April 7, 2011

Final Report

Penn State AE Senior Thesis

Office Building - G

Eastern USA

Dominic Coassolo

Construction Management

Dr. Robert Leicht

Office Building – G | Eastern USA

Dominic Coassolo | Construction Management

http://www.engr.psu.edu/ae/thesis/portfolios/2011/drc5066/index.html

PROJECT TEAM

General Contractor : Turner Construction
Architect: Hellmuth, Obata + Kassabaum, Inc.
Structural Engineer: SK&A Structural Engineers, PLLC
MEP Engineer: GHT Limited
Civil Engineer: Loiederman Soltesz Associates, Inc.
Landscape Architect: Parker Rodriguez, Inc.
Geotechnical Engineer: Schnabel Engineering North, LLC

PROJECT INFORMATION

Size (total square feet): 649,461 SF
Number of stories above grade/total levels: 14 stories above grade with 4 levels of underground parking
Dates of Construction: Summer 2010 – Summer 2012
Project delivery method: Design-Bid-Build

ARCHITECTURAL FEATURES

A glass curtain wall is the main attraction on the new Office Building – G. Architectural cast in place columns with a rubbed finish are used along with concrete beams behind the curtain wall. Precast and metal panels, punched and ribbon windows make up the other elevations of the building. A high end lobby includes stone flooring and wood panels along with stainless steel elevator doors and frames. Leading into the building are stone stairs with brick pavers used for the sidewalk.

CONSTRUCTION LOGISTICS

The construction logistics plan is very critical for the new Office Building-G project. Turner Construction will use a Design-Bid-Build delivery system. Three phases will be involved in the construction process: excavation, superstructure, and interior finishing. The parking garage underneath the building will be critical along with the metro station that is nearby.

STRUCTURAL SYSTEM

The structural system of the new Office Building-G contain post-tensioned girders with 7” slabs for the core floors (4-13). Lateral resistance will come from the interior shear walls. The columns will range from 24”x24” with a 10,000psi load in the garage to 30”Ø 6000psi load in the upper floors. The spread footings will support loads that range from 64k to 1025k.

MECHANICAL AND ELECTRICAL SYSTEMS

The mechanical system includes 3 variable speed drive chillers that provide chilled water to the AHUs. VAV and CAV fans provide airflow to the building. A fully integrated building automation system (DDC) will also be installed. The building also includes a variety of lighting fixtures and lamps. The main feed is a 265/460v, 3 phase, 4 wire system.

2. EXECUTIVE SUMMARY

The final thesis report in intended to discuss findings of the three analyses performed on the new Office Building-G project. The project is a fourteen story office building with four levels of underground parking totaling 650,000 SF. Each analysis is intended to improve efficiency in the construction industry. The three analyses include: the use of a tieback system, implementation of photovoltaic glass in the curtain wall, and material delivery details during peak traffic hours.

Analysis #1: ***Use of Tieback System***

The adjacent metro station calls for special considerations to be taken during the excavation phase on the new Office Building-G project. While the project team decided to use a raker system to account for the underground metro tunnel, it was suggested in the geotechnical report to use a tieback system. This analysis entailed a look at both tieback and raker excavation support systems, a cost analysis, and a schedule acceleration analysis. The findings show that if a tieback system is the only excavation support system used, the project can save $177,450 and roughly 11 working days.

Analysis #2: ***Implementation of Photovoltaic Glass in Curtain Wall***

After attending the PACE conference in October, I became interested in the use of photovoltaic glass that was mentioned in one of the sessions I attended. The new Office Building-G is projected to attain a LEED Silver rating and I thought this would be my best opportunity to focus more on this product and learn more about it. It was determined that implementing photovoltaic panels on the southern façade would be the most logical position on the building for the PV system. By using transparent PV panels, they will replace the current glass panels on the south side of the curtain wall. This change will have no effect on the structural support of the curtain wall. The electrical analysis provides a recommendation for connection to the existing building system. After taking rebates and incentives into account, the feasibility study shows that the system will make back its initial cost within 12 years of use.

Analysis #3: ***Material Delivery Details During Peak Traffic Hours***

The new Office Building-G site is located between an adjacent metro station and the parking garage where the metro's users park daily. The pedestrians will walk past the site everyday during their commutes to and from work. During this time, pedestrian traffic will be high and material deliveries should be reduced to a minimum for safety of the pedestrians. This analysis shows a peak pedestrian volume between the hours of 9am and 11am, and also between 1pm and 4pm. Also discussed are strategies taken to determine the total time a truckload of a certain trade material takes to get delivered. The total estimated time it will take to deliver all the materials needed for the week of September 12, 2011 to September 16, 2011 is 27 hours and 10 minutes. With that information, a proposed material delivery schedule during the week of September 5, 2001 to September 9, 2011 was generated. Each day is scheduled to have 3 or 4 truckloads of material delivered.

3. ACKNOWLEDGEMENTS

ACADEMIC:

PENN STATE AE FACULTY
DR. ROBERT LEICHT

INDUSTRY:

Turner

hok

The SK&A Group

SPECIAL THANKS:

TURNER PROJECT TEAM
PACE INDUSTY MEMBERS
FAMILY AND FRIENDS

TABLE OF CONTENTS

1. THESIS ABSTRACT 2
2. EXECUTIVE SUMMARY 3
3. ACKNOWLEDGEMENTS 4
4. TABLE OF CONTENTS 5
5. PROJECT OVERVIEW 7
    5.1. PROJECT INTRODUCTION 7
    5.2. PROJECT DELIVERY SYSTEM 8
    5.3. PROJECT STAFFING PLAN 9
6. DESIGN AND CONSTRUCTION OVERVIEW 10
    6.1. BUILDING SYSTEMS 10
        6.1.1. CAST IN PLACE CONCRETE 10
        6.1.2. PRECAST CONCRETE 10
        6.1.3. MEP SYSTEMS 10
        6.1.4. FAÇADE 11
    6.2. PROJECT COST EVALUATION 11
    6.3. LOCAL CONDITIONS 12
    6.4. GENERAL CONDITIONS ESTIMATE 12
    6.5. DETAILED PROJECT SCHEDULE 13
    6.6. SITE LAYOUT PLANNING 14
7. ANALYSIS #1: *USE OF TIEBACK SYSTEM* : 16
    7.1. BACKGROUND 16
    7.2. PROBLEM/GOAL 16
    7.3. RESEARCH STEPS 16
    7.4. EXPECTED OUTCOME 16
    7.5. ANALYSIS 16
        7.5.1. TIEBACK SYSTEM OVERVIEW........ 16
        7.5.2. TIEBACK VS. RAKER 17
        7.5.3. TIEBACK COST DATA 19
        7.5.4. SCHEDULE ACCELERATION ANALYSIS 20
    7.6. TIEBACK STRUCTURAL ANALYSIS (STRUCTURAL BREADTH) 21
    7.7. CONCLUSION 22
8. ANALYSIS #2: *IMPLEMENTATION OF PHOTOVOLTAIC GLASS IN CURTAIN WALL*: 23
    8.1. BACKGROUND 23

8.2. PROBLEM/GOAL 23
8.3. RESEARCH STEPS 23
8.4. EXPECTED OUTCOME 23
8.5. ANALYSIS 24
  8.5.1. PHOTOVOLTAIC GLASS INFORMATION 24
  8.5.2. PV REPLACEMENT 25
  8.5.3. STRUCTURAL IMPLICATIONS 27
  8.5.4. LIFE-CYCLE AND PAYBACK 27
    8.5.4.1. STATE INCENTIVES AND REBATES 28
    8.5.4.2. PAYBACK PERIOD 28
8.6. ENERGY AND ELECTRIC IMPACT (ELECTRICAL BREADTH) 29
  8.6.1. ENERGY PRODUCTION 29
  8.6.2. ELECTRICAL COMPONENTS AND SYSTEM TIE-IN 31
8.7. CONCLUSION 33
9. ANALYSIS #3: *MATERIAL DELIVERY DETAILS DURING PEAK TRAFFIC HOURS*: 34
9.1. BACKGROUND 34
9.2. PROBLEM/GOAL 34
9.3. RESEARCH STEPS 34
9.4. EXPECTED OUTCOME 34
9.5. ANALYSIS 34
  9.5.1. PEDESTRIAN TRAFFIC INFORMATION 34
  9.5.2. MATERIAL DELIVERY ANALYSIS 36
  9.5.3. ANALYSIS OF PROPOSED MATERIAL DELIVERY SCHEDULE 38
9.6. CONCLUSION 39
10. CONCLUSIONS 40
11. RESOURCES 42
APPENDIX A: EXISTING CONDITIONS PLAN 43
APPENDIX B: GENERAL CONDITIONS ESTIMATE 45
APPENDIX C: DETAILED PROJECT SCHEDULE 48
APPENDIX D: SITE LAYOUT PLAN 55
APPENDIX E: STRUCTURAL BREADTH ANALYSIS 57
APPENDIX F: CENTENNIAL SOLAR PANEL SPECIFICATIONS 59
APPENDIX G: PAYBACK PERIOD ANALYSIS 63
APPENDIX H: INVERTER SPECIFICATIONS 65

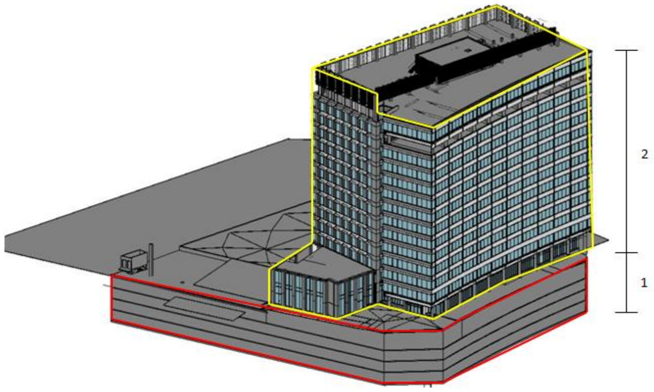
5. PROJECT OVERVIEW

5.1. PROJECT INTRODUCTION

The new Office Building-G is a 14 story, 380,100 SF office building along with a four level underground parking garage that totals around 269,000 SF. The building features a glass curtain wall along the southern elevation with the rest being made up of architectural precast concrete with punched out glazing. LEED Silver status is projected for the project with the usage of green and white roofs, water reuse/ reduction techniques and the use of recycled materials to name a few key aspects.

The project began in November of 2009. Turner was not the first to be awarded the project at the beginning, another contractor was selected. However, things did not work out with that contractor and Turner was awarded the project on December 4, 2009. The process for the building and the garage permits began in March 2010 and the Guaranteed Maximum Price (GMP) contract with the owner began development in May 2010. The GMP contract is for roughly $70 million. Turner plans to implement a design-bid-build delivery system as well.

The project is scheduled to take around two years to complete with a project completion date on September 12, 2012. In figure 1, you see a graphic the building structure along with the underground parking levels.



1. Four Level Underground Parking Garage (Outlined in RED)
2. 14 Story Office Building (Outlined in Yellow)

Figure 1:
EXTERIOR BUILDING VIEW

The project team has many challenges to overcome on the project, but none more evident than the adjacent metro station to the west of the building footprint. Many careful considerations and guidelines needed to be followed according to the metros adjacent construction manual. Figure 2, below, shows the metro station in relation to the building footprint.

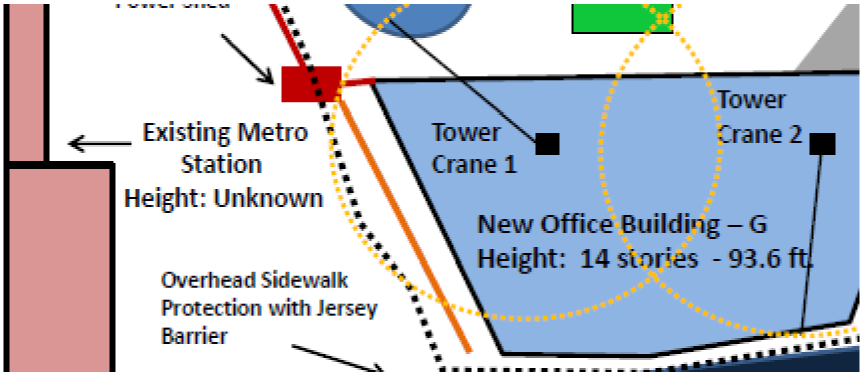


Figure 2: SITE PLAN

5.2. PROJECT DELIVERY SYSTEM

Turner holds a GMP (guaranteed maximum price)with the owner and a lump-sum contract with all of the subcontractors. Due to owner restrictions, the types of contracts held between the owner and the architects and engineers are not known. What is known is that the architect has contracts with the engineers and other architects. Figure 3 shows the contractual agreements between all parties. Turner has bonds with all of the subcontractors on the project with what they call Subcontractor Default Insurance or Subguard. They also utilize CCIP (Construction Controlled Insurance Program) with their own private insurance carrier.

