI 18.4.2**	
f_c (psi)	6000	
Compression (psi)	2700	Compression = 0.45*f'ci
Tension (psi)	465	Tension = $3\sqrt{f'_{ci}}$
Average Precompression Limits	**ACI 18.12.4**	
P/A		
min (psi)	125	
max (psi)	300	
Target Load Balance		
$.75w_{dl}$ (psf)	112.5	
Prestress Required for Balance		
$w_b=.75w_{dl}$ (k/ft)	5.12	
$P(req)=w_bL^2/8a_{end}$ (k)	2108	
Precompression Allowance		
Tendons Req'd	79.2	
Tendons Used	70	
P_{actual} (k)	**1863.54**	
w_b (k/ft)	4.52	125psi < P_{actual}/A <300psi , therefore ok.
P_{actual}/A (psi)	284.42	
Check Interior Span Force		
P	1106.80	Less than C. Bay
w_b (k/ft)	8.62	
w_b/w_{dl}	76%	

w_b/w_{dl} = 76% < 100% , there it's acceptable for design

Tendon Profile:

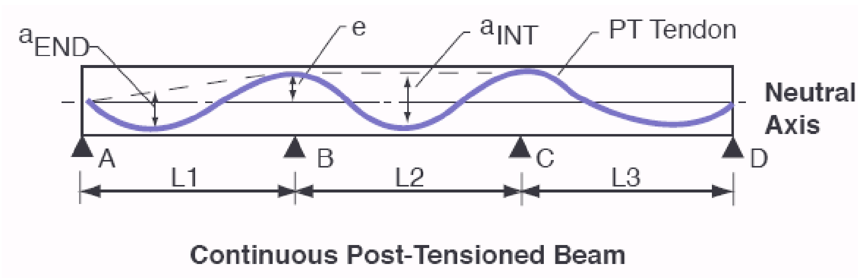
Parabolic shape;

For a layout with spans of similar length, the tendons will typically be located at the highest allowable point at the interior columns, the lowest possible point at the mid-spans, and the neutral axis at the anchor locations. This provides the maximum drape for load-balancing.

Tendon Ordinate	Tendon (CG) Location*
Exterior Support - Anchor	5”
Interior Support -Top	9”
Interior Span - Bottom	1”
End Span Bottom	1.75”

(CG) = center of gravity

*Measure from bottom of slab



Cover Required:

Rating	2hr
Min Cover	0.75”
Act Cover	1”
a_{int}	10”
a_{end}	5.25”

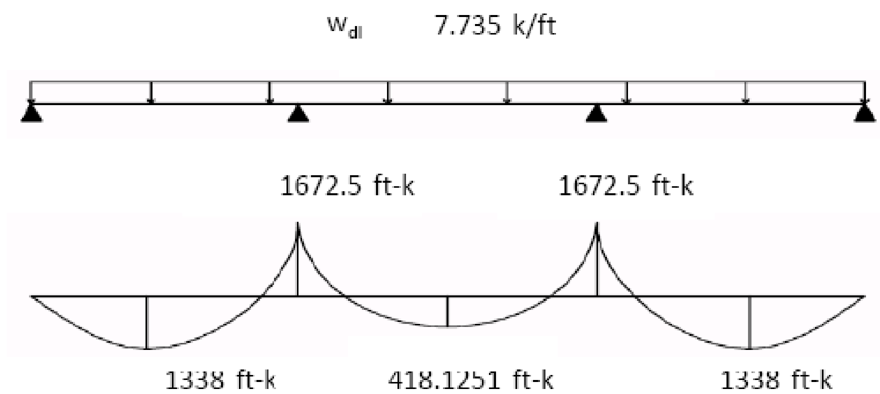
a_{int} = 12” – 2*1” = 10”

a_{end} = (5” + 9”) /2 – 1.75” = 5.25”

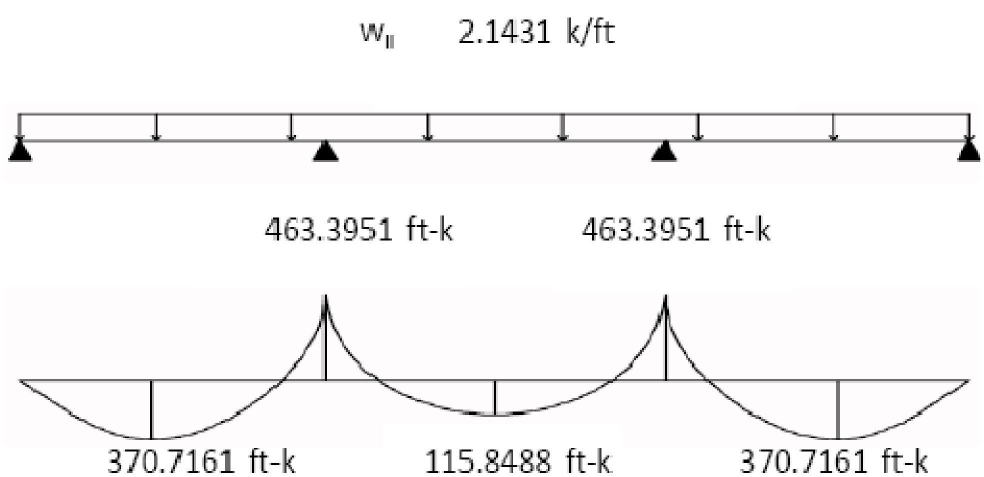
Check Slab Stresses:

Separately calculate the maximum positive and negative moments in the frame for the dead, live, and balancing loads. A combination of these values will determine the slab stresses at the time of stressing and at service loads.

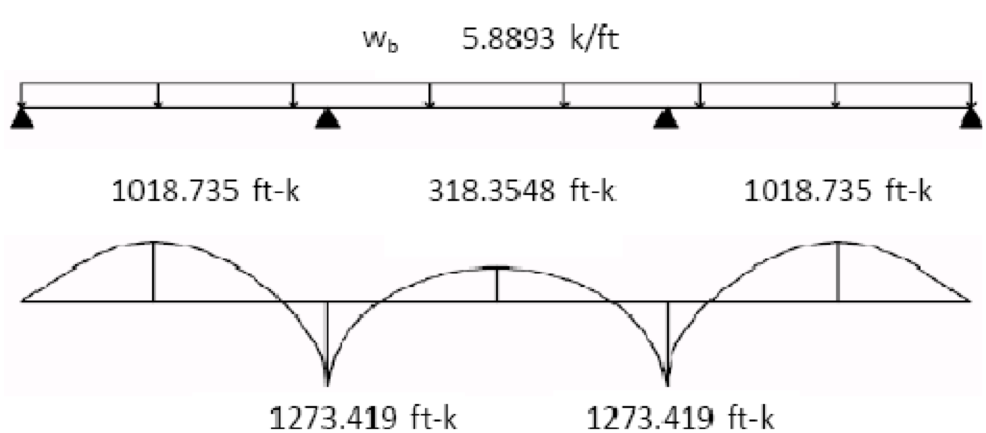
Dead Load Moments:



Live Load Moments:



Total Balancing Moments, M_{bal}:



Stage 1: Stresses immediately after jacking (DL + PT) ACI 18.4.1.

	Midspan Stresses		Support Stresses	Limits
	Int. Span	End Span		
S	13104.00	13104.00	13104.00	1800
P/A	284.42	284.42	284.42	164.3168
f_{top}	-925.7971154	-576.7903846	81.03605769	2250
f_{bot}	356.9509615	7.944230769	-649.8822115	424.2641

Stage 2: Stresses at Service Load (DL + LL + PT) ACI 18.3.3 & 18.4.2

	Midspan Stresses		Support Stresses	Limits
	Int. Span	End Span		
S	13104.00	13104.00	13104.00	1800
P/A	284.42	284.42	284.42	164.3168
f_{top}	-1031.885731	-916.2739538	420.5196269	2250
f_{bot}	463.0395769	347.4277999	-649.8822115	424.2641

Ultimate Strength:

Determine factored moments.

Primary PT Moments	
P (k)	1863.54
e (in)	5
M_1 (ft-k)	776.475
Secondary PT Moments	
M_{bal} (ft-k)	1273.419
M_1 (ft-k)	776.475
M_{sec} (ft-k)	496.944

The primary PT moments, M_1, vary along the length of the span.

The secondary PT moments, M_{sec}, vary linearly between supports.

Ultimate Strength ($1.2M_{DL}+1.6M_{LL}+1.0M_{sec}$)	
At Midspan	2447.22
At Support	-2251.49

Determine Minimum Bonded Reinforcement:

This is to check the ultimate strength.

Positive Moment Region		
Interior Span:		
f_t (psi)	463.04	>2√f'c= 154.9193
y	0.025811745	
Nc	0.069393268	
As_{min} (in2)	0.002313109	
Av (in2)	0.6	#7
# of bars	42	
A_{prov}	25.20	Aprov>A min
s_{req} (in)	18.00	ACI 18.9.4.2
s_{used} (in)	12.00	ACI 18.9.3.3
Exterior Span:		
f_t	347.43	>2√f'c= 154.9193
y	0.02291072	
Nc	0.250176182	
As_{min} (in2)	0.01	#7
Av (in2)	0.6	
# of bars	42	
A_{prov}	25.20	Aprov>A min
s_{req} (in)	18.00	ACI 18.9.4.2
s_{used} (in)	12.00	ACI 18.9.3.3

Negative Moment Region		
Interior Supports:		
A_{cf} (in2)	6624	
As_{min} (in2)	4.968	.00075Acf
Av (in2)	0.6	#7
# of bars	30	
A_{prov}	18.00	Aprov>A min
s_{req} (in)	18.00	ACI 18.9.4.2
s_{used} (in)	18.00	ACI 18.9.3.3
Exterior Supports:		
A_{cf} (in2)	6624	
As_{min} (in2)	4.968	.00075Acf
Av (in2)	0.6	#7
# of bars	30	
A_{prov}	18.00	Aprov>A min
s_{req} (in)	18.00	ACI 18.9.4.2
s_{used} (in)	18.00	ACI 18.9.3.3

Ultimate Strength		
A_{ps} (in)	10.71	
L/h	46.5	>35 ACI 18.7.2
f_{ps} (psi)	184000+743d	
a (in)	$(A_sf_y+A_{ps}f_{ps})/(.85f'_c*b)$	
At Supports:		
d (in)	10.75	
f_{ps} (psi)	191987.25	
a (in)	1.13	
ϕM_n	2396.09	>Mu
At Midspan:		
d (in)	10	
f_{ps} (psi)	191430	
a (in)	1.28	
ϕM_n	2500.77	>Mu

Final Design:

(70) 1/2" 7-Wire Strand Post-Tension Unbonded Tendons
12" Slab depth
42 #7 Reinforcement Bars @ Interior Span spaced ≤12" oc
42 #7 Reinforcement Bars @ Exterior Span spaced ≤12" oc
30 # 7 Reinforment Bars @ Interior Supports spaced ≤18" oc
30 # 7 Reinforment Bars @ Exterior Supports spaced ≤18" oc

Conclusion and Recommendations

The purpose of this analysis was to prove it was possible to create a design that could ensure structural stability and at the same time still leave the floor plan open for the tenants. I feel that this design did both. The new column layout works structurally with the reinforcement designated above and the same thickness slab that is used in the building now and the floor plan is more open then before.