Turner has a design-bid-build delivery system in place for the project. This delivery system is effective because of the size of the project. It allows the general contractor to focus on the

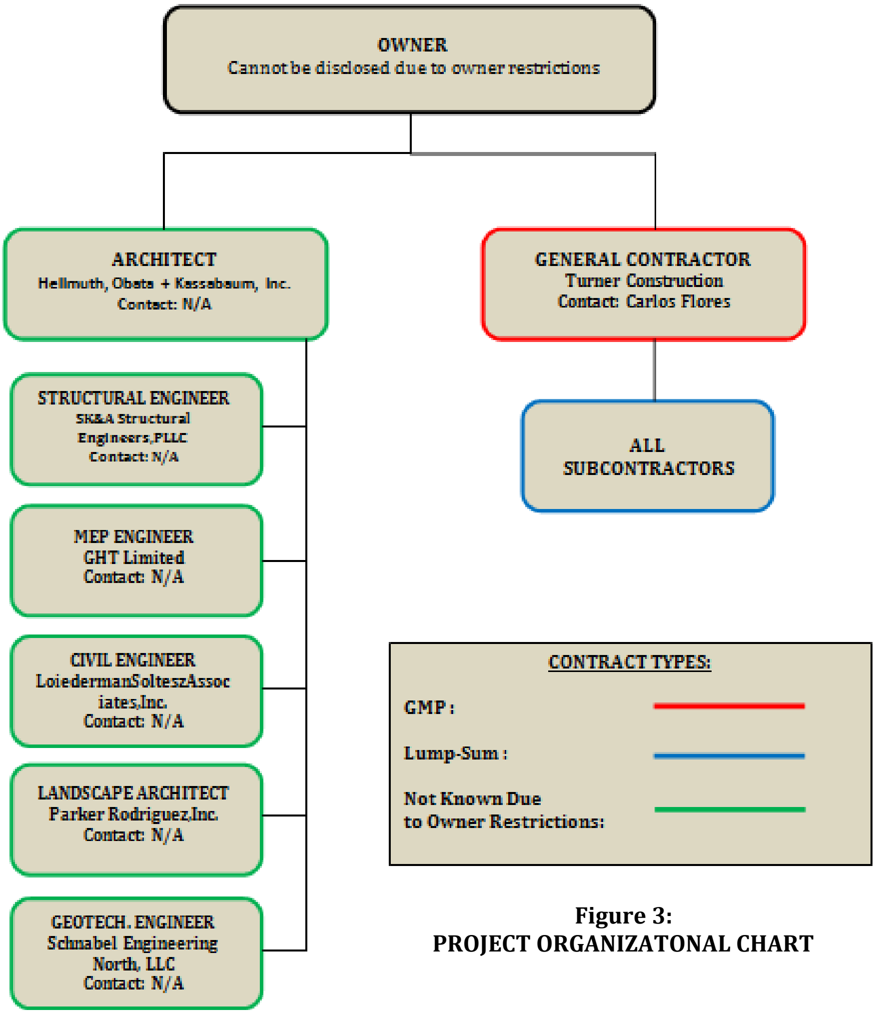


Figure 3:
PROJECT ORGANIZATONAL CHART

construction of the project and the many complexities that will need the full attention of the general contractor

5.3. PROJECT STAFFING PLAN

Turner's managing staff for the new Office Building-G project is split into two groups, the office staff and the field staff. Figure 4 shows the office staff, including the project VP, senior project manager, project manager, accountant, cost engineer, project engineer and any engineers or interns who preside below the project engineer. The field staff includes the project supervisor, field engineer, scheduler, superintendent and safety manager.

Turner's staff sizes vary on each project. More or less staff may be assigned depending on the sizes of the project. Figure 3 shows the current staffing plan for the new Office Building-G but the plan can change if more help is needed on the project. The same goes for all Turner projects.

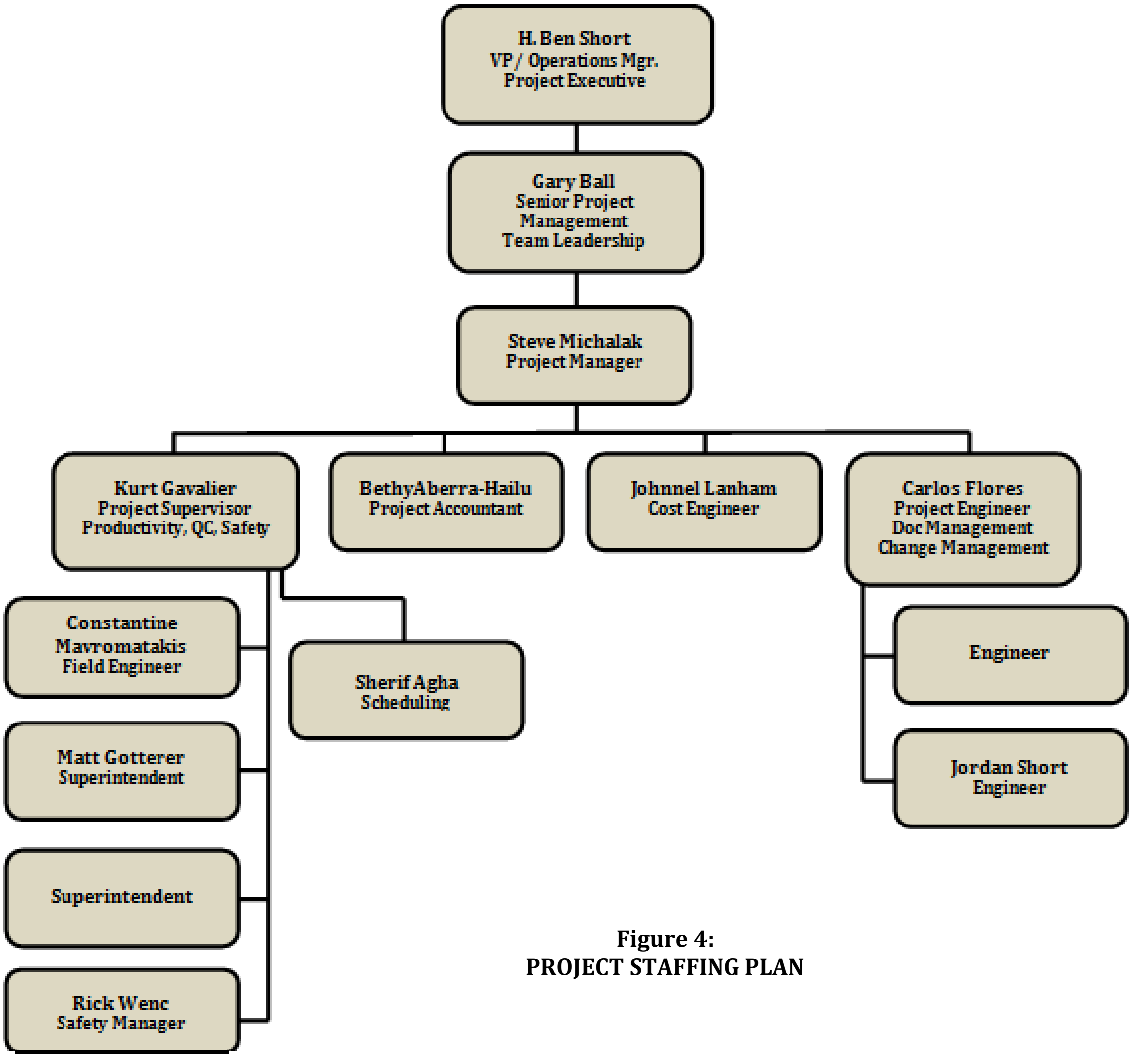


Figure 4:
PROJECT STAFFING PLAN

6. DESIGN AND CONSTRUCTION OVERVIEW

6.1. BUILDING SYSTEMS

6.1.1. CAST IN PLACE CONCRETE

The cast in place concrete system is the predominant system used in the new Office Building -G. The system contains 7" slabs with a 5000 psi load on the core floors, 4-13, along with post-tensioned girders as well. Columns range from 24" x 24" in size with a 10,000 psi load, used in the garage, to columns with 6000 psi maximum load in the building. Interior shear walls will provide lateral resistance. Plywood and metal will be used for horizontal and vertical formwork. Form-facing panels will be used in areas where smooth-formed finish is required. Reinforcing steel will come from the steel frame tower that will be used along with joist tower aluminum beams. Also, steel reinforcing bars will follow ASTM A615/A 615M grade 60. The CIP concrete placement methods are being developed and not known at this time.

6.1.2. PRECAST CONCRETE

The precast concrete system used on the project is intended to establish and maintain an airtight and waterproof skin on the structure while staying within the limitations and performance standards specified by the wall system design. The precast is also being utilized for architectural purposes that include the facade of the building along with the punched ribbon windows. The precast will fasten onto the structural concrete of the building by means of anchors, embeds, connections and inserts of different types. The precast concrete's casting location is off site and cannot be disclosed due to project restrictions. Two tower cranes will be used to place the precast concrete, they are to be placed on the north side of the building for use. The exact type and size of the tower cranes are not known at this time.

6.1.3. MEP SYSTEMS

The mechanical system has rooms dedicated to mechanical support on the penthouse and first floor garage level. The system includes three variable speed drive chillers that provide chilled water to the air handling units (AHUs). Each floor of the building has 1 VAV system. A fully integrated building automation system is also included in the mechanical system. The building have a total of eight elevators throughout the building, six traction in the building and two hydraulic in the garage levels. The main electrical system is a 265/460V, 3 phase, 4 wire with a 4000A breaker service. The main electrical room is on the top level of the underground parking garage with electrical rooms on each floor of the building, including the penthouse. There are many different lighting fixtures that make up the new Office Building-G. They range from simple ceiling lighting in the office spaces to aesthetically pleasing pendant and recessed lighting for specialty areas. The lamp types also vary as much as the mounting type. Regular T8 lamps up to highly technical LED lamps are used. The vast majority of the lighting fixtures use a 265V source while others use 120V.

6.1.4. FAÇADE

The curtain wall on the new Office Building-G project is to be constructed on the southern side of the building. The curtain wall is made up of both glass and aluminum and while it will look curved, it is really made up of segmented glass pieces. The curtain wall subcontractor will own the design and engineering responsibilities, but all decisions must be approved by the architect before any changes are made. Before construction began, the owner made a contractual change to the façade to incorporate a blast façade. For load bearing purposes, CMUs and concrete building brick will be used. Reinforcing steel along with joint reinforcing wire will be used for both interior and exterior walls. The CMUs to be used are specified to be lightweight, type I, moisture-controlled units. The concrete building brick are also lightweight, type I, grade N.

6.2. PROJECT COST EVALUATION

The costs shown are based on information recieved from Turner Construction. The amounts are rough estimates and not actual costs of the project.

PROJECT INFORMATION:

	OFFICE BUILDING-G	UNDERGROUND GARAGE
PERIMETER	730 LF	1090.5 LF
SQUARE FOOTAGE	380,741 SF	268,720 SF
FLOOR HEIGHT	12.25 FT	10 FT
ELEVATORS	8	2 (UP TO LOBBY FLOOR)

COST SUMMARY:

OFFICE BUILDING - G	COST	COST/SF
CONSTRUCTION COST	$ 63,283,188.00	$ 166.21
TOTAL PROJECT COST	$ 69,662,980.00	$ 182.97

BUILDING SYSTEMS COST:

BUILDING SYSTEM	COST	COST/SF
CIP CONCRETE	$ 14,909,500.00	$ 39.16
PRECAST CONCRETE	$ 3,049,823.00	$ 8.01
GLAZING	$ 6,047,032.00	$ 15.88
ELEVATORS	$ 2,584,000.00	$ 6.79
HVAC/PLUMBING	$ 8,322,123.00	$ 21.86
ELECTRICAL	$ 5,132,167.00	$ 13.48
FIRE PROTECTION	$ 787,538.00	$ 2.07

6.3. LOCAL CONDITIONS

- ***Please refer to Appendix A for Existing Conditions Plan***

The location of the new Office Building-G is in a location where many buildings use Cast-In-Place concrete as their primary structure. Height restrictions limit the maximum height buildings can be constructed to, so concrete can be utilized instead of steel.

Due to the condensed area this new building is in, parking areas have to be utilized efficiently. That is why many parking garages being built in the area are either underground or above ground. Also, luckily for the project team, there is ample parking for the construction staff to the east of the project site.

From the geotechnical report, it was stated that the new Office Building-G site contains compact soils of Stratum B and disintegrated rock of Stratum C. The report recommends that spread footings should be used as means of foundation support for the building. The spread footings are suggested to be designed to support soil bearing pressure of 15,000 psf. The report also took groundwater readings and found the presence of water as high as 14 ft below existing grade. Thus, dewatering systems will be provided during construction. Drilled caissons are also recommended in the report in areas of Stratum C soil. The caissons should be designed for an end-bearing pressure of 40 tsf and an allowable skin friction value of 1500 psf within the disintegrated rock of Stratum C.

Due to the existing metro station to the west of the building, special considerations must be made. The metro's adjacent construction design manual must be carefully studied and be in accordance with the project design plans. The metro's tunnel is in the vicinity of the site which makes it sensitive to changes in loading. The sensitivity is due to the compressible nature of the residual soil supporting the tunnel. Because the tunnel is only a few feet below the ground, it probably was constructed using sloped elevations, therefore, sheeting and shoring may not exist for the tunnel structure. The new office building is within the metro's "zone of influence", so special precautions will need to be made that include tie backs beneath the track and tunnel. Rakers and heel blocks may be required if tie backs cannot be used. For more information on the conditions of the project, please refer to ***Appendix A*** for the existing conditions site plan.

6.4. GENERAL CONDITIONS ESTIMATE

- ***Please refer to Appendix B for Complete General Conditions Estimate***

The estimate shown below in figure 5 summarizes the general condition line items for the new Office Building-G project. The data is an approximation and are not the actual estimates used by Turner Construction.

GENERAL CONDITIONS SUMMARY				
Description	**Unit Rate**	**Unit**	**Quantity**	**Cost**
Personnel	$ 24,929.00	WEEK	100	$ 2,492,900.00
Facilities and Equipment	$ 2,795.00	WEEK	100	$ 279,500.00
Temporary Utilities	$ 2,580.00	WEEK	100	$ 258,000.00
Miscellaneous Equipment	$ 11,724.00	WEEK	100	$ 1,172,400.00
			TOTAL	**$ 4,202,800.00**

Figure 5:
GENERAL CONDITIONS SUMMARY

The estimate was broken down into four sections: Personnel, Facilities and Equipment, Temporary Utilities, and Miscellaneous Equipment. The Personnel section includes the cost for the Vice President, Senior Project Manager, Project Manager, Senior Superintendents, Project Engineers, Safety Managers, Purchasing, Project Estimator, and Project Accountant. The Facilities section has items such as the office trailer rental, along with installation and removal. Also included is the technology fee, computer fee, office supplies and printer/copier costs. Temporary Utilities includes power installation, power and lighting, toilet installation and monthly cost, and potable water. Finally, miscellaneous items included in the general conditions report consist of any taxes and insurance, company travel expenses, mail service, documentation, and progress photos.

After collecting all of the general conditions data, it was clear that the majority of the costs were due to the project's personnel expenses. The overall general conditions cost of $ 4,202,800.00 is 6% of the entire project cost of $ 70,000,000.00

6.5. DETAILED PROJECT SCHEDULE

- ***Please refer to Appendix C for Complete Detailed Project Schedule***

Construction on the new Office Building - G began on August 20, 2010 with piles being drilled on the west end of the project. Excavation and shoring is scheduled to last until December 2010 with construction of the underground parking garage to begin in November 2010, a month prior to the excavation completion date. Construction of the garage will last until the following Summer with a scheduled completion date of July 29, 2011. Immediately after, the core building structure will commence. Core construction will last through the Summer of 2011 along with the facade and roof construction as well. Interior fitouts will begin in August 2011 and last until the end of February 2012. Commissioning and inspections will follow along with the tenant fitout as well. Tenant occupancy is scheduled for June 12, 2012 with a project completion date of September 12, 2012.

Description	Start Date	End Date
START OF PROJECT	11/18/2009	-
DESIGN AND PROCUREMENT	12/14/2009	7/3/2010
EXCAVATION	6/21/2010	12/10/2010
UNDERGROUND GARAGE	10/29/2010	7/29/2011
CORE BUILDING STRUCTURE	5/4/2011	9/9/2011
FAÇADE AND ROOF	6/30/2011	6/4/2012
INTERIOR FITOUTS	8/26/2011	2/24/2012
PROJECT COMPLETION	-	9/12/2012

Figure 6:
MAJOR MILESTONE PROJECT DATES

6.6. SITE LAYOUT PLANNING

- ***Refer to Appendix D for Project Site Layout***

The new Office Building-G is located in the eastern United States. Due to owner restrictions, the exact location of the building cannot be disclosed. If you refer to ***Appendix D***, you will see the site layout plan for the new Office Building-G. The site will have two entrances, with the main entrance being to the north. The entrance that is behind the building footprint will be used for special deliveries and also for construction equipment to enter the project site. The office trailers for Turner Construction and the project subcontractors on site will be to the north of the building footprint. Along side of the trailers will be waste dumpsters and portable toilets. There will be limited parking near the trailers for Turner workers. Subcontractor employees will have to park in the parking lot that is located to the east of the site. The layout for the office trailers are shown in figure 7. The Turner trailers are in yellow, the subcontractor trailers are in purple, and the dumpsters and toilets are in red.

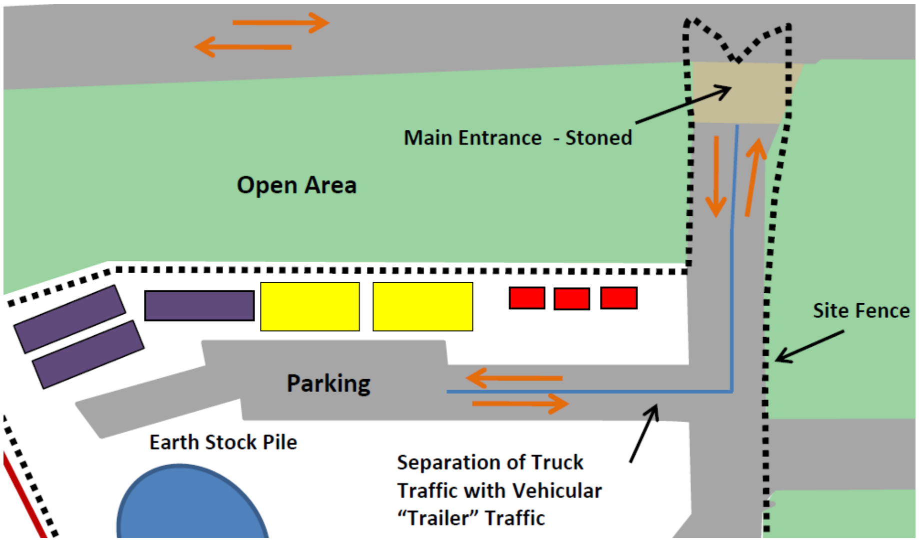


Figure 7:
PARKING AND ON SITE TRAILERS

Along the western side of the building footprint, tiebacks will be utilized during excavation due to the adjacent metro station. In the geotechnical report, tiebacks were suggested because of the closeness of the metro line to the project. Also, because the metro station will stay open throughout the entire construction process, overhead protection will be installed over the sidewalk on the southern end of the site for pedestrian protection. The overhead protection will be installed on the southern end because pedestrians who use the metro daily park in a lot that is next to the designated subcontractor parking. Temporary utilities come from the northwest side of the building footprint and the temporary electricity will be routed through a power shed that is located to the west of the site.

Concrete Phase

The major site layout Turner currently has is the **Concrete Phase** of the construction project. Turner will utilize on site batch plants along with two tower cranes and one mobile crane. Each tower crane has a boom of 100 feet and will be the major means moving material about the site. The exact size and location of the mobile crane to be used is not known. From figure 8 below, you can see the planned locations of the two tower cranes on the new Office Building-G site. The concrete phase is one of the most critical phases of the project because the building's structure is primarily concrete (cast-in-place). The concrete mixing stations are located where the green square is. It is critical to have the mixing locations close to the site because when dealing with concrete, time is crucial from the mixing to placing of the concrete.

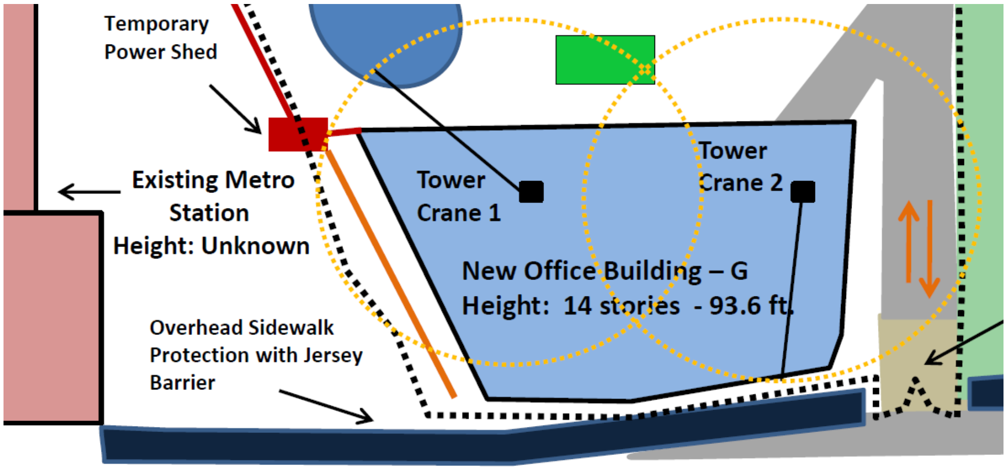


Figure 8:
TOWER CRANE LOCATIONS

7. ANALYSIS #1: *USE OF TIEBACK SYSTEM*

7.1. BACKGROUND

Due to the adjacent metro station to the west of the new Office Building-G footprint, excavation support for the project is most critical along with following the guidelines to the metro's adjacent construction design manual. Currently, the excavation support system for the project is a 3-tier tieback system with soldier beam support. Along the metro's side of the building, a raker system is utilized. From the geotechnical report conducted, it was suggested that the use of a tieback system would be best suitable for excavation support.

7.2. PROBLEM/GOAL

The goal of this analysis is to look more closely at tieback and raker systems, finding out whether the use of the tieback system is more cost efficient as well as looking at the schedule for acceleration opportunities will be determined as well.

7.3. RESEARCH STEPS

- Research on tieback systems and situations where they are most effective
- Compare and contrast tieback systems vs. raker systems
- Contact Turner's excavation contractor
- Collect cost data on tieback systems
- Analyze advantages and disadvantages of a tieback system
- Develop a summary of findings and provide details as to which system would be best for the new Office Building-G project
- Checking to make sure tieback system is in accordance with adjacent metro's construction design manual.
- Analyze schedule acceleration with use of tieback system

7.4. EXPECTED OUTCOME

Through research and analysis, it is expected that the use of a tieback system will be better suited for excavation support. The tieback system will provide the necessary support for the metro's tunnel structure as well as the building as detailed in the geotechnical report. While cost differences are not yet known, a tieback system can provide schedule acceleration through its installation period compared to a raker system.

7.5. ANALYSIS

7.5.1. TIEBACK SYSTEM OVERVIEW

The tieback system used on the new Office Building-G project is a 3-tier system with soldier beam supports. The system is utilized on three sides of the building footprint. The total length of the system is approximately 925 LF. The figure below show the installation of the tieback system on the project.

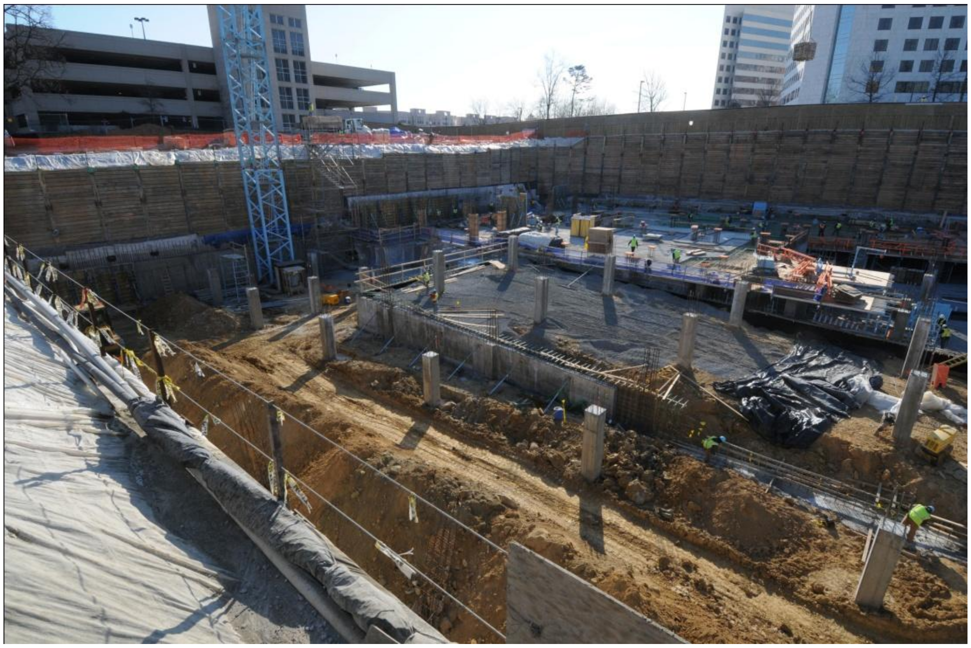


Figure 9:
TIEBACK EXCAVATION SYSTEM

7.5.2. TIEBACK VS. RAKER

Raker and tieback systems are both similar types of systems. The tieback system utilizes post tensioning in the foundation wall. Because the support of the tieback is drilled inside the foundation wall, that allows for room to work in the project footprint. Tieback systems are very successful in preventing any movement in these excavation walls, a very important factor when determining which type of excavation system to use for a particular project. For most cases, this project included, the tieback is usually left in place after the permanent construction inside the excavation is complete. The structural system of the tieback acts in tension and receives support from the earth or rock it is attached to. The system consists of a tension member, which transfers the load from the retention system to the earth/rock, a stressing unit, which allows the tendon to be stressed, and the earth/rock which provides the support for the system. Figure 10 depicts a typical tieback in tension.

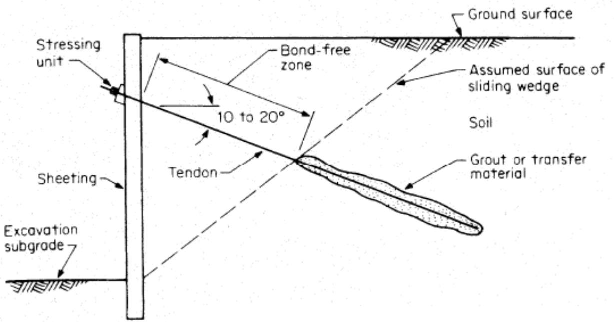


Figure 10:
TYPICAL TIEBACK

Along with the tieback system, soldier piles and wood lagging are the most common and most economical systems to use along with the tieback. The wood lagging is installed to maintain the soil between the soldier piles and the tieback supports the lateral earth pressure. Figure 11 shows the wood lagging and soldier piles installed on the project site.

Figure 11:
WOOD LAGGING AND SOLDIER PILES

Raker systems differ a little from the tieback system. The raker system's supports are not drilled into the foundation wall. Rather, the raker is placed against the wall of the foundation by means of a wale connection. The other side of the raker, or commonly called a strut, is braced against the foundation slab for support. Figure 12 shows the basic design of the raker system and figure 13 shows the raker system installed on the Office Building-G project site. Even though the rakers extend towards the project work area, they are positioned where they do not take up much of the work area.

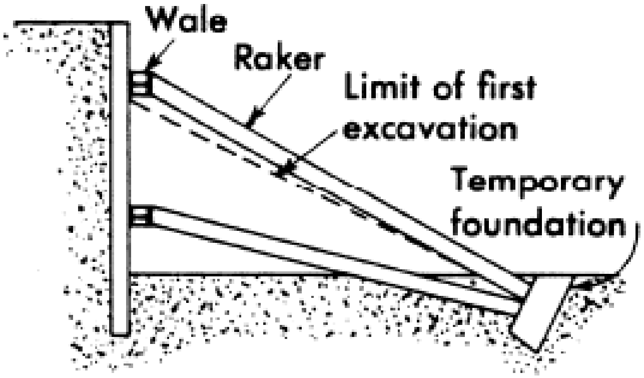


Figure 12:
RAKER SYSTEM

Figure 13:
RAKER SYSTEM ON PROJECT

7. 5.3. TIEBACK COST DATA

The cost data obtained from Turner Construction on the tieback and raker systems can be seen in figure 14 . The approximate cost of the tieback system was $550,000. That was determined for 925 LF of tieback support, or $595 per LF. The cost of the raker system was approximately $276,000 for 165 LF, or $1,673 per LF. That totals to be $826,000 for the entire excavation support system. By implementing the tieback system for the whole project, there would be a total savings of $177,450.