Even with this analysis being a success, whether or not to use this layout is dependent completely on if the partial removal of the column-free perimeter is proved worthwhile. It should be noted that the design was very conservative and another could be created with less reinforcement by someone who is more skilled in structural design techniques.

As far as cost, schedule, and constructability impacts go specifically for this analysis, the only item worth mentioning is that the slab designed would be easier to construct then the original because of the consistency and stability in this design verses the irregularity of the original design. Cost and schedule differences would be insignificant because of how close the design is to the original. Moving around 12 columns will not affect much in the construction process.

Analysis II – Solar Implementation (Electrical Breadth / Critical Industry Issue)

Problem

With today's economy in a recession and the growing global awareness of green technologies, saving money and the environment is on everyone's mind. As a soon to be construction manager, both topics are of the utmost importance to me and lead me to the question: *what can I do about it*?

Solution

One answer to this question is to do everything in my power to try to incorporate as much sustainable design into my projects as possible. A great way to add sustainable design into Lafayette Tower would be the introduction of photovoltaic panels into the current building systems in order to utilize one of nature's greatest energy sources, the sun. The penthouse roof would be an ideal location for the implementation of solar technologies which would lower the buildings energy costs in the future and make the building more sustainable as a whole.

Methodology

The method that I plan to follow for implementing solar design into Lafayette Tower is to start by finding out how much sun is actually going to get to the penthouse roof. I will do this by collecting exposure data for Washington, DC and then also creating a Google Sketch Up model to perform a shadow analysis.

After that, the next step is to choose the equipment being used. This includes both the panel and the inverter which is followed by sizing an array based their specifications. Once a panel is chosen, its dimensions need to be taken into account and a layout on the roof needs to be developed. The last couple of steps are to find a material provider for the chosen equipment and an installer located in the DC metro area, calculate the cost of the system along with its payback period and then determine if the system is worth implementing.

Resources

In order to obtain the necessary information, I will rely on both the contacts I have made in the construction industry as well as knowledge gained through my sustainable design. Any other needed facts or values will be found through research online or through contacts found from that research.

Concluding Remarks

I expect that the final assessment of the incorporation of solar design will prove it is worth installing and benefit the building in the long run.

Background

2008 PACE Roundtable Discussion of Critical Industry Issues

During the technical training section of the seminar, there were three possible topics to attend; LEED Evolution, BIM Strategies, and Energry &Economy. I chose the last of the three because I felt that I've had the least amount of experience with it and also the current state of the economy has been something that has interested me given my rapidly approaching graduation. The session was hosted by Dr. Riley and was focused on how are energy prices affecting business and what sectors will flourish in the current economic downturn.

We started out by diving into the topic of energy. Most of the discussion was carried by the industry members because they deal with these issues on a day-to-day basis and have much more experience. The volatility of materials and dependancy on oil were our first topics. Possible solutions we discussed were using alternative, less well known materials to try to save in product costs or using materials from a local vender to try to save in transportation.

Some of the other ways we focused on to fight the rising enegry costs were to spend a little extra money up front and invest in an upgraded mechanical system. With the more sophisticated controls and continuous commissing throughout the life of the building, a better mechanical system will rapidly pay for itself and save money over the life of the building. Another building component that was stressed was the integrationg of TP-1 transformers due to the fact that they are more energy efficient and environmentally friendly then old transformers.

This discussion brought about my interest in energy conservation not only in construction but during the building's life cycle. Solar implementation was not discussed specifically but from prior experiences I knew it would be another way to decrease the amount of energy needed to be brought into the building. It would also help the building become more environmentally friendly which is always a major concern in today's construction industry.

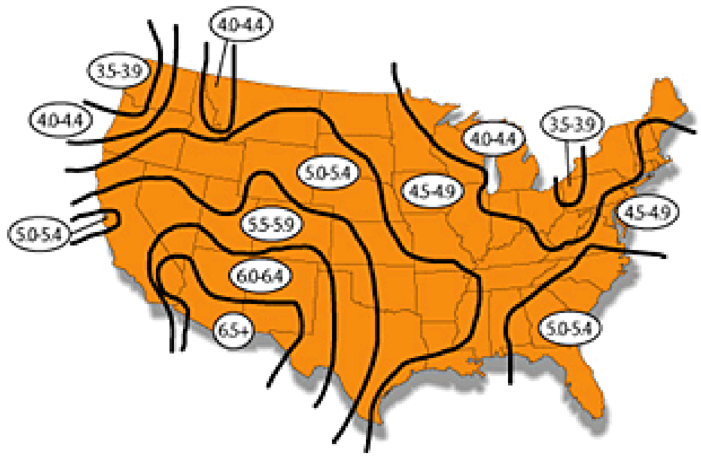


Figure 18 - Solar Insolation Zone Map

This solar isolation zone map gives a general idea of how many full sun hours per day a location will receive. Washington DC is in the 4.5-4.9 hours per day range. Irradiance measures the sun's power available at the surface of the earth and it averages around 1000 watts per square meter. Panel efficiency typically ranges between 14-16% which would translate to 140-160W per square meter.

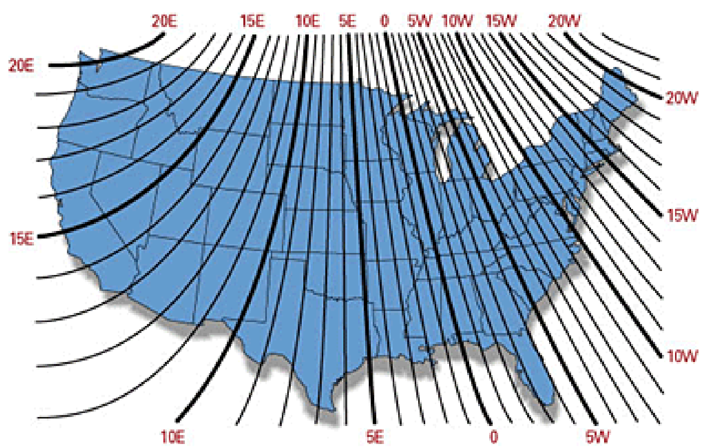


Figure 19 - Solar Declination Map

This solar declination map helps you to determine the angle at which you should aim your solar module because true south doesn't match magnetic south. Setting at the angle that corresponds with your location will maximize your daily output. Another important factor for maximizing your output is to make sure the solar arrays tilt angle corresponds with the site's latitude. For best year round power output with the least amount of maintenance, you should set the solar array facing true south at a tilt angle equal to your latitude with respect to the horizontal position. If you plan to adjust your solar array tilt angle seasonally, a good rule of thumb to go by is latitude minus 15° in the summer, latitude in the spring/fall and latitude plus 15° in the winter.

Analysis

Site's Solar Availability

Through The University of Oregon Solar Radiation Monitoring Laboratory's Sun Path Chart Program (http://solardat.uoregon.edu/SunChartProgram.php), sun path charts were created in order to learn when sun exposure is greatest on site. These charts were generated using the following information:

- Latitude: 38° 54' N
- Longitude: 77° 02' W
- Time Zone: EST
- Address: 801 17th St. NW, Washington D.C. 20006

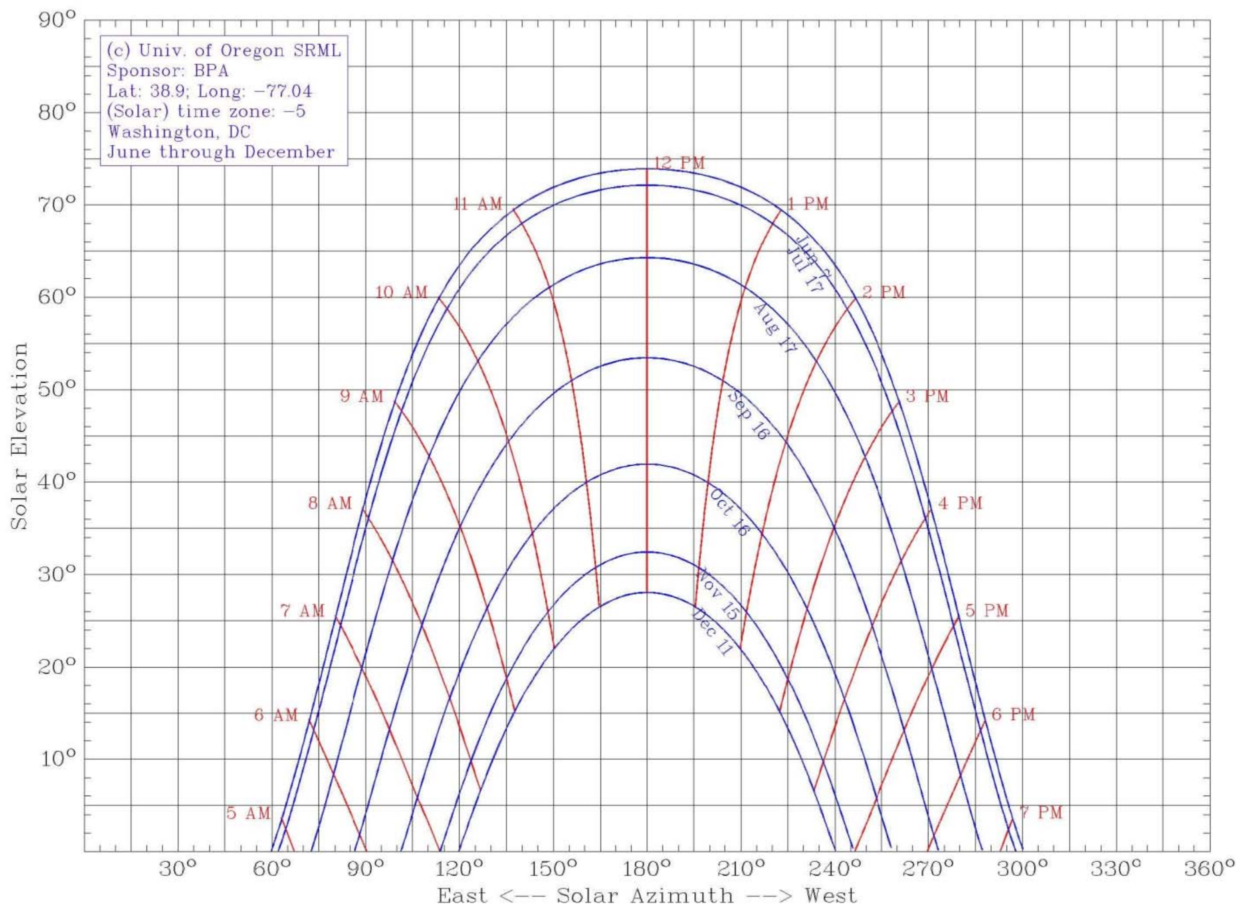


Figure 20 - Sun Path Chart for Washington, DC (June through December)

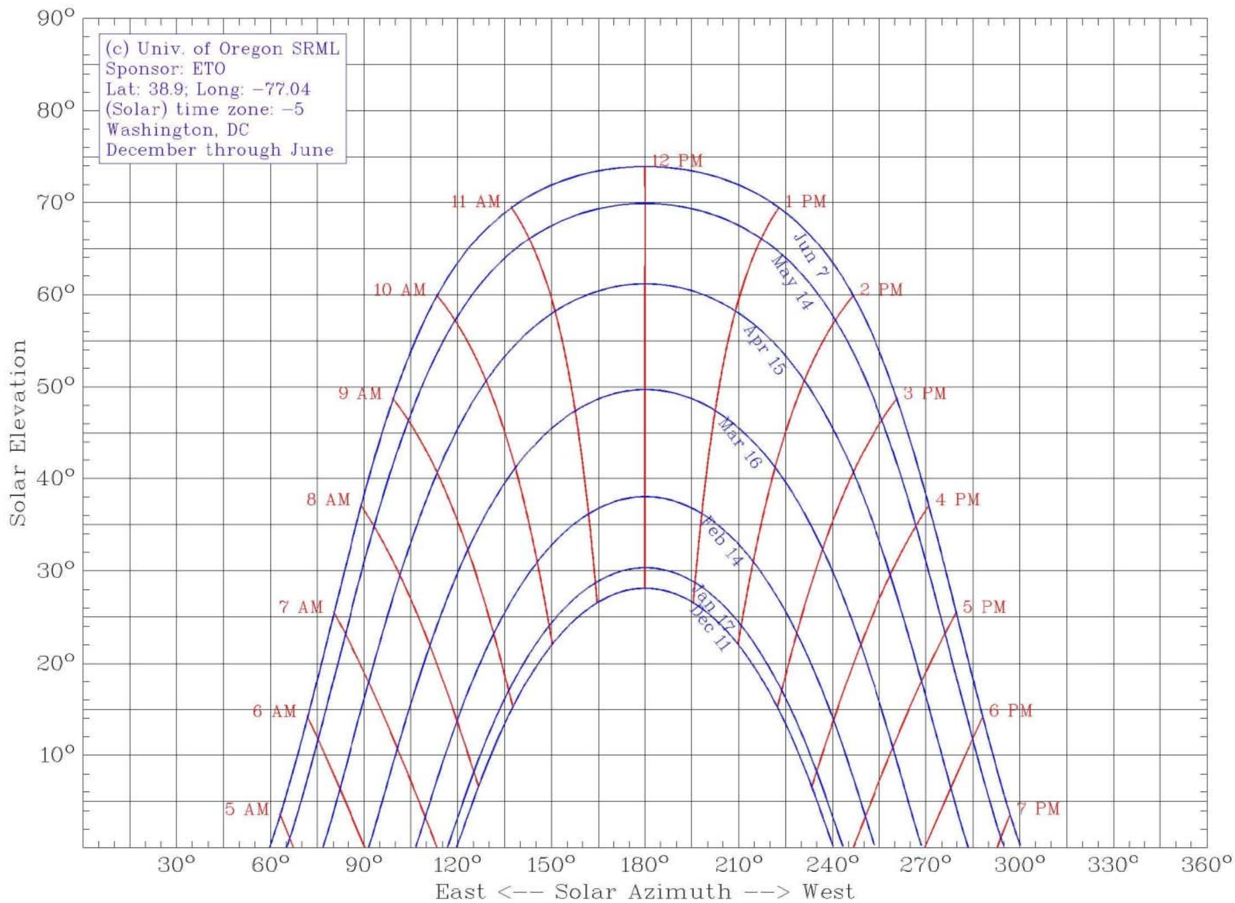


Figure 21 - Path Chart for Washington, DC (December through June)

Sun path charts enable you to locate the position of the sun at any time of day, during any month and for any location. It is a plot of the sun's altitude versus azimuth at different times throughout a given day. They also show when the sun is highest in the sky which allows for maximum sun exposure. As a general rule of thumb, the arrays should have unobstructed sunshine from 9:00 am – 3:00 pm for optimal solar applications. The sun path charts show the angle of the sun at those times for any given day throughout the year.

Another way to determine if shade will be an issue on-site is to create a shadow plan using Google Sketch Up and Google Earth. Once a model is created in Google Sketch Up, it can be imported into Google Earth and set at its actual location and orientation. From there, the time and date can be set and a shadow will appear across the building. Because Lafayette Tower was completed in December 2008, the time frame for the shadow simulation was throughout the course of 2009, the first year of operation.

There are 4 important dates to consider for solar performance throughout the year. The dates are as follows:

Vernal Equinox	March 20th	11:44 am
Summer Solstice	June 21st	5:46 am
Autumnal Equinox	September 22nd	9:19 pm
Winter Solstice	December 21st	5:47 pm

These dates were obtained from www.timeanddate.com's seasonal calendar. Snapshots from the shadow plans at these dates are displayed on the following pages. Each page displays the building at 6:00am, 9:00am, 12:00pm, 3:00pm, and 6:00pm.

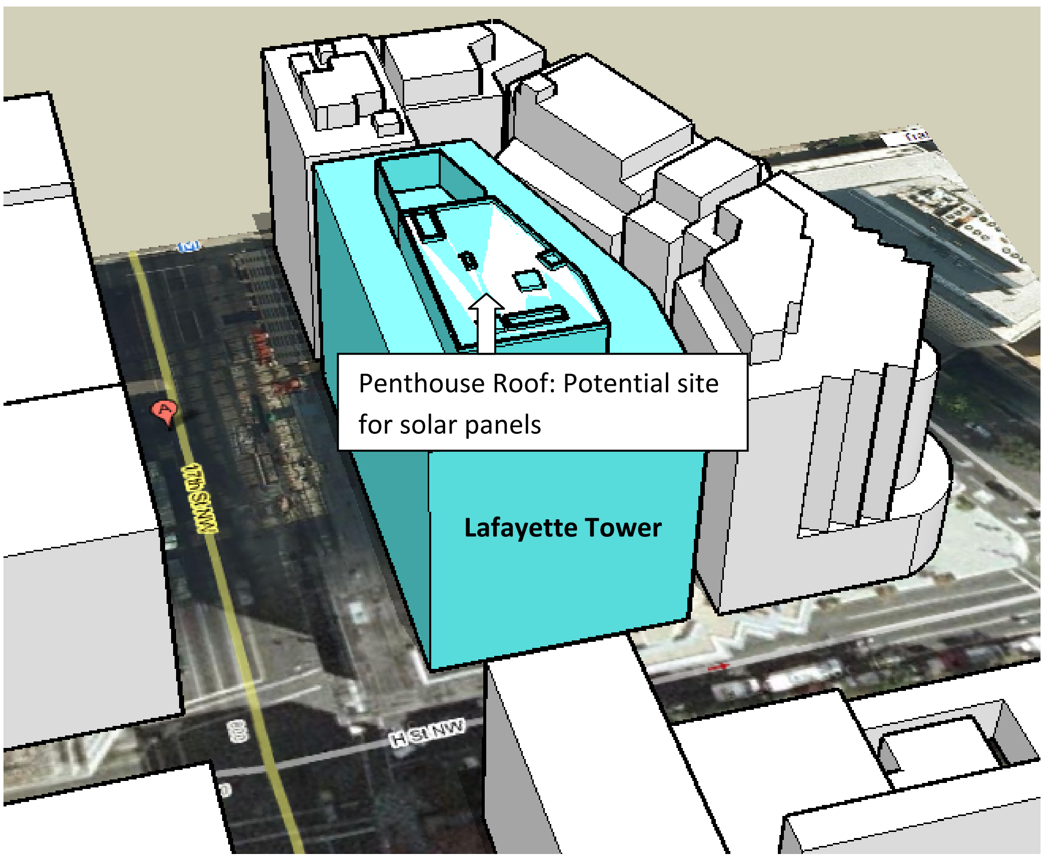
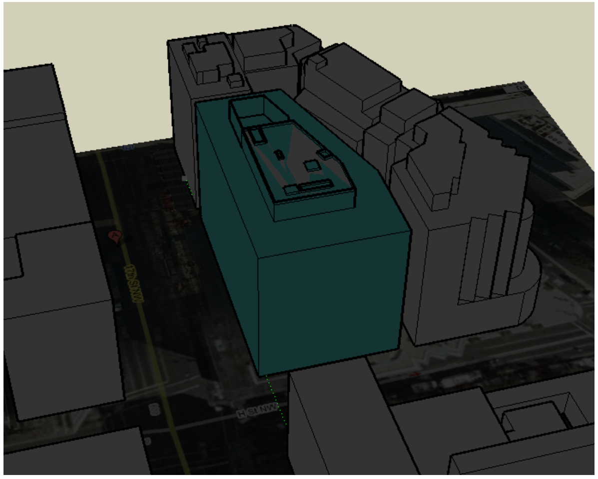
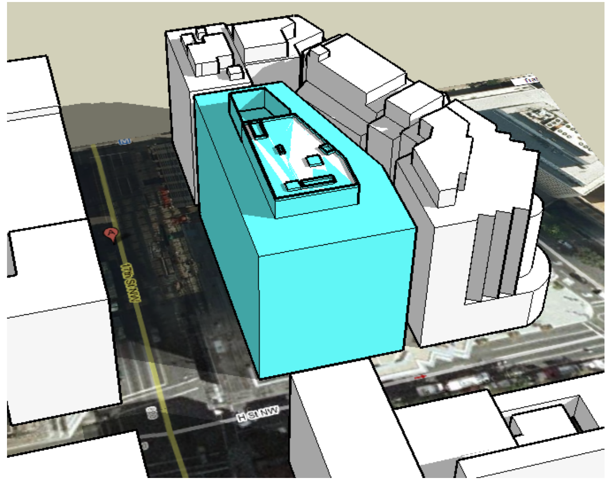