Excavation System Cost Analysis			
Current System			
	Total LF	**Total Cost ($)**	**Cost/LF**
Tieback System	925	$550,000	$595
Raker System	165	$276,000	$1,673
Total	**1090**	**$826,000**	
Proposed System			
Tieback System	1090	$648,550	$595
Total	**1090**	**$648,550**	
Total System Cost Savings = $177,450			

Figure 14:
EXCAVATION COST ANALYSIS

7.5.4. SCHEDULE ACCELERATION ANALYSIS

Excavation on the new Office Building-G began on August 20, 2010 and concluded excavation on December 10,2010, almost four months total. Piles on the west and south sides of the project began first, due in part because the west side is the metro's side and the south side being next to the main roadway. Those piles were completed on the 9th of September. Tieback installation on those sides then began and lasted until the end of September. From there, the east and north piles were drilled along with the installation of the dewatering system. The last piles on the north side were drilled on October 21,2010. Excavation then began from the 1st to the 2nd tier and then from the 2nd tier to the 3rd tier ending on November 11. Once the excavation and lagging was completed, the raker system began installation. The system took roughly 30 days to install completely with bottoming out occurring on December 10,2010.

By excluding the raker system and implementing the tieback system for the entire excavation support, that can reduce the overall duration of the sheeting and shoring operations. From the schedule given by Turner Construction, the tieback system installation (including piles, tieback, and lagging) took roughly 95 days to complete. On an estimated 8 hour work day, that equates to 760 total hours, or roughly 50 minutes per LF of tieback. The total duration for the raker system was approximately 30 days or 240 total hours assuming 8 hour work days. That equates to roughly 1 hour and 30 minutes per LF of raker system installed. That totals to be 125 total work days or 1000 work hours for the excavation system installation.

The installation of the tieback system alone would take roughly 50 minutes per LF. With 1090 LF of excavation support, that equates to 909 total hours or work needed, or 114 days. That would save over 11 days of working time, or roughly 90 hours. This schedule change would not affect the critical path of the schedule, which is mock-up testing. The testing was set to be completed at the end of August, before construction started, so this will not affect the critical path. Figure 15 shows a summary of the schedule acceleration analysis.

Schedule Acceleration Analysis			
Current System			
	Total LF	**Time (hours)**	**Time/LF**
Tieback System	925	760	50 min
Raker System	165	240	1 hr 30 min
Total	**1090**	**1000**	
Proposed System			
Tieback System	1090	909	50 min
Total	**1090**	**909**	
Total Schedule Savings = ~ 11 Working Days or 90 Hours			

Figure 15:
SCHEDULE ACCELERATION SUMMARY

7.6. TIEBACK STRUCTURAL ANALYSIS (STRUCTURAL BREADTH)

Analysis 1 presented the opportunity to examine the loading requirements of the tieback system on the new Office Building-G project, specifically the west elevation foundation wall where the tieback system will replace the raker system. From the test boring reports found in the geotechnical report, boring B-119 (closest test boring to metro) found that the estimated top of the bedrock near the metro was 356 ft. Also determined from the geotechnical report was the soil conditions near the metro rail. The soil conditions were determined to be sandy silt. The tables below show the soil loading factors and design factors that were calculated in accordance with the metro's construction design manual.

Soil Loading Diagram

	Elev.	Soil Type	Soil Density	Friction Angle	Active Press. Coeff.	Vert. Stress	Active Press. Top	Active Press. Bottom	Pressure Area
Layer 1	406	Fill	120	26	0.39	0	0	258	709
Layer 2	400.5	Sandy Silt	130	34	0.283	660	187	1675	37699
Subgrade	360					5925			

Figure 16:
SOIL LOADING FACTORS

Design Factors	
Stiffness Factor	1.25
Total Pressure	38408
Ave. Soil Density	128.8
Eq. Active Coeff.	0.282
Eq. Friction Angle	34.1

Figure 17:
DESIGN FACTORS

Using the information above, the maximum pressure was determined using a foundation wall height of 42 feet (wall height). The maximum pressure from the foundation wall was determined using the following equation.

p(max) = (Stiffness Factor x Total Pressure) / (0.8 x Height)

= (1.25 X 38408) / (0.8 X 42) = **1429 psf**

From the data above, an equivalent loading equation can be determined:

- **p(max) = 34.0 x H psf**

With the equation above, the maximum load that the tieback system will need to support can be determined. With a backslope height of 46 feet, that will be substituted for H in the above equation.

p(max) = 34.0 x 46 = **1,564 psf**

The load of 1,564 psf represents the maximum amount of load the tieback system will need to support on the metro's side of the building (west foundation wall). Refer to ***Appendix E*** for complete design factors and equations used.

7.7. CONCLUSION

Based upon the information in section 7.5, both tieback excavation systems and raker excavation systems are both adequate means of excavation support for many different types of projects. Section 7.5.3. shows that there can be a significant savings of $177,450 if the raker system was not used and the tieback system was the only excavation system. Also, by using only the tieback system, section 7.5.4. shows that there can be a schedule savings of approximately 11 working days or roughly 90 working hours. Section 7.6 shows that if the tieback system were to be implemented on the metro rail's side, a maximum load of 1,564 psf will need to be supported by the tieback system. Upon further review of the metro's adjacent design and construction manual, the metro does not allow any other types of excavation support other than raker excavation support. While it would be recommended to replace the raker system with the tieback system, due to the design manual that cannot occur.

8. ANALYSIS #2: *IMPLEMENTATION OF PHOTOVOLTAIC GLASS IN CURTAIN WALL*

8.1. BACKGROUND

The second analysis is dealing with the implementation of transparent photovoltaic panels into the southern façade of the curtain wall. The new Office Building-G is projected to attain a LEED Silver rating. These building types usually account for large amounts of energy usage throughout their lifetime. Lighting, computers, security and MEP systems will require a large amount of energy and most of these systems will be running constantly. Photovoltaic glass could be looked at to help reduce the total building energy consumption. They are an effective sustainable technique that can be utilized on this project.

8.2. PROBLEM/GOAL

After attending the PACE seminar this past October, transparent photovoltaic panels were discussed and I became interested in learning more about them. That presented the opportunity to research this newer technology and look into using them on the new Office Building-G project. After looking at the curtain wall, particularly the southern façade, that presented the opportunity to incorporate the transparent PVs into the curtain wall. The goal of this analysis is to analyze the implementation of the transparent photovoltaic glass into the curtain wall on the southern elevation of the building. Determining whether the use of photovoltaic glass is feasible and if it will reduce energy costs of the building will also be analyzed. This analysis will serve as my critical industry research.

8.3. RESEARCH STEPS

- Research photovoltaic glass and the design techniques
- Contact glass manufacturer on design techniques
- Analyze the structure to determine the effect of the photovoltaic loads
- Analyze the connection between the existing power and photovoltaic glass
- Perform analysis on life-cycle cost and payback
- Determine quantity of glass needed for curtain wall

8.4. EXPECTED OUTCOME

Through research and analysis, it is expected that the implementation of photovoltaic glass will provide an energy savings technique to add to the LEED techniques already being used on this project. While the whole building will not run off of the renewable energy from the glass, it will account for a good portion of the total building energy. Through cost research, it is believed that the photovoltaic glass will be affordable to the owner and both beneficial through the life-cycle costs and incentives.

8.5. ANALYSIS

8.5.1. PHOTOVOLTAIC GLASS INFORMATION

The first step to begin this analysis is to research photovoltaic products and learn what kinds are made and what types of PV panels are available. After using the internet to look for companies that produce photovoltaic panels, it became apparent that there are many different types of panels produced, and the idea to put them into the curtain wall of a building was not very common. I learned that the transparent photovoltaic panels are relatively new and not many companies produce them, especially in the United States. Still, I found a couple of suppliers that do produce transparent PV panels.

There are two types of transparent panels currently being produced, semi-transparent and fully transparent. An example of a semi-transparent panels is in figure 18 below, where the solar panel is in half of the window and the other half is clear to look thought. Fully transparent PV glass is what it sounds like, regular glass that is tinted, but still can be viewed through. An example is in figure 19.

Figure 18:
SEMI-TRANSPARENT PV GLASS
UNIVERSITY OF SOUTHAMPTON

Figure 19:
FULLY TRANSPARENT PV GLASS
RAINBOW SOLAR, INC.

My plan is to use fully transparent panels on the southern façade of the curtain wall on the new Office Building-G. The southern side of the building will receive the most sunlight which makes it most beneficial and logical to incorporate the panels on that elevation. I looked at several manufacturers that produced this type of photovoltaic glass including Rainbow Solar Inc., Trina Solar, Centennial Solar, and Schuco. A major concern when using these panels is the structural integrity of the system they are being incorporated in. The weight of each panel will need to be analyzed to determine whether any structural changes will need to be made to curtain wall system. Due to time constraints, a simple calculation will be made comparing the weight of the current glass to the weight of the panels I plan to use.

After looking at each company's product, I decided to use the panels from Centennial Solar. These panels are shown below in figure 20. The panel specifications and description can be found in ***Appendix F.***

Figure 20:
TRANSPARENT PV GLASS
CENTENNIAL SOLAR

The specific panels I choose are the BIPV this film modules type THRU-4-IO, which are the double glazing modules. Because these modules will be replaced in the curtain wall system, I felt the double glazing would be the best option to use since it includes the glass glazing on both sides of the PV panel. While the double glazing limits the maximum solar heat gain compared to the non-double glazing modules, it will be more beneficial to use the double glazing on the curtain wall system.

8.5.2. PV REPLACEMENT

Currently on the southern façade of the curtain wall, there are four glass panels that are 4'-8" x 8'-5" which equals to a total of 18'-8" x 8'-5" (224"x 101") total. A detail of this can be seen below in figure 21. Replacing these four glass panels will be five 3'- 8" x 8'-5" Centennial Solar transparent PV panels. This exact product dimension is not listed on the description page of Centennial Solar, however, after talking to one of their consultants, I learned they can produce modules to specific dimensions. For the purposes of this analysis, the module that is 1007mm x 2338mm (roughly 3'-5" x 8') will be used since it is closest to the dimensions that will be used. Figure 22 shows the proposed orientation of the five PV panels on the curtain wall.

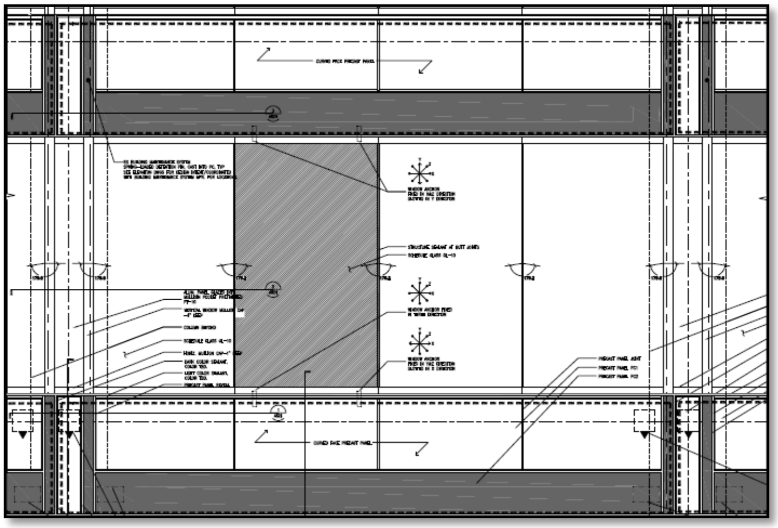


Figure 21:
CURRENT CURTAIN WALL DETAIL

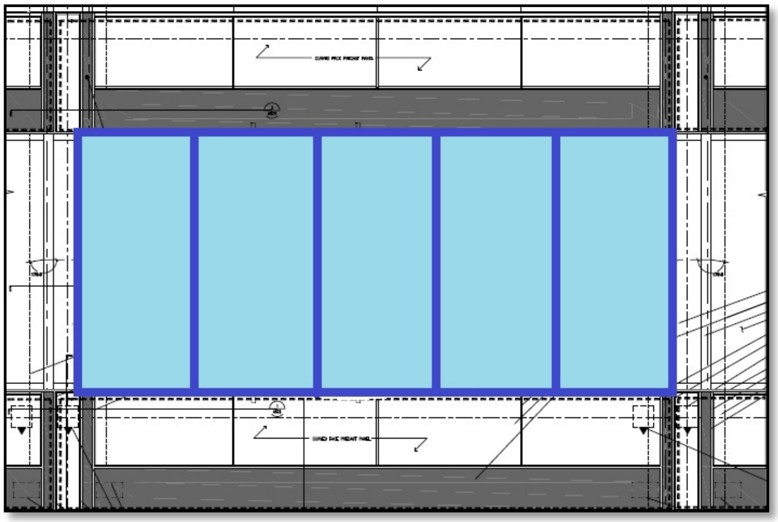


Figure 22:
PROPOSED CURTAIN WALL DETAIL

There are a total of 10 18'-8" x 8'-5" (224"x 101") spaces on each floor of the curtain wall. Multiplied by 13 floors that equates to a total of 130 spaces on the curtain wall. Each space will have five panels, that equates to 650 photovoltaic panels. At the end of each floor on both sides is also another panel that will be replaced by one PV panel. That equals to 26 total. Adding it all up, that equates to a total of **676 transparent photovoltaic panels** on the southern façade of the curtain wall.

8.5.3. STRUCTURAL IMPLICATIONS

On the southern façade of the curtain wall, there are a total of 520 panels of glass. Those 520 panels will be replaced with 676 transparent PV panels. Since PV panels weigh more than glass most of the time, a analysis of the structural effects of replacing the glass with the PV panels needs to be analyzed and addressed. From information obtained through Turner Construction and the structural engineers, the total weight of glass on the project is 570,000 lbs. The curtain wall contains roughly half of that glass, so around 300,000 lbs. From take-offs obtained from the drawings, it was determined that there are a total of 936 glass panels on the curtain wall, each weighing roughly 321 lbs. Each space on the southern façade can sustain a total load of approximately 1285 lbs. From the product description, the panels I plan to use weight 112 kg, or 247 lbs. each. Multiply that by 5 panels to get a total load of 1235 lbs.