Figure 22 - Snapshot of Lafayette Tower from Google Sketch Up

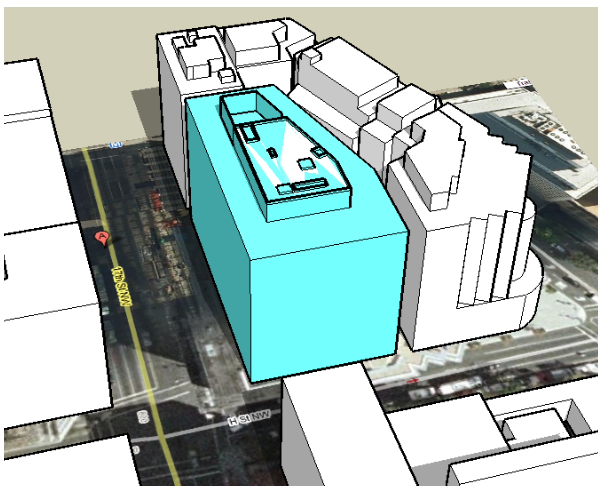
Vernal Equinox - March 20, 2009



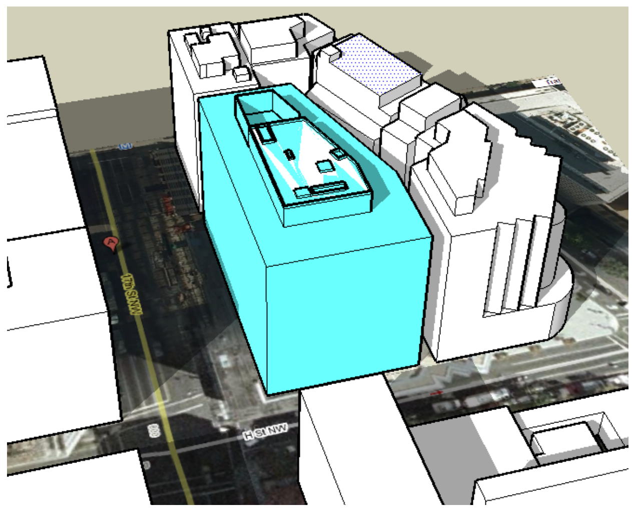
6:00AM



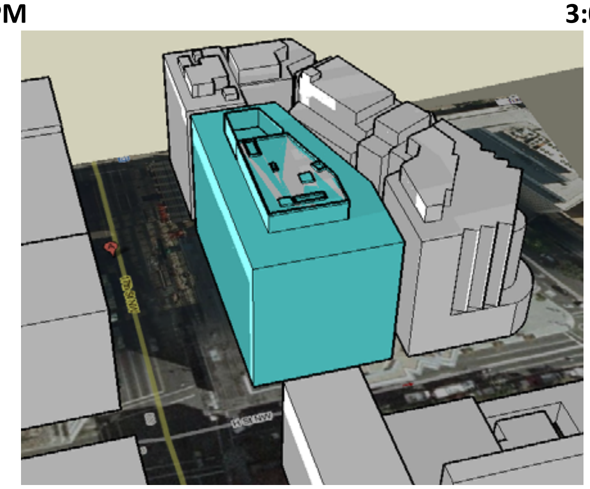
9:00AM



12:00PM

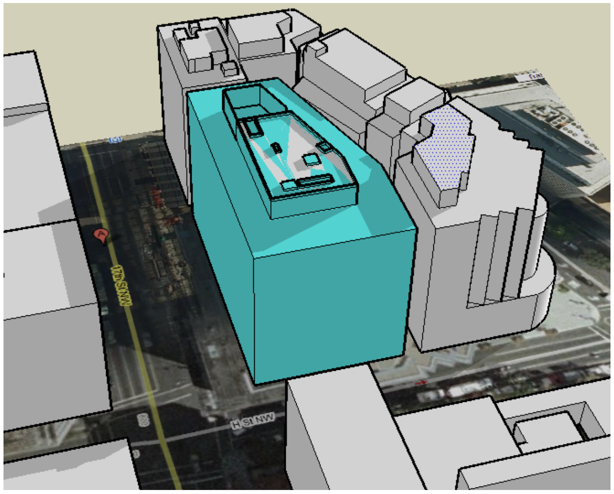


3:00PM



6:00PM

Summer Solstice - June 21, 2009



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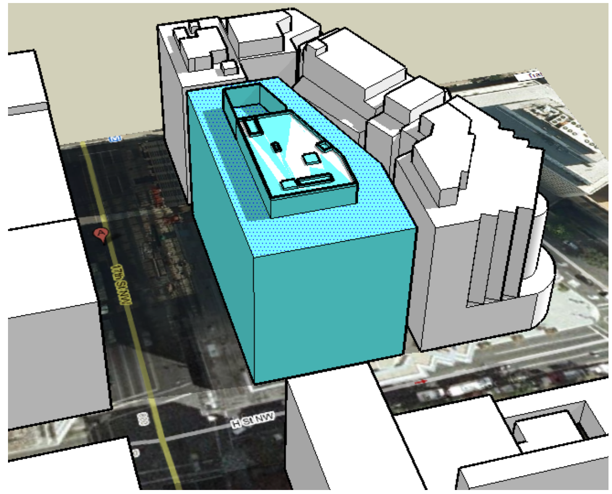
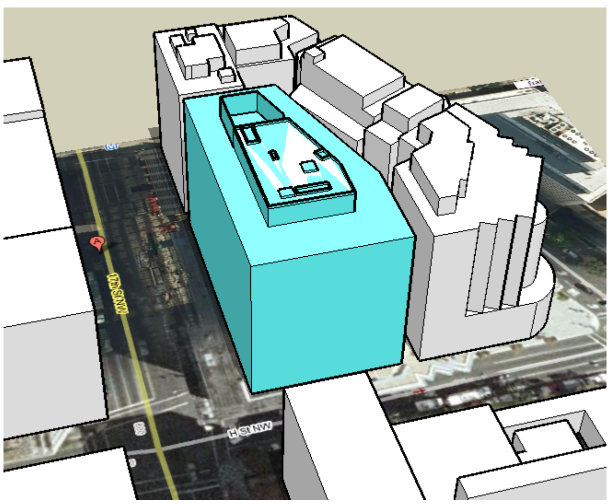


9:00AM



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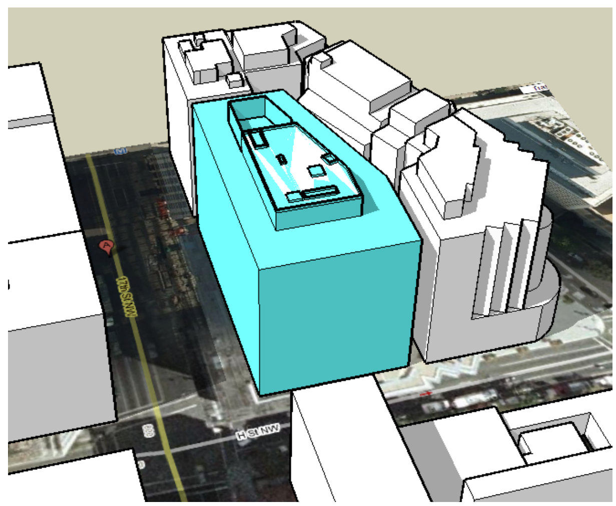

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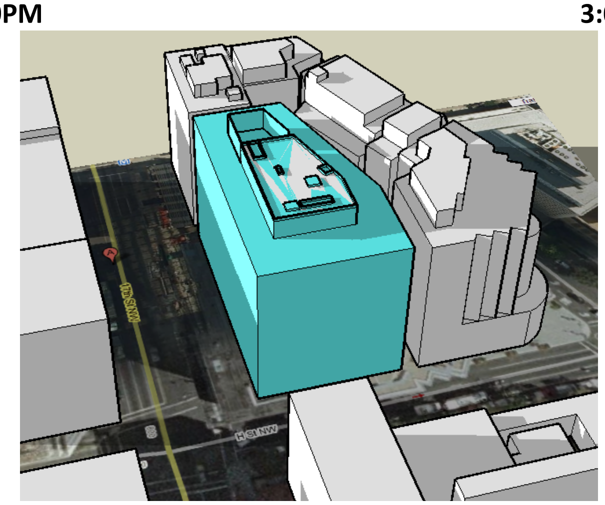

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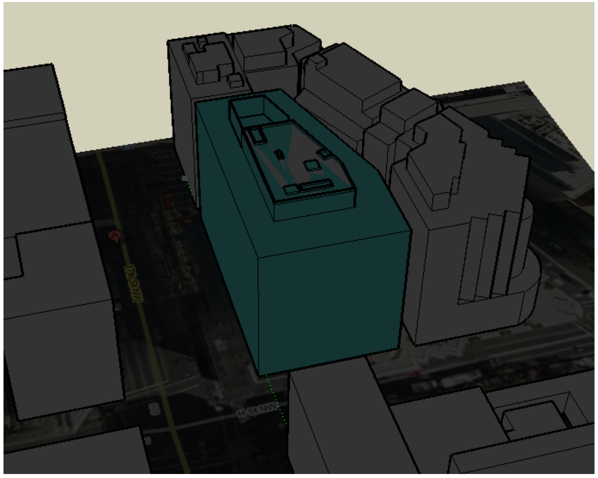
Autumnal Equinox - September 22, 2009



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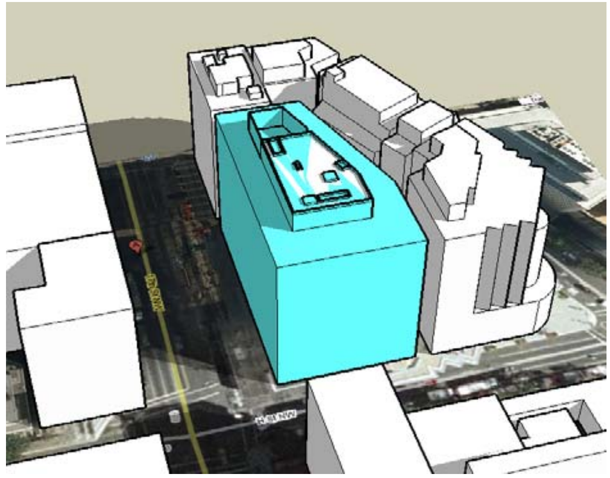

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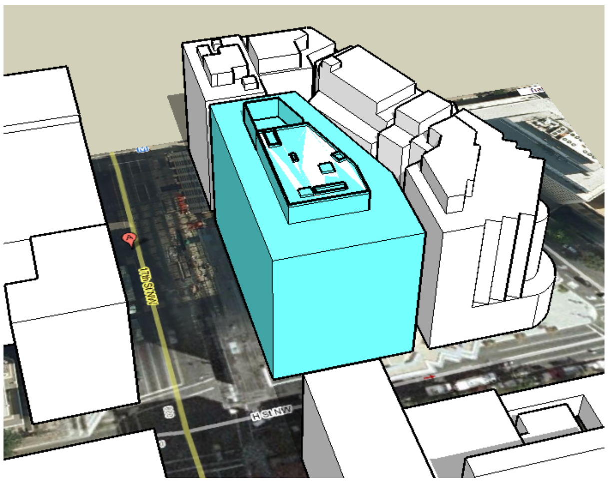

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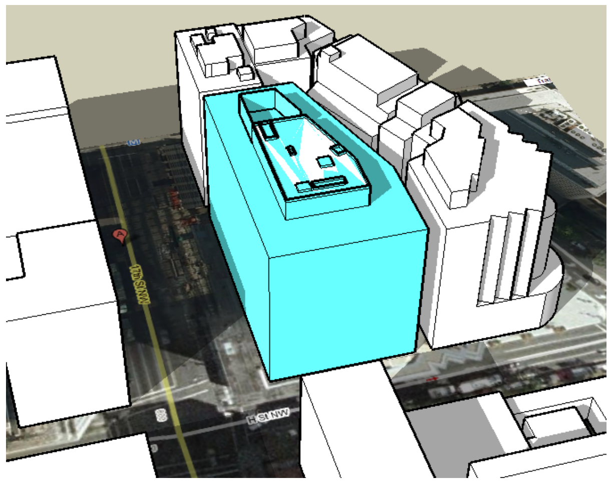

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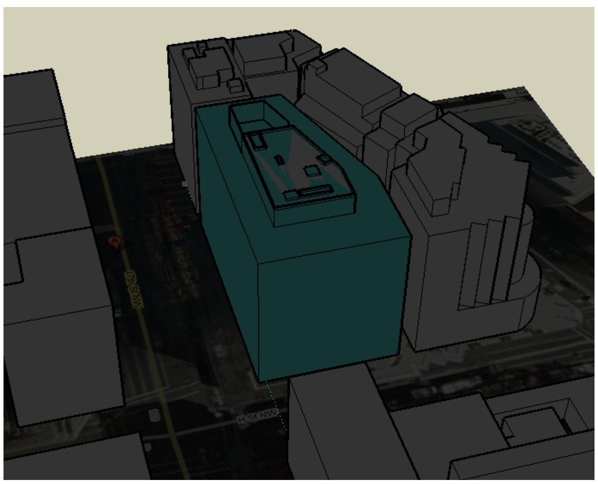
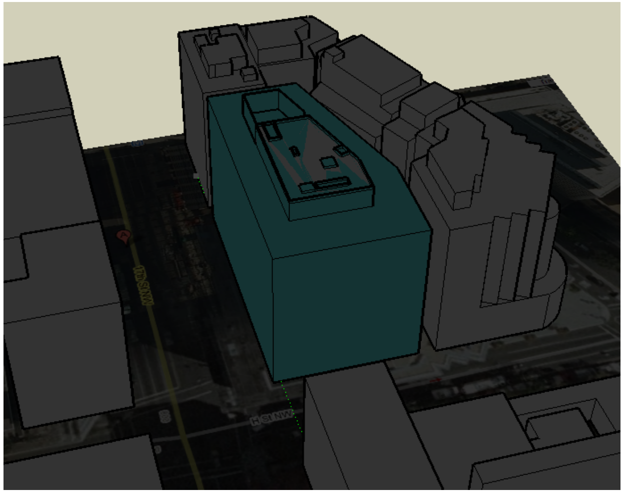


6:00PM

Winter Solstice - December 21, 2009



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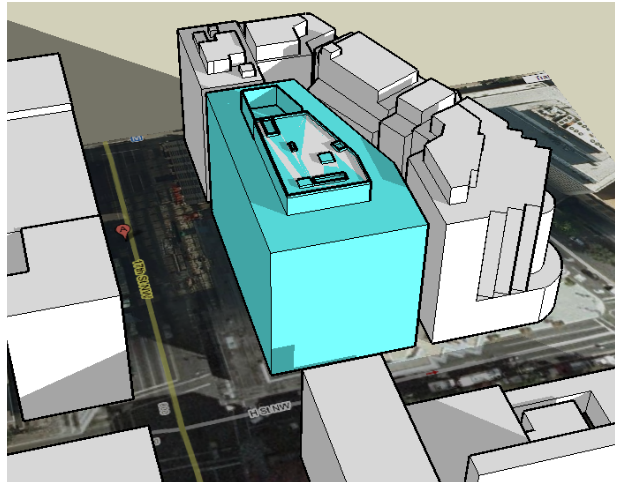

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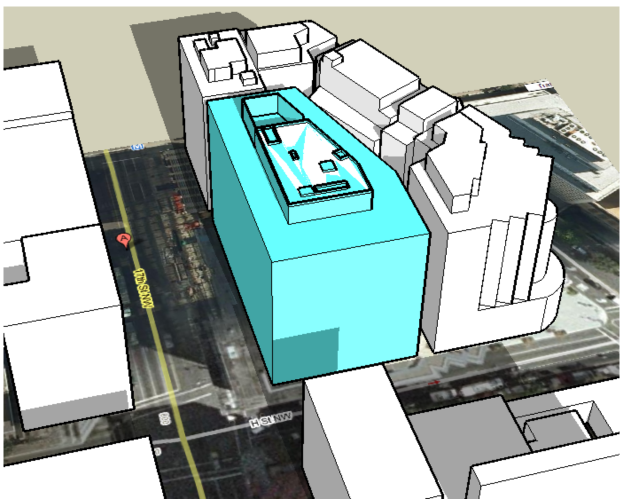

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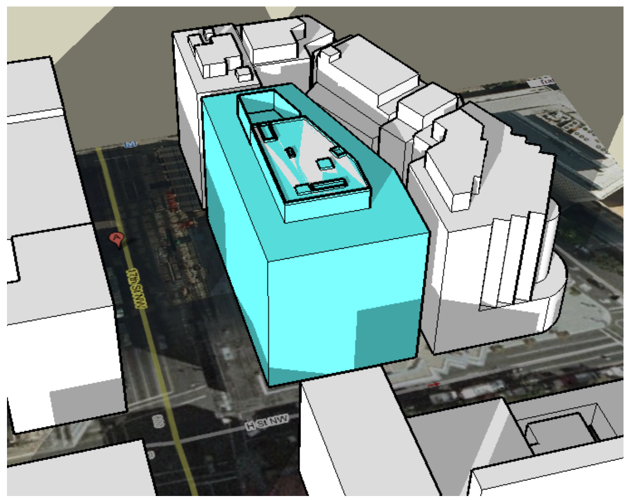

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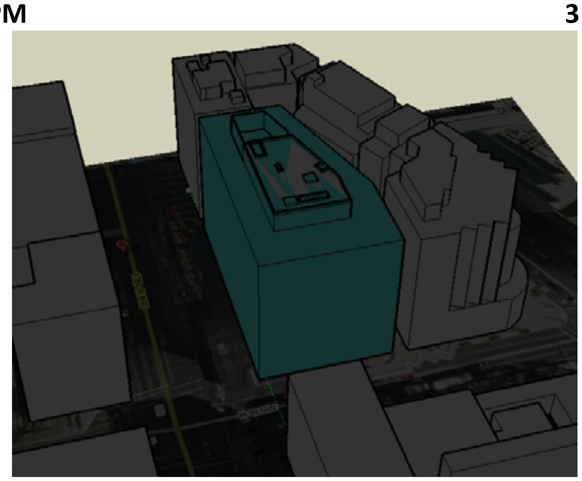


6:00PM

Selecting a PV Panel

The solar panel chosen for Lafayette Tower needed to match the theme for the rest of the building, cutting edge and luxurious. Below is a list of the criteria:

- Is the company well-known and reputable? Are they on the forefront of technology?
- Is the panel made for large commercial usage?
- Is the panel made for grid tied systems?
- Is there a vender nearby?

There were a few different companies with panels that met these criteria but in the end, I chose to use Kyocera's KD210GX-LT panel.

General Product Information	
Company	Kyocera
Name / Model	KD210GX-LT
Unique Features - Integration with building, mounting, collection	Extremely efficient (over 16%)
Company URL	http://www.kyocerasolar.com
Product Data Sheet URL (if available)	http://www.kyocerasolar.com/pdf/specsheets/kd_210gx-lp_081508_web.pdf

Product Details	
Weight	40.8 lbs
Type (thin-film, poly-crystal, CIGS, CeTe, etc.)	Highly efficient multi-crystal
Connectors	Plug-in
Operating temperature	-40ºC to +90ºC
Temperature Coefficient (Pmp)	(-)0.40%/ºC
Temperature Coefficient (Voc)	(-)0.12%/ºC
Temperature Coefficient (Vmp)	(-)0.34%/ºC
Temperature Coefficient (Isc)	0.52%/ºC
Temperature Coefficient (Imp)	0.19%/ºC
Max power current (Imp)	7.90 A
Short-circuit current (Isc)	8.58 A
Rated power at PTC (Pptc)	184.6 W
Durability features	All weather construction
Module Construction/Materials	These cells are encapsulated between a tempered glass cover and a pottant with back sheet to provide efficient protection from the severest environmental conditions. The entire laminate is installed in an anodized aluminum frame to provide structural strength and ease of installation.

The specification sheets for Kyocera's KD210GX-LT are located on the next two pages.

THE NEW VALUE FRONTIER

KYOCERA

KD210GX-LP

HIGH EFFICIENCY MULTICRYSTAL
PHOTOVOLTAIC MODULE

LISTED

HIGHLIGHTS OF KYOCERA PHOTOVOLTAIC MODULES

Kyocera's advanced cell processing technology and automated production facilities produce a highly efficient multicrystal photovoltaic module.
The conversion efficiency of the Kyocera solar cell is over 16%.
These cells are encapsulated between a tempered glass cover and a pottant with back sheet to provide efficient protection from the severest environmental conditions.
The entire laminate is installed in an anodized aluminum frame to provide structural strength and ease of installation.
Equipped with plug-in connectors.

APPLICATIONS

KD210GX-LP is ideal for grid tie system applications.

- Residential roof top systems
- Large commercial grid tie systems
- Water Pumping systems
- High Voltage stand alone systems
- etc.