Structural Implications Analysis			
Glass Panels		**Photovoltaic Panels**	
Total Panels	936	**Total Panels**	676
Total Weight	300,000 lbs	**Total Weight**	167,000 lbs
Weight Per Panel	321 lbs	**Weight Per Panel**	247 lbs
Total load on Space (Panel Wt. x 4)	1285 lbs	**Total load on Space (Panel Wt. x 5)**	1235 lbs

*** NOTE: PHOTOVOLTAIC PANELS INFORMATION ONLY ACCOUNT FOR SOUTHERN ELEVATION. GLASS PANELS INFORMATION ACCOUNTS FOR ENTIRE CURTAIN WALL (SOUTH, EAST, and WEST ELEVATIONS)**

Figure 23:
STRUCTURAL IMPLICATIONS

From the results shown above, it was determined that replacing the current glass on the curtain wall with transparent photovoltaic glass will not have an effect of the structural integrity of the curtain wall system.

8.5.4. SYSTEM PAYBACK AND COST ANALYSIS

In order to properly determine cost and payback data of the photovoltaic system, an estimate of the PV system must first be determined. According to the U.S. Department of Energy, the average cost of a PV system in the eastern United States is roughly $7.50/Watt for this year. To determine the estimated cost of the PV system proposed, the total size of the system can be multiplied. Figure 24 below shows the estimated cost of the system.

Estimated Cost of PV System		
Size (kW)	**$/Watt**	**Total Cost**
67.6	7.50	$507,000

Figure 24:
ESTIMATED PV SYSTEM COST

8.5.4.1. STATE INCENTIVES AND REBATES

The state that the new Office Building-G is being built in offers incentives and rebates for the installation of production dealing with renewable energy. The incentives vary for commercial and residential structures. The following information applies to the new Office Building-G.

- 15% Installation Cost (up to $25,000 max.)
- $500/kWh produced rebate each year

8.5.4.2. PAYBACK PERIOD

In order to determine the payback period of the photovoltaic system, some factors have to be determined in order to calculate the period. First, from the United States Energy Information Administration, it was determined that the retail cost of electricity for this past year for the state in which the building is in was 0.1268$/kWh, with an expected increase of 1.00% each year. In order to determine the total payback period, the retail cost (while taking into account the 1.00% increase each year) will be multiplied by the projected AC energy (found in Section 8.6.1). That value will be added to the rebate value to determine the total payback for that year. The table below shows a summary of the payback period of the photovoltaic system. The cost of the system with incentives was determined to be $482,000. The 25 year savings of the system was determined to be $1,036,420 and a 25 year value of $554,420.

System Size	
Size	67.6 kW
Cost/W	$7.50
Total Cost	$507,000
Incentives	15% Installation
Total System Cost	$482,000
Savings	
Savings/Month (Year 1)	$3,381.66
25 Year Savings	**$1,036,420**
25 Year Value	**$554,420**

Figure 25:
PAYBACK PERIOD SUMMARY

The figure below shows that by the end of year 12, all of the costs for the total photovoltaic system will be recuperated.   A complete analysis of the payback period can be found in ***Appendix G.***

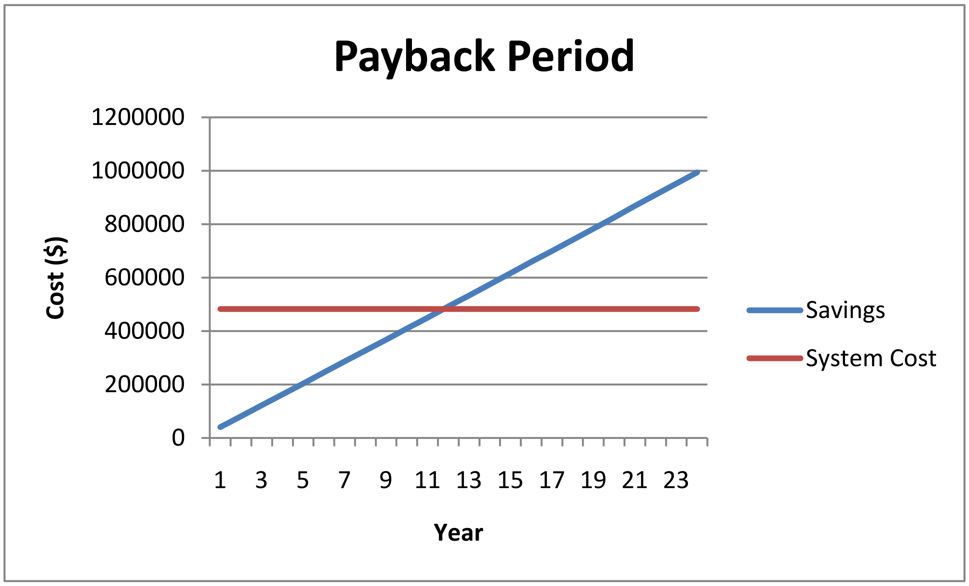


Figure 26:
PAYBACK PERIOD

8.6. ENERGY AND ELECTRIC IMPACT (ELECTRICAL BREADTH)

8.6.1. ENERGY PRODUCTION

The yearly value of energy produced by the photovoltaic system is a key aspect when determining life-cycle and paybacks costs of the PV system. It is also important to know this information when determining how to tie-in the system to the building electrical system. In order to calculate this value, the photovoltaic design and local conditions have to be used to find the estimated yearly value of energy produced. By using the PV Watts calculator at nrel.gov, a yearly value of $4,170.58 was determined. The exact location of the project was used to obtain this value, but due to owner restrictions, that information cannot be disclosed. A DC rating of 67.6 kW was determined by multiplying the total number of PV panels by 100W (power produced by each panel). Figure 27 below, shows the station identification factors use to determine the yearly energy value. Figure 28 shows the energy value for each month along with the AC energy that will be produced by the PV system.

Station Identification	
City:	NA
State:	NA
Latitude:	NA
Longitude:	NA
Elevation:	47 m
PV System Specifications	
DC Rating:	67.6 kW
DC to AC Derate Factor	0.77
AC Rating	52.1 kW
Array Type	Fixed Tilt
Array Tilt	90.0°
Array Azimuth	180.0°
Energy Specifications	
Cost of Electricity	7.8 ₵ kWh

Figure 27:
STATION IDENTIFICATION

PV Energy Watts Results			
Month	**Solar Radiation ($kWh/m^2/day$)**	**AC Energy (kWh)**	**Energy Value ($)**
1	3.46	5689	443.74
2	3.92	5798	452.24
3	3.46	5268	410.9
4	2.91	3961	308.96
5	2.56	3266	254.75
6	2.46	2821	220.04
7	2.55	3070	239.46
8	2.81	3558	277.52
9	3.25	4354	339.61
10	4.04	6103	476.03
11	3.35	5108	398.42
12	2.8	4473	348.89
Year	**3.13**	**53469**	**4170.58**

Figure 28:
PV ENERGY WATTS RESULTS

From the information in the tables above, it was determined that the photovoltaic system will produce roughly 146.5 kWh per day.

8.6.2. ELECTRICAL COMPONENTS AND SYSTEM TIE-IN

One of the most important details when installing a photovoltaic system is the tie-in to the main building system. After talking with Turner consultants, it was determined that there are two ways of going about this. One way is to tie-in the PV system via a load-side tap on the main breaker panel. One factor that needs to be taken into account with this tie-in strategy is the load capacity of the main bus.

I decided to go with the second approach discussed with the Turner consultants. The method I choose is to tie-in the PV system to the main building electrical system via a supply-side interconnection. The connection deals with a meter box that combines power supplies from the PV system and transformer. The supply-side interconnection requires six electrical components in order to connect the PV system to the existing building electrical system. The components include DC and AC wire run and disconnects, an inverter to convert DC power to AC power, and a service-tap meter box that combines the PV power with the utility power feed. The figure below depicts the supply-side interconnection.

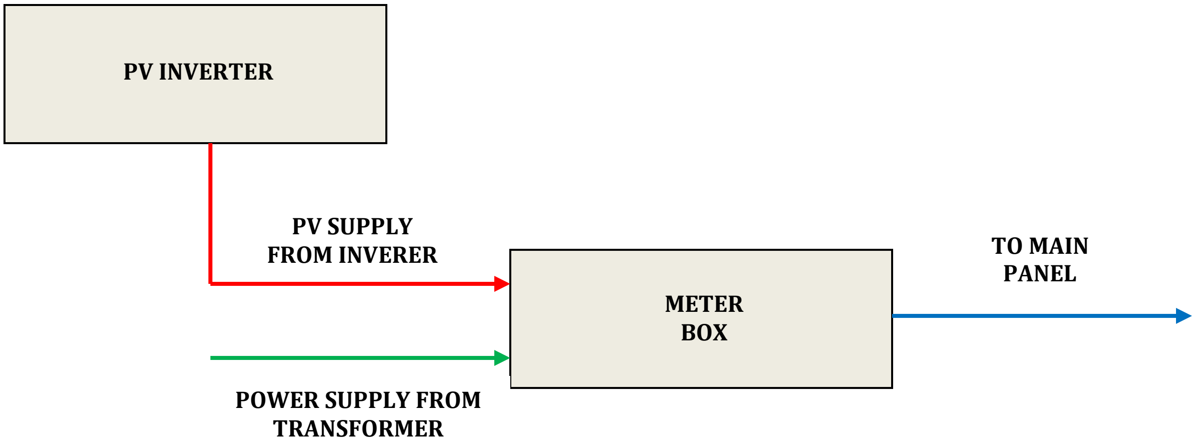


Figure 29:
SUPPLY-SIDE INTERCONNECTION

Since DC wire is more expensive than AC wire, the intent is to try to use the least amount of DC wire as possible. Since the main electrical room is on the top floor of the parking garage, that is where the PV system will be tied into the main building system. The figure below shows the DC wire run from each set of 5 panels to a long run DC wire down the southwest corner of the building. The wire will be concealed by the aluminum panel of the curtain wall.

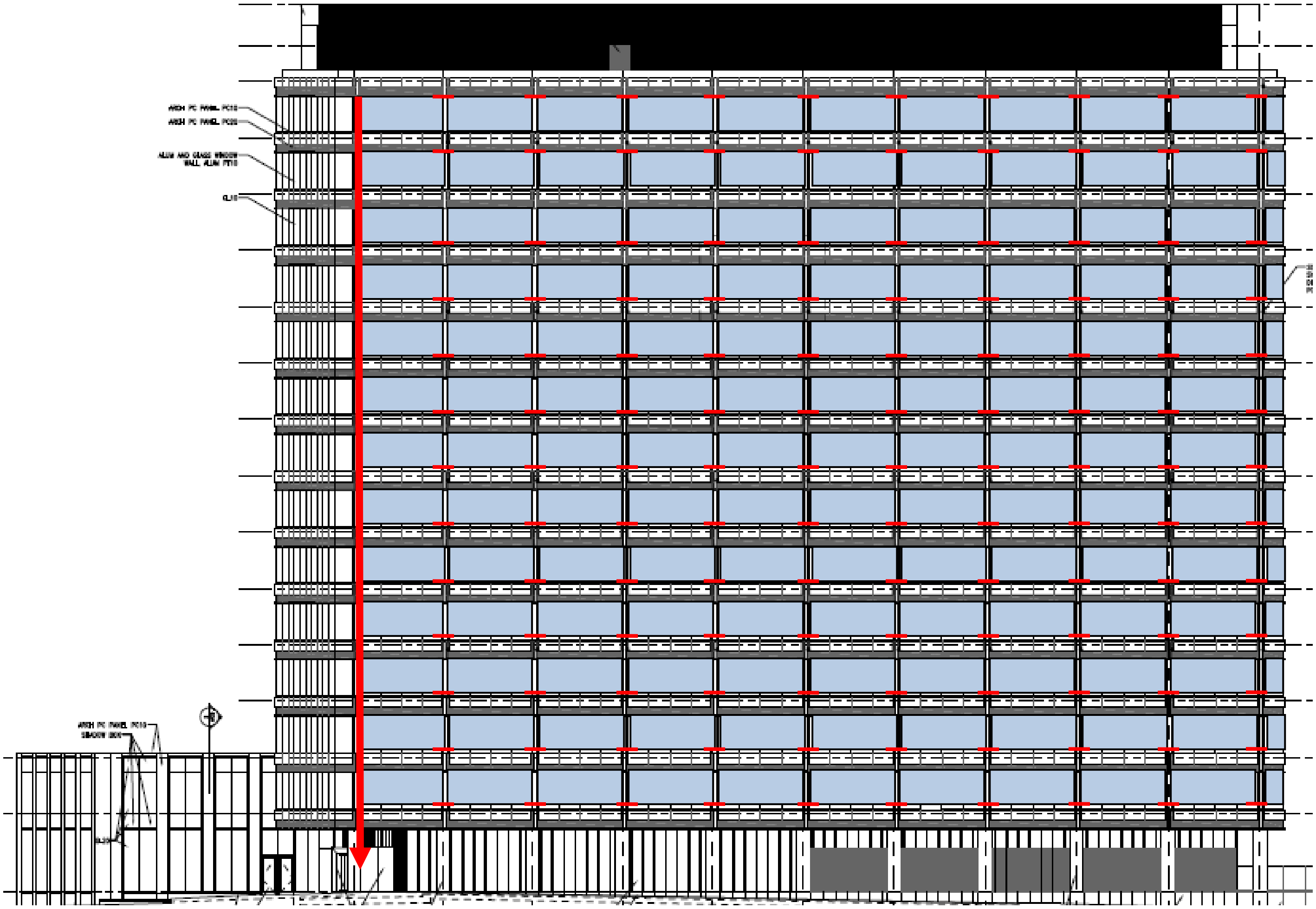


Figure 30:
DC WIRE RUN

The inverters chosen must be able to hold a PV power rating of 67.6 kW, the size of the proposed PV system. After looking at different suppliers, the selected inverter comes from PV Powered. There PVP75kW inverter can hold a maximum power of 75kW and comes with all the required AC and DC disconnects needed for the supply side connection. The inverter will be located in the electrical room on the first floor of the building. Please refer to ***Appendix H*** for complete inverter product details. Also, the transformer that will be tied into the system in located on the first floor. From the inverter in the electrical room on the first floor, AC wire and transformer wire will run to the main electrical room on the top floor of the parking garage (directly below first floor) where the meter box will be located. The size and weight of the inverters will not be an issue in the electrical room. This proposed design is the most efficient way to use the least amount of DC wire. The more DC wire used, the greater the amount of cost and possibility of a large amount of voltage drop.