QUALIFICATIONS

- **MODULE** : UL1703 listed
- **FACTORY** : ISO9001 and ISO 14001

QUALITY ASSURANCE

Kyocera multicrystal photovoltaic modules have passed the following tests.

- Thermal cycling test
- Thermal shock test
- Thermal / Freezing and high humidity cycling test
- Electrical isolation test
- Hail impact test
- Mechanical, wind and twist loading test
- Salt mist test
- Light and water-exposure test
- Field exposure test

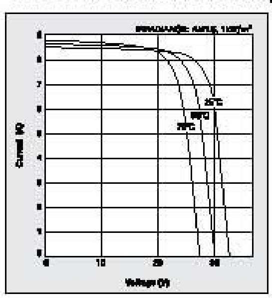
LIMITED WARRANTY

※1 year limited warranty on material and workmanship
※20 years limited warranty on power output: For detail, please refer to "category IV" in Warranty issued by Kyocera

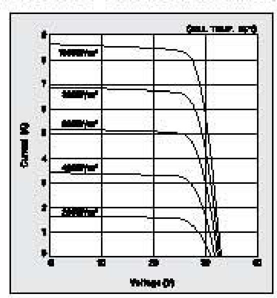
(Long term output warranty shall warrant if PV Module(s) exhibits power output of less than 90% of the original minimum rated power specified at the time of sale within 10 years and less than 80% within 20 years after the date of sale to the Customer. The power output values shall be those measured under Kyocera's standard measurement conditions. Regarding the warranty conditions in detail, please refer to Warranty issued by Kyocera)

ELECTRICAL CHARACTERISTICS

Current-Voltage characteristics of Photovoltaic Module KD210GX-LP at various cell temperatures



Current-Voltage characteristics of Photovoltaic Module KD210GX-LP at various irradiance levels



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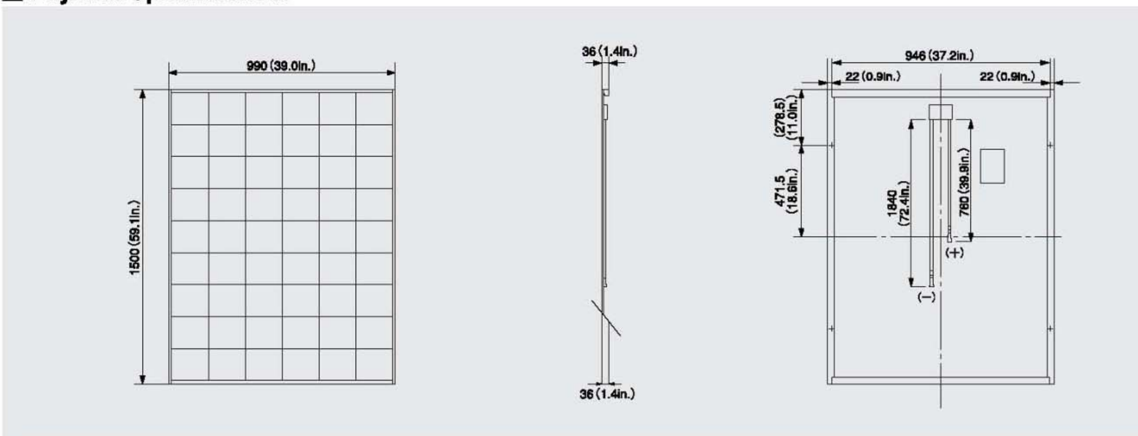
SPECIFICATIONS

KD210GX-LP

Physical Specifications

Unit : mm (in.)



Specifications

Electrical Performance under Standard Test Conditions (*STC)	
Maximum Power (Pmax)	210W (+5%/−5%)
Maximum Power Voltage (Vmpp)	26.6V
Maximum Power Current (Impp)	7.90A
Open Circuit Voltage (Voc)	33.2V
Short Circuit Current (Isc)	8.58A
Max System Voltage	600V
Temperature Coefficient of Voc	−0.120 V/℃
Temperature Coefficient of Isc	5.15×10^{-3} A/℃

*STC : Irradiance 1000W/m², AM1.5 spectrum, cell temperature 25℃

Electrical Performance at 800W/m², *NOCT, AM1.5	
Maximum Power (Pmax)	148W
Maximum Power Voltage (Vmpp)	23.5V
Maximum Power Current (Impp)	6.32A
Open Circuit Voltage (Voc)	29.9V
Short Circuit Current (Isc)	6.98A

*NOCT (Nominal Operating Cell Temperature) : 49℃

Cells	
Number per Module	54

Module Characteristics	
Length × Width × Depth	1500mm(59.1in)×990mm(39.0in)×36mm(1.4in)
Weight	18.5kg(40.8lbs.)
Cable	(+)760mm(29.9in),(-)1840mm(72.4in)

Junction Box Characteristics	
Length × Width × Depth	100mm(3.9in)×108mm(4.3in)×15mm(0.6in)
IP Code	IP65

Others	
*Operating Temperature	−40℃～90℃
Maximum Fuse	15A

*This temperature is based on cell temperature.

Please contact our office for further information

KYOCERA

KYOCERA Corporation

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LIE/I10A0711-SAGM

Selecting an Inverter

After the PV panel is chosen, the next step is to select an inverter which will convert the DC power that the array collects from the sun to AC power that can be used normally. When choosing an inverter, I followed the same criteria as mentioned above for selecting the PV panel but I also wanted an inverter that would work well with the Kyocera Panel. After further review of Kyocera's website, I found that they are tied to another company, Xantrex, who makes inverters. The Xantrex inverter that seemed to fit the needs of the system being implemented at Lafayette Tower the best was the GT5.0. It's a 5.0kVA inverter that is ideal for grid tied systems. The 5.0kVA is the largest in the series. I assume the entire system will require more than one inverter but not enough to make using one of the much larger inverters a feasible option.

From EDSNG 498A, the following charts are used to help determine the optimal configuration of panels in series and number of strings connected to each inverter.

Panel Characteristics at STC				
Rated power at STC (Pmp)	210	W	Temp Coefficient of Pmp (/°C)	-0.0040
Open circuit voltage (Voc)	33.2	V	Temp Coefficient of Voc (/°C)	-0.0012
Maximum power voltage (Vmp)	26.6	V	Temp Coefficient of Vmp (/°C)	-0.0034
Short-circuit current (Isc)	8.58	A	Temp Coefficient of Isc (/°C)	0.0005
Maximum power current (Imp)	7.9	A	Temp Coefficient of Imp (/°C)	-0.0019
Rated power at PTC (Pptc)	184.6	W	UL series fuse rating (amps)	15

Inverter	
Power (W)	5000
Number	1
Input V_min	235
Input V_max	550
MPPT min	240
MPPT max	550
Input I_max	22
Efficiency	0.959
Derate Factor	0.95

Environment	
	Temp (°C)
Min	-20
Max	40
STC	25
T_rise	30

www.weatherbase.com provided the regional temperature information

Washington, District of Columbia

Elevation: 3 meters Latitude: 38 51N Longitude: 077 02W

Highest Recorded Temperature Years on Record: 51

	YEAR	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
°C	40	26	27	31	35	37	38	40	39	38	34	30	23

Lowest Recorded Temperature Years on Record: 51

	YEAR	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
°C	-20	-20	-15	-10	-4	1	8	12	9	3	-1	-8	-16

The specification sheets for Xantrex GT series inverters are located on the next two pages.

Smart choice for power™

xantrex™

Xantrex™ GT Series Grid Tie Solar Inverters

The Xantrex™ Grid Tie Solar Inverter (GT Series) is designed to convert photovoltaic (PV) electricity produced by solar modules into utility-grade power that can be used by the home or sold to the local electrical utility. Offering high efficiency (up to 96.0 %), clean aesthetics, high reliability, and a low installed cost, through ease of installation and integrated features, the GT Series is a proven, high-frequency design in a compact enclosure.

The GT Series may be installed as a single inverter, for a single PV array, or in a multiple-inverter configuration for large PV systems.

Technology

- An NEC compliant, integrated DC/AC disconnect, standard in the GT Series, eliminates the need for external DC (PV) disconnects, and in some jurisdictions, AC disconnects
- Large heat-sink offers extraordinary heat dispersion without the need for a cooling fan
- Liquid crystal display (LCD) provides instantaneous information – power level, daily and lifetime energy production, PV array voltage and current, utility voltage and frequency, time online "selling", fault messages, and installer-customized screens
- LCD vibration sensor allows the tap of a finger to turn backlight on and cycle through display screens

Installation

- Flexible module selection and sizing due to wide PV input MPPT tracking voltage range
- Lightweight and versatile mounting bracket
- Easy access DC (photovoltaic) and AC (utility) terminal block simplifies wiring
- Rugged NEMA 3R inverter enclosure allows reliable indoor and outdoor installations

Performance

- Best-in-class efficiency to maximize solar system return on investment
- Accurate MPPT tracking ensures maximum energy harvest under any conditions
- FCC Part B compliance provides less external electronic interference

Serviceability

- 10-year standard warranty
- Sealed inverter enclosure can be quickly separated from the wiring box allowing DC/AC connections to remain intact in the unlikely event the inverter needs to be serviced

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xantrex GT SERIES WARRANTY 10 YEARS

Standard 10-year warranty

UL 1741 CSA 107.1-01 PHOTOVOLTAIC POWER INVERTER

Xantrex Technology Inc.
Customer Service/Technical Support
customerservice@xantrex.com
Toll free: 1-800-670-0707

www.xantrex.com

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Xantrex™ GT Series Grid Tie Solar Inverters

Electrical Specifications - Output

Models	GT5.0		GT4.0N		GT3.8		GT3.3N		GT2.8	
Maximum AC power output	5000 W	4500 W	4000 W	3800 W	3800 W	3500 W	3300 W	3100 W	2800 W	2700 W
AC output voltage (nominal)	240 V	208 V	240 V	208 V	240 V	208 V	240 V	208 V	240 V	208 V
AC output voltage range	211-264 Vac 183-229 Vac									
AC frequency (nominal)	60 Hz									
AC frequency range	59.3 - 60.5 Hz									
Maximum continuous output current	21 A	22 A	16.7 A	18.3 A	15.8 A	16.8 A	13.8 A	14.9 A	11.7 A	13.0 A
Maximum output over-current protection	30 A		25 A		20 A	25 A	20 A		15 A	
Maximum utility backfeed current	0 A									
Total harmonic distortion (THD)	< 3 %									
Power factor	> 0.99 (at rated power), > 0.95 (full power range)									
Utility monitoring, islanding protection	UL1741-2005 / IEEE 1547									
Output characteristics	Current source									
Output current waveform	True sine wave									

Electrical Specifications - Input

Models	GT5.0		GT4.0N		GT3.8		GT3.3N		GT2.8	
Maximum array open-circuit voltage	600 Vdc									
MPPT voltage range (CEC & CSA)	240 - 550 Vdc		240 - 480 Vdc		195 - 550 Vdc		200 - 400 Vdc		195 - 550 Vdc	
MPPT operating range	235 - 550 Vdc		235 - 550 Vdc		195 - 550 Vdc		200 - 550 Vdc		193 - 550 Vdc	
Maximum input current	22.0 Adc	20.0 Adc	18.0 Adc	17.0 Adc	20.8 Adc	19.5 Adc	17.5 Adc	16.5 Adc	15.4 Adc	14.9 Adc
Maximum array short-circuit current	24.0 Adc									
Reverse-polarity protection	Short-circuit diode									
Ground-fault protection	GF detection, IDIF > 1 A									
Maximum inverter efficiency	95.9%	95.5%	96.0%	95.7%	95.9%	95.6%	95.9%	95.6%	95.0%	94.6%
CEC efficiency	95.5%	95.0%	95.5%	95.0%	95.0%	95.0%	95.5%	95.0%	94.0%	93.5%
Night-time power consumption	1 W									

Environmental Specifications

	GT5.0	GT4.0N	GT3.8	GT3.3N	GT2.8
Operating temperature range	-13°F to 149°F (-25°C to 65°C)				
Enclosure type	NEMA 3R (outdoor rated)				
Inverter weight	58.0 lb (25.8 kg)	58.0 lb (25.8 kg)	58.0 lb (25.8 kg)	49.0 lb (22.2 kg)	49.0 lb (22.2 kg)
Shipping weight	65.0 lb (27.2 kg)	65.0 lb (27.2 kg)	65.0 lb (27.2 kg)	57.0 lb (25.9 kg)	57.0 lb (25.9 kg)
Inverter dimensions (H x W x D)	28 1/2 x 16 x 5 3/4" (72.4 x 40.3 x 14.5 cm)				
Shipping dimensions (H x W x D)	34 x 20 1/2 x 10 5/16" (86.6 x 51.8 x 26.2 cm)				

Mechanical Specifications

	GT5.0	GT4.0N	GT3.8	GT3.3N	GT2.8
Mounting	Wall mount (mounting bracket included)				
Input and output terminal	AC and DC terminals accept wires sizes of #14 to #6 AWG				
PV / Utility disconnect	Eliminates need for external PV (DC) disconnect. Complies with NEC requirements				
Cooling	Convection cooled, fan not required				
Display	Backlit, two-line, 16-character liquid crystal display provides instantaneous power, daily and lifetime energy production, PV array voltage and current, utility voltage and frequency, time online "selling", fault messages, and installer-customizable screens				
Communications	Integrated RS232 and Xanbus™ RJ45 communication ports				
Wiring box	PV, utility, ground, and communications connections. The inverter can be separated from the wiring box.				
Warranty	10-year standard				
Model number (negative ground)	GT5.0-NA-240/208 UL-05	GT4.0N-NA-240/208 UL-05	GT3.8-NA-240-/208 UL-05	GT3.3N-NA-240/208 UL-05	GT2.8-NA-240/208 UL-05
Part number (negative ground)	864-1009	864-1008	864-1032	864-1006	864-1001
	Positive ground inverters are also available				

Regulatory Approvals

Certified to UL1741 1st Edition: 2005 version CSA 107.1-01 CSA 2 C22.2 No.107-1-01 general use power power supplies.

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The following charts are a continuation of the EDSNG exercise:

Maximum Modules in Series (Manual)	
Voc max =	Voc + (temp differential * temp coefficient of Voc)
=	**34.9928**
Nmax ≤	Inverter input Vdc_max ÷ Voc_max
≤	15.71751903
=	**15**

Maximum Modules in Series (*NEC*)	
Voc max =	Voc * Factor from *NEC* Table 690.7
=	**36.52**
Nmax ≤	Inverter input Vdc_max ÷ Voc_max
≤	15.06024
=	**15**

Minimum Modules in Series	
Vmp_min =	Vmp + (temp differential * temp coefficient of Vmp)
=	Vmp + ((Trise + Tmax - Tstc)*(temp coef. of Vmp * Vmp)
Vmp_min =	**25.1636**
Nmin ≥	Inverter input Vdc_min ÷ Vmp_min
≥	9.33888633
Nmin =	**10**

Max Strings in Parallel	
N ≤	Inverter Input I_max ÷ Imp
≤	2.78481013
N =	**2**

Maximum Array Capacity	
Inverter power ≤	N * PTC * CEC weighted efficiency
N ≤	Power ÷ PTC ÷ CEC wieghted efficiency
≤	28.2435771
N ≤	**28 modules**
With Additional Derate Factor	
Inverter power ≤	N * PTC * CEC weighted efficiency * Derate factor
N ≤	Power ÷ PTC ÷ CEC wieghted efficiency ÷ Derate factor
≤	29.7300812
N ≤	**29 modules**

The first two tables on the previous page are used to determine the maximum number of modules or PV panels per string. Both charts determined that the maximum was 15 panels per string. The 3rd table is used to determine the minimum amount of panels per string which turns out to be 10. The 4th table tells us the maximum amount of strings that can connected to the inverter. No more than 2 strings can be run from a single inverter. And the final table tells us what the total number of modules or panels that can be connected to any single inverter. This can be found by multiplying the number or panels per string by the number of strings. This number ended up being 28 panels under normal conditions and 29 panel if the derate factor is included.

Below is a condensed version of the string configuration table. Because the maximum number of strings was 2, I cut it off there.

String Configurations for the Chosen Inverter						
# of Modules in Series	1 String			2 Strings		
	#	**Pac out (W)**	**% of max**	**#**	**Pac out (W)**	**% of max**
1	1	168	3	2	336	7
2	2	336	7	4	673	13
3	3	505	10	6	1009	20
4	4	673	13	8	1345	27
5	5	841	17	10	1682	34
6	6	1009	20	12	2018	40
7	7	1177	24	14	2355	47
8	8	1345	27	16	2691	54
9	9	1514	30	18	3027	61
10	10	1682	34	20	3364	67
11	11	1850	37	22	3700	74
12	12	2018	40	24	4036	**81**
13	13	2186	44	26	4373	**87**
14	14	2355	47	28	4709	**94**
15	15	2523	50	30	5045	**101**
16	16	2691	54	32	5382	**108**
17	17	2859	57	34	5718	114
18	18	3027	61	36	6054	121

The table automatically highlights the cells that are within a percentage of the optimal condition for the inverter and panels chosen. Therefore, the table is telling us that for 2 strings, somewhere between 12 and 16 panels should be chosen to best utilize the inverters max output.

14 modules per string is a good selection because it falls in between all the ranges determined above and it is the closest value to 100% output without going over.

Panel Layout

Now that the number of panels per inverter has been determined, a location needs to be selected for them. The most logical place to place the panels would be on the penthouse roof as indicated in the first Google Sketch Up snapshot. By looking at the series of snapshots, it is clear that very few significant shadows are cast onto the penthouse roof throughout the year. Lafayette Tower is as tall, if not taller than, the surrounding buildings.

Below is layout I created for the PV panels. Panels in similar location are grouped by the inverter which they serve.

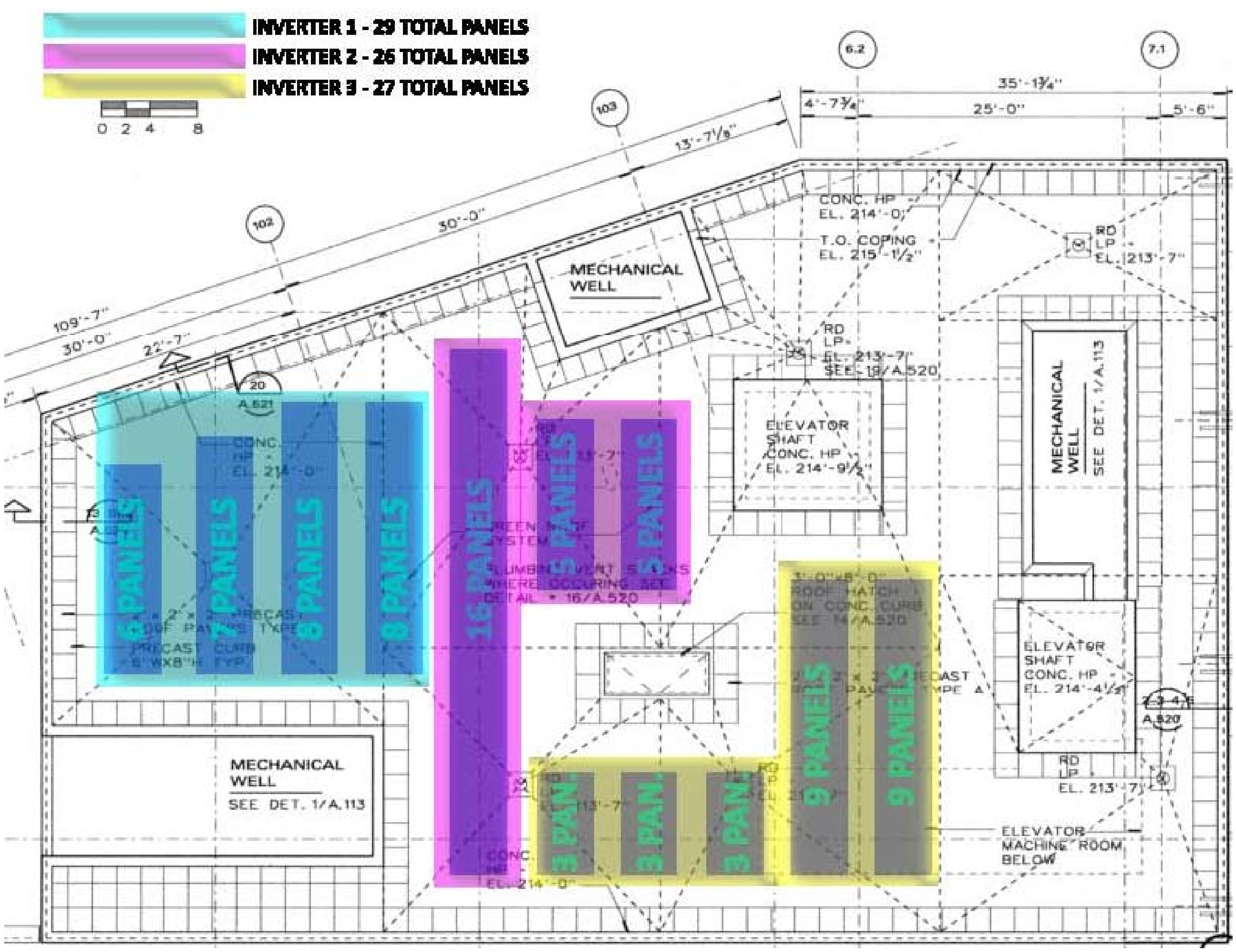


Figure 23 - PV Panel Layout on Penthouse Roof

As the figure indicates, there are 3 inverters and 82 panels included in the design. Inverter 1 has 29 panels on it, inverter 2 has 26 panels on it and inverter 3 has 27 panels on it. Placement was based off of using completely vacant space for the good. Gaps of 3 feet were left in between panels to allow for room to maneuver.