8.7. CONCLUSION

Section 8 of the report discusses the proposed PV system to be implemented on the southern façade of the curtain wall. The location was chosen because the southern side will receive the most sunlight, therefore it will be the best location to produce the maximum amount of PV power. Section 8.5.1. discusses the transparent solar panels from Centennial Solar that will be implemented into the design. The panels will be grouped in sets of five with ten sets of five panels on each floor. The total amount of panels to be installed will be 676. Section 8.5.3. shows that no structural changes will be needed on the curtain wall system. The system cost was determined to be $507,000. After looking at state incentives and rebates, the payback period for the PV system was calculated to be 12 years with a 25 year value of $554,420. Section 8.6 shows an estimated yearly energy value of $4,170.58 and an annual energy production of 53,468 kwh. The best way to tie-in the PV system is by means of a supply-side interconnection where a sized inverter will turn DC energy into AC energy that can be tied into the existing building system.

9. ANALYSIS #3: *MATERIAL DELIVERY DETAILS DURING PEAK TRAFFIC HOURS*

9.1. BACKGROUND

The new Office Building-G is located between the heavily used metro station and parking garage where metro users park. The pedestrians that walk past the project site and must cross the construction entrance of the site in order to reach the metro station. During the morning commute hours and afternoon commute hours, pedestrian traffic will be at its highest along the project site. With material deliveries being made daily, it is important that the majority of these deliveries be made when pedestrian traffic is not high.

9.2. PROBLEM/GOAL

The goal of this analysis will be to perform an in-depth scheduling and material delivery analysis. Looking at the metro pedestrian traffic timetable and being able to research the amount of materials needed to be delivered for a particular week will show the amount of production management and schedule considerations needed to successfully keep the project on schedule.

9.3. RESEARCH STEPS

- Interview Turner Project team on re-sequencing
- Contact metro officials
- Determine highest pedestrian traffic timetable
- Determine materials needed on site for a particular work week
- Develop material delivery schedule in accordance with the metro pedestrian traffic flow

9.4. EXPECTED OUTCOME

Through analysis and research, it is expected that the material delivery schedule will be congested into a timeframe where major deliveries will be made within the time window where pedestrian traffic is at its lowest. It is believed that from this analysis, a delivery schedule will be produced that will concentrate deliveries within the safest timeframe to limit any accidents that can occur during peak pedestrian traffic hours.

9.5. ANALYSIS

9.5.1. PEDESTRIAN TRAFFIC INFORMATION

The first part of this analysis is to research the daily pedestrian traffic flow of metro rail users. From information obtained from the metro station and its officials, the total amount of metro users per year is roughly 1.36 million people. That equates out to approximately 11,335 people per month and about 3,700 people per day. The figures below show the adjacent metro station in relation to the building footprint. Also pictured is the path the pedestrians take to the metro station.

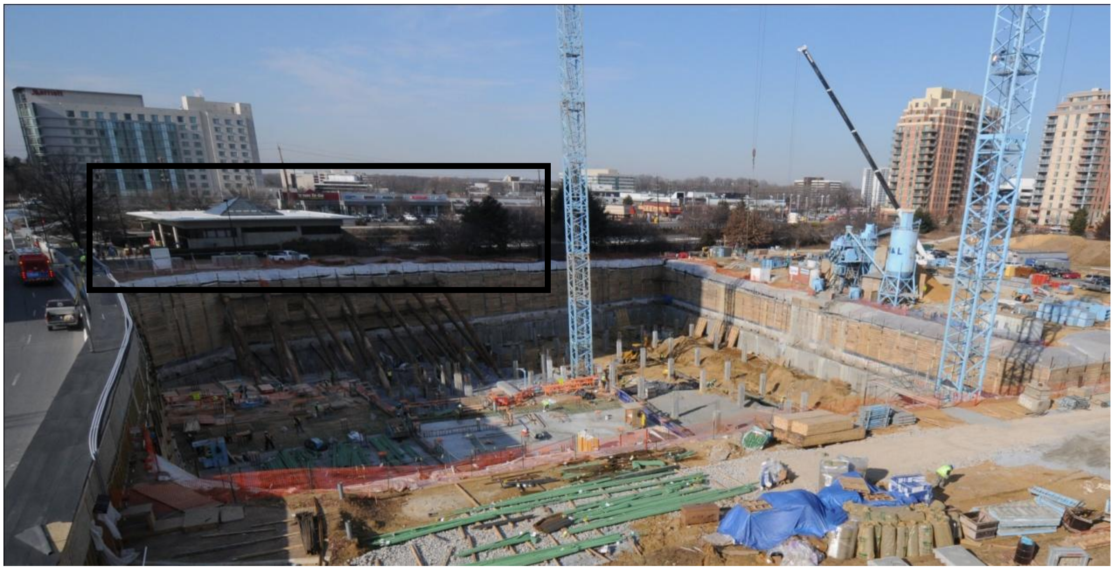


Figure 31:
METRO STATION

Figure 32:
LOOKING WEST (COVERED WALKWAY)

Figure 33:
LOOKING EAST (COVERED WALKWAY)

For the purposes of this analysis, the amount of people per day will be analyzed. The highest amount of pedestrian traffic was determined to be between three periods throughout the day, between 6am and 9am, 11am and 1pm, and finally between 4pm and 6pm. The reason for these periods being the highest traffic volume is due to the fact that most metro users use the metro rail to commute to and from work. Also, during the middle of the day (11am-1pm) the traffic volume increases slightly, but not as high as during the morning and afternoon commuting hours. The figure below shows a graphical representation of pedestrian traffic flow around the project site. The graph data is only estimates and not exact values.

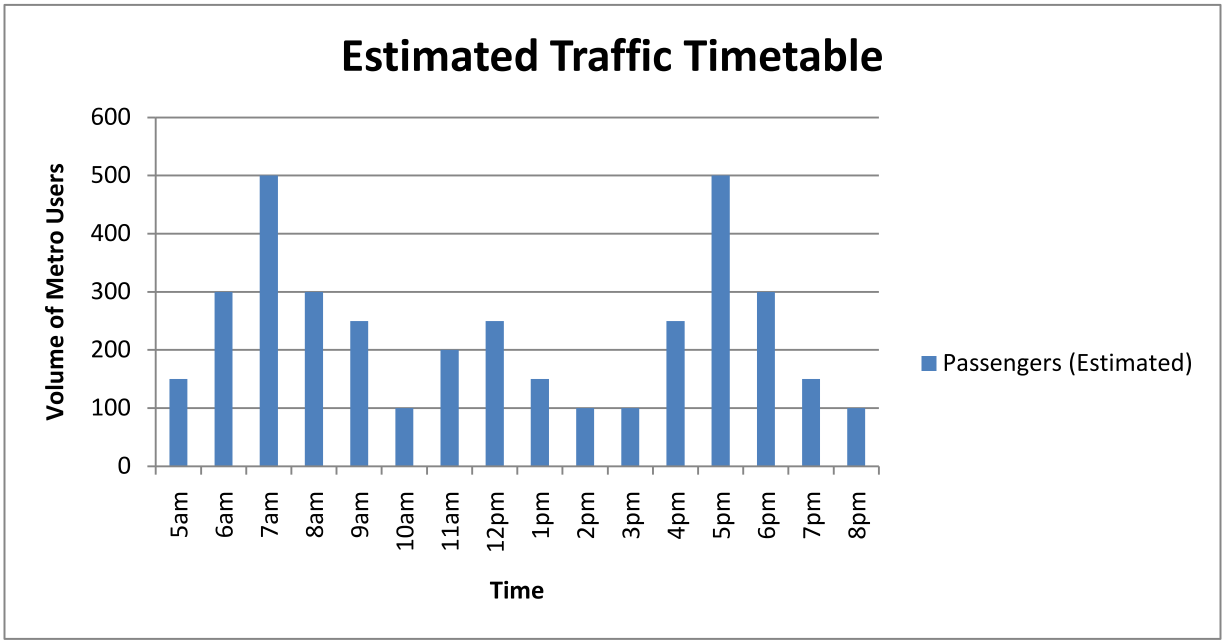


Figure 34:
PEDESTRIAN TRAFFIC TIMETABLE

From the graph above, it can be determined that the best material delivery times during the day are between 9am and 11am, and also between 1pm and 4pm. These time periods show the least amount of pedestrian traffic, thus being the best time for materials to be delivered. Since the normal workday for Turner Construction ranges from 7am to 5pm due to noise ordinances in the area, those two time periods would result in the safest time periods for materials to be delivered onto the site. Turner also works weekends from 8am to 3pm, but we assume that deliveries will only be made during the week.

9.5.2. MATERIAL DELIVERY ANALYSIS

In order to produce a material delivery schedule, a typical work week must be looked at. During the week of September 12, 2011 - September 16, 2011, 11 different trades are scheduled to be in progress on each floor. In order for these trades to run smoothly, the materials needed for each must be present on site and in the correct area. In order to produce a delivery schedule, the amount of time it takes to deliver and set each material on site must be determined. In order to determine the time, the number of truckloads, pallets per truckload, and time to unload each pallet needs to be calculated. An example would be the metal stud framing on floor 7. Floor 7 has 300 LF of framing, same goes for each floor of the building. To find the amount of studs that will be needed per floor, I refered to RS Means to determine the amount of studs that a typical crew can assemble in one day. That

was found to be roughly 54 LF per day. For this project, the crew will assemble 60 LF per day. Now that the LF per day is known, it can be determined that that is equivalent to 40 vertical studs and 10 horizontal studs, or 50 total. It was assumed that in a truckload there are 50 studs per pallet. Knowing that information, it was determined that it will take one truckload to deliver the 5 pallets of studs for the framing. Assuming that it will take 15 minutes to unload the frames and set them in the area where the workers can get to them easily, that equates to a total delivery time of 1 hour and 50 minutes. Figure 35 shows a summary of the information above.

Floor 7: Wall Framing - Summary				
Total Framing (LF)	**RS Means**	**Material Per Day**	**Total Studs Per Floor**	**Studs Per Pallet**
300 LF	2 workers - 54 LF per day	50 studs	250	50

Figure 35:
FLOOR 7 MATERIAL SUMMARY

The same method can be used for each trade. The summary of the total truckloads, pallets per truck, unloading time per pallet, and total unloading time for each trade shown below are estimates and not exact. A total delivery time for all material for all trades during the week of September 12, 2001 to September 16, 2011 equated to **27 hours and 10 minutes**. A schedule will be developed for the previous week that will show when each trades materials will be delivered.

Material Delivery Details (Week of 9/12/11 - 9/16/11)					
Floor	**Trade**	**# of Truckloads of Material**	**Pallets Per Truck**	**Unloading Time Per Pallet**	**Total Time to Place Material in Area**
2	**Drywall**	2	10	10 min	3 hours 20 minutes
3	**MEP Wall Close-In**	1	5	10 min	50 minutes
4	**Elect. Rough-In**	1	5	10 min	50 minutes
5	**Plumbing Rough-In**	1	5	10 min	50 minutes
6	**Mech. Rough -In**	2	5	12 min	2 hours
7	**Wall Framing**	1	5	10 min	50 minutes
8	**Door Frames**	1	5	15 min	1 hour 50 minutes

9	**None**	NA	NA	NA	NA
10	**None**	NA	NA	NA	NA
11	**Sprinkler Distribution**	1	5	10 min	50 minutes
12	**Elect. Distribution**	1	5	10 min	50 minutes
13	**Duct Distribution**	5	8	15 min	10 hours
14	**MEP Risers**	1	5	10 min	50 minutes
	TRASH	2	NA	5 min	10 minutes
				Total Time to Unload Materials	**27 hours 10 minutes**

Figure 36:
MATERIAL DELIVERY DETAILS

9.5.3. ANALYSIS OF PROPOSED MATERIAL DELIVERY SCHEDULE

From the information compiled above, a material delivery schedule was generated for the week prior to September 12, 2001 to September 16, 2011. Each day, three to four trucks will be on site delivering materials for each trade that will be needed for the following week. The figure below shows the proposed days each trade material will be delivered along with the expected time of arrival and time of departure. The length of time each truck will be on site was determined from the information in figure 36 in the previous section. While this schedule is an example, actual material delivery schedules must take into account the time production companies can deliver each trade material. That factor alone can greatly affect the material delivery schedule. While that factor was not taken into account in the schedule below, it was accounted for when researching this analysis.

Material Delivery Schedule (Week of 9/5/11 - 9/9/11)			
Day	**Trade Materials Delivered**	**Time Arrival**	**Time Departure**
Monday (9/5)	MEP Wall Close-In	Truck 1 - 9:00:00 AM	Truck 1 - 9:50:00 AM
Monday (9/5)	Elect. Rough-In	Truck 1 - 10:00:00 AM	Truck 1 - 10:50:00 AM
Monday (9/5)	Plumbing Rough-In	Truck 1 - 2:00:00 PM	Truck 1 - 2:50:00 PM
Tuesday (9/6)	Wall Framing	Truck 1 - 9:00:00 AM	Truck 1 - 9:50:00 AM
Tuesday (9/6)	Sprinkler Distribution	Truck 1 - 10:00:00 AM	Truck 1 - 10:50:00 AM
Tuesday (9/6)	Elect. Distribution	Truck 1 - 2:00:00 PM	Truck 1 - 2:50:00 PM
Tuesday (9/6)	MEP Risers	Truck 1 - 3:00:00 PM	Truck 1 - 3:50:00 PM
Tuesday (9/6)	Trash	Truck 1 - 4:00:00 PM	Truck 2 - 4:05:00 PM
Wednesday (9/7)	Duct Distribution	Truck 1 - 9:00:00 AM	Truck 1 - 11:00:00 AM

Wednesday (9/7)	Duct Distribution	Truck 2 - 11:00:00 AM	Truck 2 - 1:00:00 PM
Wednesday (9/7)	Duct Distribution	Truck 3 - 1:00:00 PM	Truck 3 - 3:00:00 PM
Wednesday (9/7)	Duct Distribution	Truck 4 - 3:00:00 PM	Truck 4 - 5:00:00 PM
Thursday (9/8)	Duct Distribution	Truck 5 - 9:00:00 AM	Truck 5 - 11:00:00 AM
Thursday (9/8)	Door Frames	Truck 1 - 1:00:00 PM	Truck 1 - 2:50:00 PM
Thursday (9/8)	Mech. Rough -In	Truck 1 - 3:00:00 PM	Truck 1 - 4:00:00 PM
Friday (9/9)	Mech. Rough -In	Truck 2 - 9:00:00 AM	Truck 2 - 10:00:00 AM
Friday (9/9)	Drywall	Truck 1 - 10:00:00 AM	Truck 1 - 11:40:00 AM
Friday (9/9)	Drywall	Truck 2 - 2:00:00 PM	Truck 2 - 3:40:00 PM
Friday (9/9)	Trash	Truck 2 - 4:00:00 PM	Truck 2 - 4:05:00 PM

Figure 37:
PROPOSED MATERIAL DELIVERY SCHEDULE

Trucks will be entering the site from the north entrance and exiting through the north entrance as well. Originally I thought the site entrance on the south side would be utilized as well. However, after talking to Turner Consultants, I learned that that entrance would be used for emergencies only and that they did not want to use that entrance for material deliveries. Refer to ***Appendix D*** for the site layout plan.

9.6. CONCLUSION

Based on information in section 9.4.1. of this report, the safest hours for material deliveries to the project site are between the hours of 9am and 11am, and also between 1pm and 4pm. These are the periods in which there is the least amount of pedestrian traffic around the project site. Section 9.4.2. discusses strategies to determine the total time a truckload of a certain trade material takes to get delivered. The total estimated time it will take to deliver all the materials needed for the week of September 12, 2011 to September 16, 2011 is 27 hours and 10 minutes. Finally, section 9.4.3. shows the proposed material delivery schedule during the week of September 5, 2001 to September 9, 2011. Each day is scheduled to have 3 or 4 truckloads of material delivered.

10. CONCLUSIONS

During the past two semesters, the new Office Building-G project has been evaluated and analyzed to in order to enhance and make the project more efficient. This final report is a compilation of research and analysis for the three main topics of discussion: the use of a tieback system for the entire excavation support system, the implementation of transparent photovoltaic panels into the southern façade of the curtain wall system, and a detailed analysis of the material delivery schedule for the project. The findings are not exact and do not represent any mistakes made by the project team. The previous analyses are theoretical and performed for the purposes of the senior thesis project.

The critical industry issue, and first analysis examined was the use of a tieback system for the entire excavation system. Currently, a raker system is used on the metro's side of the building footprint. This analysis studies both tieback excavation systems and raker excavation systems, both being adequate means of excavation support for many different types of projects. Through the analysis, it was determined that there can be a significant savings of $177,450 if the raker system was not used and the tieback system was the only excavation system. Also, by using only the tieback system, there can be a schedule savings of approximately 11 working days or roughly 90 working hours. After studying the soil characteristics of the project site, if the tieback system were to be implemented on the metro rail's side, a maximum load of 1,564 psf will need to be supported by the tieback system. Upon further review of the metro's adjacent design and construction manual, the metro does not allow any other types of excavation support other than raker excavation support. While it would be recommended to replace the raker system with the tieback system, due to the design manual that cannot occur.

The second analysis discusses the proposed PV system to be implemented on the southern façade of the curtain wall. The location was chosen because the southern side will receive the most sunlight, therefore it will be the best location to produce the maximum amount of PV power. The proposed transparent PV panels to be used are from Centennial Solar. The panels will be grouped in sets of five with ten sets of five panels on each floor. The total amount of panels to be installed will be 676. After looking at the structural implications of the proposed PV panels, it was determined that no structural changes will need to be made to the curtain wall system. The system cost was determined to be $507,000. After looking at state incentives and rebates, the payback period for the PV system was calculated to be 12 years with a 25 year value of $554,420. An estimated yearly energy value of $4,170.58 and an annual energy production of 53,468 kwh was determined for the system. The best way to tie-in the PV system is by means of a supply-side interconnection where a sized inverter will turn DC energy into AC energy that can be tied into the existing building system.

The final analysis deals with the material delivery schedule for the project. Since the site is located between the metro station and the metro's parking garage, pedestrian traffic flow must be analyzed in order to determine the safest hours for material deliveries. From this analysis, it was determined that the safest hours for material deliveries to the project site are between the hours of 9am and 11am, and also between 1pm and 4pm. These are the

periods in which there is the least amount of pedestrian traffic around the project site. Also discussed in this section were the strategies that were used to determine the total time a truckload of a certain trade material takes to get delivered. The total estimated time it will take to deliver all the materials needed for the week of September 12, 2011 to September 16, 2011 is 27 hours and 10 minutes. Since materials for this particular week will need to be on site at the beginning of the week, a proposed material delivery schedule was developed for the week of September 5, 2001 to September 9, 2011. Each day is scheduled to have 3 or 4 truckloads of material delivered.

Overall, each analysis provides information on design and construction techniques. By using only a tieback excavation system, that can save the project money and also accelerate the schedule. The implementation of the photovoltaic system on the curtain wall shows that renewable energy can be efficient and financially feasible for the owner. The material delivery schedule depicts timing and coordination efforts that need to be taking in order to provide safety to pedestrians around the project site. Each of the analyses discussed shows that there can be improvements made on the new Office Building-G project and in the construction industry.

11. RESOURCES

- Centennial Solar. (2011). *Solar Panel Products.* Retrieved February 23, 2011, from Centennial Solar: http://www.centennialsolar.com/index.php?option=com_content&view=article&id=57&Itemid=41&lang=en

- Flores, Carlos. Turner Construction. (D. Coassolo, Interviewer)

- Microsoft Office Suites 2007.

- Nemati, Kamran M. University of Washington. Temporary Structures. Retrieved on February 12, 2011: http://courses.washington.edu/cm420/Lesson5.pdf

- PV Powered. (2011). Inverters. Retrieved March 3, 2011, from PV Powered: http://renewables.advanced-energy.com/en/PVP75kW.html

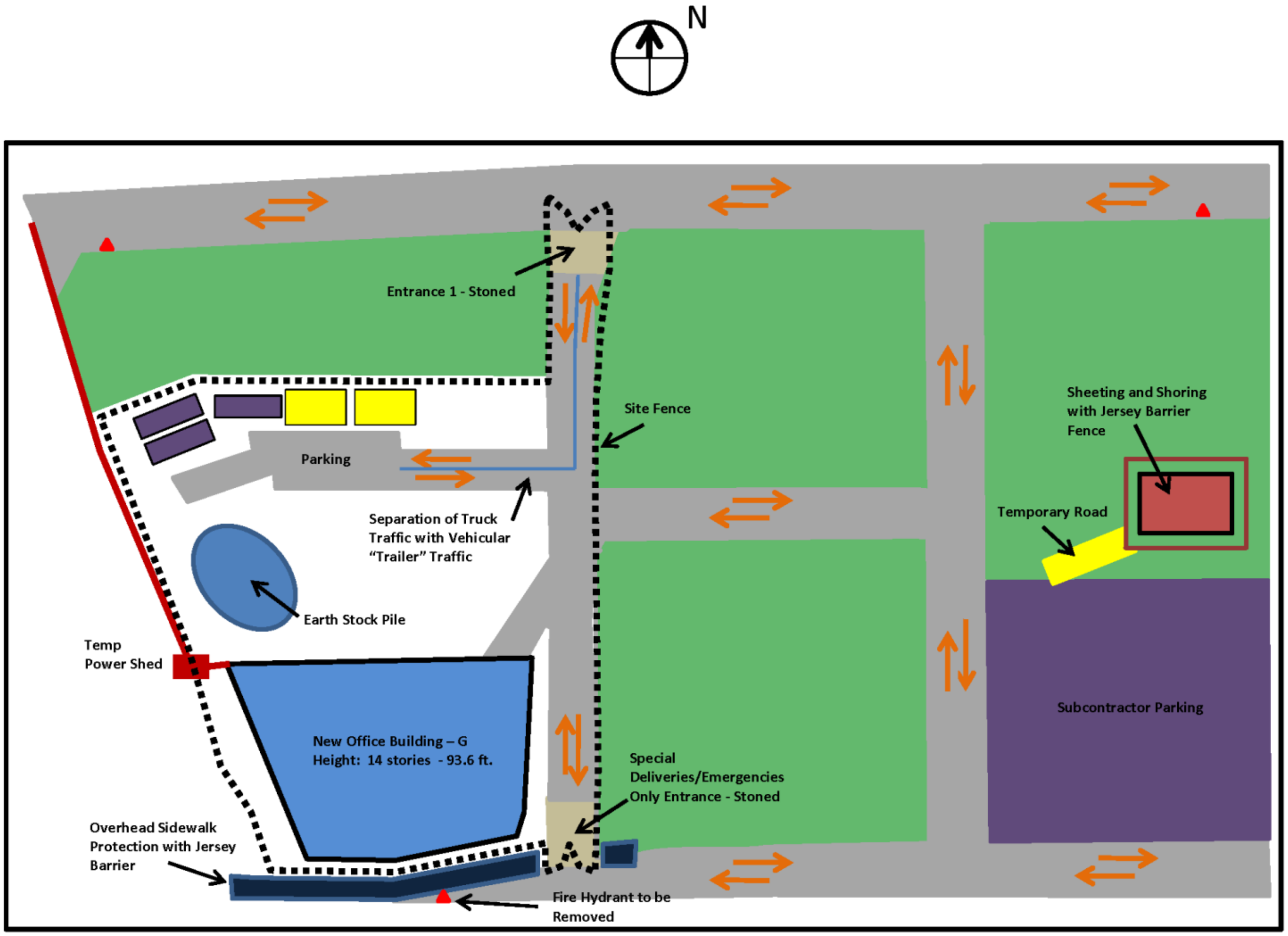
- PV Watts Calculator. (2011). Retrieved March 6, 2011, from National Renewable Energy Laboratory: http://www.nrel.gov/rredc/pvwatts/version1.html

- Short, Jordan. Turner Construction. (D. Coassolo, Interviewer)

- U.S. Department of Energy. (January 2011). *Solar Technologies Report*. NREL.

- WordPress. (2011). Electricity Price Comparison. Retrieved March 3, 2011, from Average Utility Costs by State: http://www.electricitypricecomparison.org/

APPENDIX A: EXISTING CONDITIONS SITE PLAN



LEGEND:

- ▲ Fire Hydrant
- 🟨 Turner Office Trailers
- 🟪 Subcontractor Office Trailers
- ⇄ Indicates 2-Way Traffic
- ━ Main Utility Lines into Power Shed

NOTE:
Overhead Sidewalk Protection for Pedestrian Traffic

Office Building–G

Eastern USA

Existing Conditions Site Plan

Dominic Coassolo Construction Management

APPENDIX B: GENERAL CONDITIONS ESTIMATE

PERSONNEL				
Description	**Unit Rate**	**Unit**	**Quantity**	**Cost**
Project Manager	$ 2,000.00	WEEK	100	$ 200,000.00
Senior Superintendents	$ 7,550.00	WEEK	100	$ 755,000.00
Project Engineers	$ 10,000.00	WEEK	100	$ 1,000,000.00
Safety Managers	$ 2,171.25	WEEK	80	$ 173,700.00
Purchasing	$ 5,600.00	WEEK	20	$ 112,000.00
Project Estimator	$ 1,666.67	WEEK	30	$ 50,000.00
Project Accountant	$ 8,385.00	WEEK	20	$ 167,700.00
Project Management (VP and Senior Project Manager)	$ 1,380.00	WEEK	25	$ 34,500.00
			TOTAL	**$ 2,492,900.00**

FACILITIES AND EQUIPMENT				
Description	**Unit Rate**	**Unit**	**Quantity**	**Cost**
Office Trailer Installation	$ 7,500.00	LS	1	$ 7,500.00
Office Trailer Rental	$ 1,740.00	MONTH	25	$ 43,500.00
Office Trailer Removal	$ 7,500.00	LS	1	$ 7,500.00
Telephone/Fax Service	$ 20.00	LS	3500	$ 70,000.00
Technology Fee	$ 20.00	LS	1550	$ 31,000.00
Computer Fee	$ 2,400.00	MONTH	25	$ 60,000.00
Office Supplies	$ 800.00	MONTH	25	$ 20,000.00
Office Printer/Copier	$ 1,600.00	MONTH	25	$ 40,000.00
			TOTAL	**$ 279,500.00**

TEMPORARY UTILITIES				
Description	**Unit Rate**	**Unit**	**Quantity**	**Cost**
Temporary Power Installation	$ 1,000.00	LS	1	$ 1,000.00
Temporary Lighting and Power	$ 7,800.00	MONTH	25	$ 195,000.00
Toilet Installation/Removal	$ 10,000.00	LS	1	$ 10,000.00
Temporary Plumbing	$ 2,000.00	LS	17.5	$ 35,000.00
Temporary Toilets	$ 228.00	MONTH	22	$ 5,000.00
Potable Water	$ 500.00	MONTH	24	$ 12,000.00
			TOTAL	**$ 258,000.00**