Material Provider

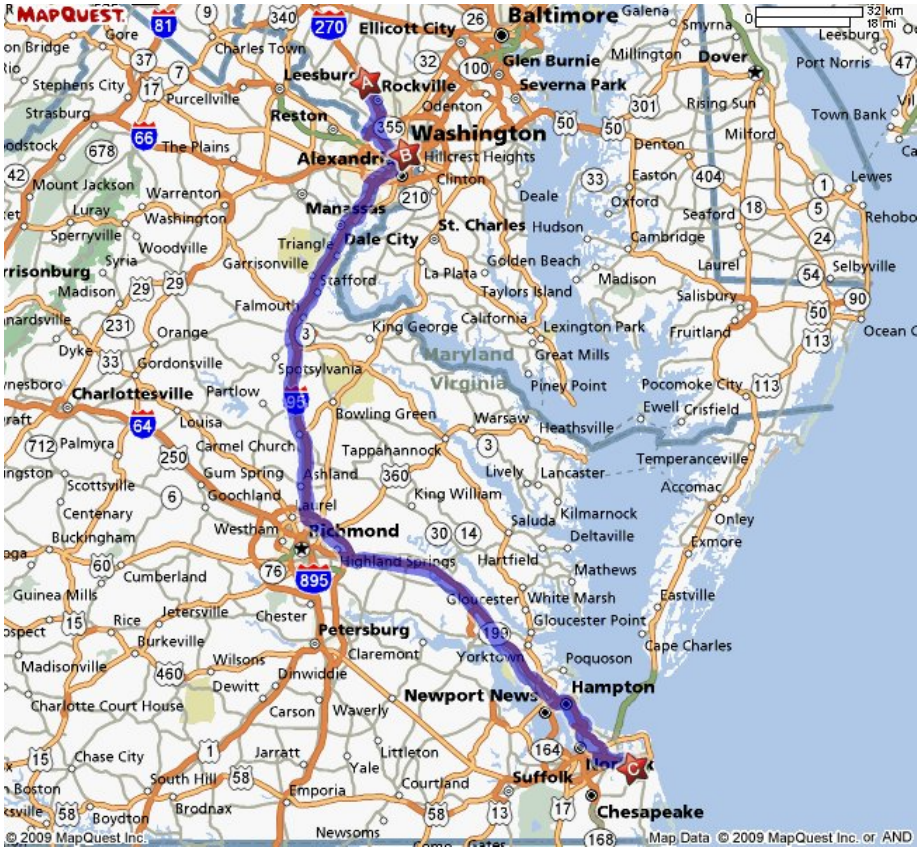


Figure 24 – Map Showing (A) System Installer, (B) Lafayette Tower, (C) Material Supplier

Fortunately, I was able to find both a supplier and installer of Kyocera/Xantrex equipment in the DC area. Standard Solar is a very reputable company that specializes in showing companies how to "*improve your corporate bottom line and image with the ethical and economically sound business practices of solar energy systems."* And Solar Services, Inc is a dealer that I found directly through the Kyocera Solar website.

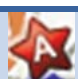
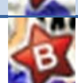
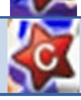
Label	Company	City	State	Distance from Arena Stage
	Standard Solar (Installer)	Gaithersburg	MD	26 miles
	**Lafayette Tower**	**Washington**	**DC**	–
	Solar Services, Inc (Supplier)	Virginia Beach	VA	205 miles

Table 6 - Solar Equipment Supplier/Installer Distances

Cost Analysis

In the above sections, the equipment was selected and quantified for the designed system. In this section, an estimate of material and labor costs will be weighed against the savings of the system and a payback period will be determined.

Figure 25 - PV Panel, Inverter, and Mounting Rack

Solar Equipment Estimate			
Material	**Cost**	**# of**	**Total Cost**
Solar Panels	$874	82	$71,668
Inverters	$3,004	3	$9,012
Mounting Kits	$46	82	$3,731
Labor	$5,000	1	$5,000
		Total	$89,411

Table 7 - Equipment and Labor Estimate

A contingency of $5000 was included for labor and mounting kits for each of the panels was also included. The entire system should be able to be installed for just shy of $90,000.

Next, I used PV Watts, a program from the National Renewable Energy Laboratory website, to help me calculate the energy savings per year and payback period for the system. The program is very simplistic but how much a solar array can expect to save per year. For a location, Washington DC was not available so the next closest alternative was used, Sterling, VA.

The following charts display the input information and results:

Station Identification	
City:	Sterling
State:	Virginia
Latitude:	38.95° N
Longitude:	77.45° W
Elevation:	82 m
PV System Specifications	
DC Rating:	17.2 kW
DC to AC Derate Factor:	0.95
AC Rating:	16.4 kW
Array Type:	Fixed Tilt
Array Tilt:	39.0°
Array Azimuth:	180.0°
Energy Specifications	
Cost of Electricity:	8.0 ¢/kWh

Table 8 - Input Data from PV Watts

Results			
Month	Solar Radiation	AC Energy	Energy Value
	(kWh/m^2/day)	(kWh)	($)
1	3.59	1888	151.04
2	4.28	1982	158.56
3	4.80	2391	191.28
4	5.34	2477	198.16
5	5.32	2426	194.08
6	5.66	2500	200.00
7	5.46	2434	194.72
8	5.38	2439	195.12
9	5.07	2271	181.68
10	4.72	2253	180.24
11	3.56	1715	137.20
12	3.03	1525	122.00
Year	4.68	26301	**2104.08**

Table 9 - Resultant Data from PV Watts

After running the simulation, it was determined that the solar arrays would save approximately $2,104.08 per year. If this rate held consistently, it would take **42.5 years** to pay off the entire system.

Incentives

On February 24th, 2009 the District Department of the Environment (DDOE) announced that DC residents, businesses, nonprofits and private schools may now apply for up to $33,000 in assistance to install renewable energy systems on their buildings. Up to $2 million for each of the next 4 years will be available which begins immediately for solar photovoltaic and wind turbine systems. PV incentives are based off of the systems kilowatt rating. It is broken off into 3 tiers.

- $3 for each of the first 3,000 installed watts of capacity
- $2 for each of the next 7,000 installed watts of capacity
- $1 for each of the next 10,000 installed watts of capacity

Lafayette Tower's solar PV system totaled 17.2kW which means it would be eligible for $30,200 in assistance. If all of this assistance was received, it would cut the 42.5 year payback period down to **28 years**.

Conclusion and Recommendations

At the very beginning of this analysis, I said, "With today's economy in a recession and the growing global awareness of green technologies, saving money and the environment is on everyone's mind. As a soon to be construction manager, both topics are of the utmost importance to me and lead me to the question: *what can I do about it*?" I believe the installation of solar PV system is an answer to that question.

The system that I purposed ended up costing $89,411 with an original payback period 42.5 years and an incentive based payback period of 28 years. Financially, a 28 year payback period isn't a good investment. But there are many other benefits to including a solar PV system. Solar electric systems generate no emissions of greenhouse gases or other pollutants, thereby reducing our impact on the global climate, solar panels provide a visible demonstration of concern for the environment, community education and proactive forward thinking, a solar electric system assures long-term electricity price stability. These are things that will attract potential tenants.

This analysis also did not include things such as the new stimulus package which will appropriate funds for the retrofit of existing buildings with sustainable systems. This means that even if the PV system wasn't included initially, it should be considered at a later time when funding is more readily available. All-in-all, I feel that this analysis demonstrates that implementing solar design, or other green systems, would be beneficial for Lafayette Tower and every other building for that matter.

Conclusions

Lafayette Tower is one of the premier office buildings located in the District of Columbia and already has had a lot of value added into it by the General Contractor, Clark Construction, but I believe that there are still some areas that could have been changed to increase the value of the building as a whole. The three areas continually mentioned above, a critique of the buildings column-free perimeters both from a construction and structural point of view and the addition of solar technologies, are items that I believe may have potential to bring more to this project.

The construction management portion of the column-free perimeter analysis was to prove if the original design, column-free exteriors along the South, West and North face of the building, could be replaced by a more simplistic version of itself that played on its strengths, keeping the cantilever on the South face. The analysis was based on a 15 year time period which is the length of a typical lease. After everything was summed up, the answer is yes and no. If less than 8 floors are being leased, then the new design bests the old but if 8 or more are leased during the first 15 years of operation, then the old design wins out. My recommendation would be to construct the building with the partial removal of the column-free exterior. I feel that the view to the South with The White House and The Washington Monument is a major selling point for the realtor but the other views are not worthwhile and for the amount of time, money and aggravation they cause, they should be cut from the building. I also think that with today's economy in a downturn, it will be hard to fill 8 or more floors with tenants and that saving money is a priority to a lot of people. And in this scenario, the partial removal wins out.

The purpose of this structural redesign analysis was to provide evidence that it was possible to create a design that could ensure structural stability and at the same time still leave the floor plan open for the tenants. I feel that the final design chosen achieved both. The new column layout works structurally and the floor plan is more open than it was previously.

In the solar analysis, the system that I purposed ended up costing $89,411 with an original payback period 42.5 years and an incentive based payback period of 28 years. Financially, a 28 year payback period isn't a good investment. But there are many other benefits to including a solar PV system. Solar electric systems generate no emissions of greenhouse gases or other pollutants, thereby reducing our impact on the global climate, solar panels provide a visible demonstration of concern for the environment, community education and proactive forward thinking, a solar electric system assures long-term electricity price stability. These are things that will attract potential tenants. This analysis also did not include things such as the new stimulus package which will appropriate funds for the retrofit of existing buildings with sustainable systems. This means that even if the PV system wasn't included initially, it should be considered at a later time when funding is more readily available. All-in-all, I feel that this analysis demonstrates that implementing solar design, or other green systems, would be beneficial for Lafayette Tower and every other building for that matter.