MISCELLANEOUS COSTS				
Description	**Unit Rate**	**Unit**	**Quantity**	**Cost**
Taxes/Insurance	$ 1,000,000.00	LS	1	$ 1,000,000.00
Travel Expenses	$ 4,000.00	MONTH	5.25	$ 21,000.00
Misc. General Expenses	$ 1,000.00	MONTH	24	$ 24,000.00
Postage/Mail Service	$ 456.00	MONTH	25	$ 11,400.00
Progress Photos	$ 400.00	MONTH	25	$ 10,000.00
Record Retention	$ 14,000.00	LS	1	$ 14,000.00
Office Cleaning	$ 500.00	WEEK	80	$ 40,000.00
Tools and Supplies	$ 880.00	MONTH	25	$ 22,000.00
Documents/Blueprints	$ 30,000.00	LS	1	$ 30,000.00
			TOTAL	**$ 1,172,400.00**

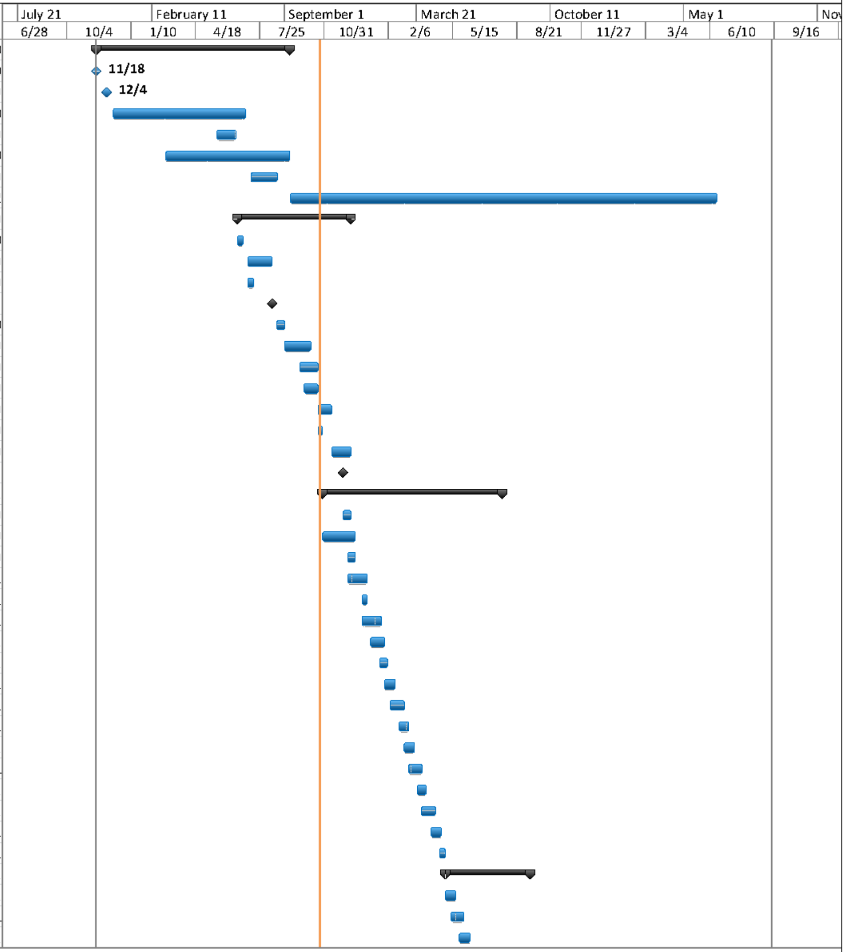
GENERAL CONDITIONS SUMMARY				
Description	**Unit Rate**	**Unit**	**Quantity**	**Cost**
Personnel	$ 24,929.00	WEEK	100	$ 2,492,900.00
Facilities and Equipment	$ 2,795.00	WEEK	100	$ 279,500.00
Temporary Utilities	$ 2,580.00	WEEK	100	$ 258,000.00
Miscellaneous Equipment	$ 11,724.00	WEEK	100	$ 1,172,400.00
			TOTAL	**$ 4,202,800.00**

APPENDIX C: DETAILED PROJECT SCHEDULE

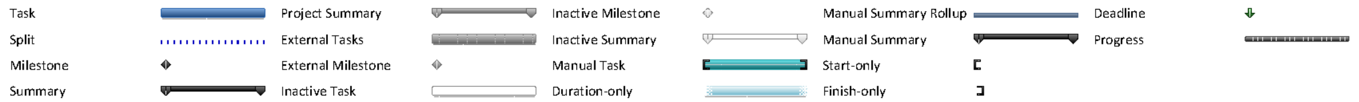
Dominic Coassolo
Construction Management
Dr. Robert Leicht

Office Building - G
Eastern United States
Detailed Project Schedule

ID	Task Name	Duration	Start	Finish
1	**PRE-CONSTRUCTION/PROCUREMENT**	211 days	Wed 11/18/09	Wed 9/8/10
2	**Start of Project**	0 days	Wed 11/18/09	Wed 11/18/09
3	**Project Awarded to Turner**	0 days	Fri 12/4/09	Fri 12/4/09
4	Design and Procurement	146 days	Mon 12/14/09	Sat 7/3/10
5	GMP Development	21 days	Fri 5/21/10	Fri 6/18/10
6	Garage Building Permits Submission/Approval	135 days	Thu 3/4/10	Wed 9/8/10
7	Temporary Electric Service	30 days	Mon 7/12/10	Fri 8/20/10
8	Construction Trailers	464 days	Fri 9/10/10	Wed 6/20/12
9	**EARTHWORK AND EXCAVATION**	125 days	Mon 6/21/10	Fri 12/10/10
10	Survey Computations	7 days	Mon 6/21/10	Tue 6/29/10
11	Install Sediment Control Devices	27 days	Wed 7/7/10	Thu 8/12/10
12	Install Construction Safety/Site Fencing	7 days	Wed 7/7/10	Thu 7/15/10
13	Begin Clearing Site		Fri 8/13/10	
14	Drill Piles - West	8 days	Fri 8/20/10	Tue 8/31/10
15	Drill Piles - South	29 days	Wed 9/1/10	Sun 10/10/10
16	Drill Piles - North	20 days	Fri 9/24/10	Thu 10/21/10
17	Excavate and Lag 1st to 2nd Tier	15 days	Fri 10/1/10	Thu 10/21/10
18	Excavate and Lag 2nd to 3rd Tier	15 days	Fri 10/22/10	Thu 11/11/10
19	Drill Holes for Shuttle Elevators	5 days	Fri 10/22/10	Thu 10/28/10
20	Excavate and Lag 3rd to 4th Tier	21 days	Fri 11/12/10	Fri 12/10/10
21	Commence Foundations		Mon 11/29/10	
22	**UNDERGROUND GARAGE**	196 days	Fri 10/29/10	Fri 7/29/11
23	Elevator Pits and Spread Footings	10 days	Mon 11/29/10	Fri 12/10/10
24	FDN Wall Footings	36 days	Fri 10/29/10	Fri 12/17/10
25	Tower Crane Foundations	10 days	Mon 12/6/10	Fri 12/17/10
26	FDN Walls and Columns to B3	22 days	Mon 12/6/10	Tue 1/4/11
27	Erect Cranes	6 days	Tue 12/28/10	Tue 1/4/11
28	Slab on Grade	22 days	Tue 12/28/10	Wed 1/26/11
29	Frame B3 Slab	16 days	Mon 1/10/11	Mon 1/31/11
30	Place B3 Slab	10 days	Mon 1/24/11	Fri 2/4/11
31	FDN Walls and Columsn to B2	13 days	Mon 1/31/11	Wed 2/16/11
32	Frame Slab B2	16 days	Wed 2/9/11	Wed 3/2/11
33	Place B2 Slab	10 days	Wed 2/23/11	Tue 3/8/11
34	FDN Walls and Columns to B1	12 days	Wed 3/2/11	Thu 3/17/11
35	Frame Slab B1	15 days	Wed 3/9/11	Tue 3/29/11
36	Place SB1 Slab	10 days	Tue 3/22/11	Mon 4/4/11
37	FDN Walls and Columns to Ground Level	15 days	Tue 3/29/11	Mon 4/18/11
38	Frame Slab Ground Level	12 days	Tue 4/12/11	Wed 4/27/11
39	Place Ground Level Slab	7 days	Mon 4/25/11	Tue 5/3/11
40	**CORE BUILDING STRUCTURE**	93 days	Wed 5/4/11	Fri 9/9/11
41	Frame, Place and Strip Level 2 Concrete	12 days	Wed 5/4/11	Thu 5/19/11
42	Frame, Place and Strip Level 3 Concrete	13 days	Fri 5/13/11	Tue 5/31/11
43	Frame, Place and Strip Level 4 Concrete	13 days	Wed 5/25/11	Fri 6/10/11



Project: Office Building - G
Technical Assignment Two

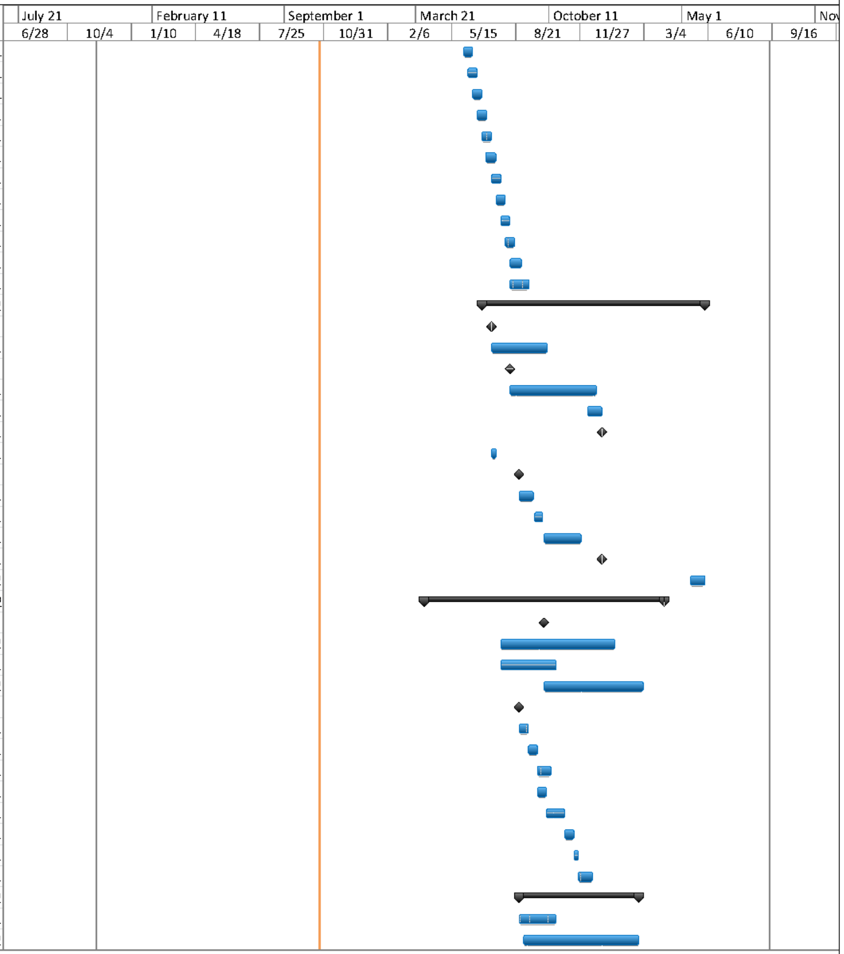


1

Dominic Coassolo
Construction Management
Dr. Robert Leicht

Office Building - G
Eastern United States
Detailed Project Schedule

ID	Task Name	Duration	Start	Finish
44	Frame, Place and Strip Level 5 Concrete	10 days	Thu 6/2/11	Wed 6/15/11
45	Frame, Place and Strip Level 6 Concrete	10 days	Thu 6/9/11	Wed 6/22/11
46	Frame, Place and Strip Level 7 Concrete	10 days	Thu 6/16/11	Wed 6/29/11
47	Frame, Place and Strip Level 8 Concrete	11 days	Thu 6/23/11	Thu 7/7/11
48	Frame, P lace and Strip Level 9 Concrete	11 days	Thu 6/30/11	Thu 7/14/11
49	Frame, Place and Strip Level 10 Concrete	12 days	Wed 7/6/11	Thu 7/21/11
50	Frame, Place and Strip Level 11 Concrete	10 days	Fri 7/15/11	Thu 7/28/11
51	Frame, Place and Strip Level 12 Concrete	10 days	Fri 7/22/11	Thu 8/4/11
52	Frame, Place and Strip Level 13 Concrete	10 days	Fri 7/29/11	Thu 8/11/11
53	Frame, Place and Strip Level 14 Concrete	10 days	Fri 8/5/11	Thu 8/18/11
54	Penthouse Columns and Slabs	12 days	Fri 8/12/11	Mon 8/29/11
55	Cure/Strip/Clean	21 days	Fri 8/12/11	Fri 9/9/11
56	**FAÇADE AND ROOF**	243 days	Thu 6/30/11	Mon 6/4/12
57	**Commence Façade**		Fri 7/15/11	
58	Precast Installation	61 days	Fri 7/15/11	Fri 10/7/11
59	Commence Glass/Glazing		Fri 8/12/11	
60	Punch and Strip Window Installation	95 days	Fri 8/12/11	Thu 12/22/11
61	Panels, Caulk, and Trim Out	16 days	Fri 12/9/11	Fri 12/30/11
62	**Façade Complete**			Fri 12/30/11
63	Install Temporary Roof	5 days	Fri 7/15/11	Thu 7/21/11
64	**Commence Roof**		Fri 8/26/11	
65	Install Lower Roof	16 days	Fri 8/26/11	Fri 9/16/11
66	Install EMR Roof	10 days	Mon 9/19/11	Fri 9/30/11
67	Install PH Roof	41 days	Mon 10/3/11	on 11/28/11
68	Building Dry In			Fri 12/30/11
69	Install Green Roof	16 days	Mon 5/14/12	Mon 6/4/12
70	**INTERIOR CORE CONSTRUCTION**	263 days	Sun 4/3/11	Tue 4/3/12
71	Commence Elevator Work		Mon 10/3/11	
72	Install Core Elevators	125 days	Fri 7/29/11	Thu 1/19/12
73	Install Shuttle Elevators	61 days	Fri 7/29/11	Fri 10/21/11
74	Install Freight Elevators	110 days	Mon 10/3/11	Fri 3/2/12
75	**Commence Penthouse**		Fri 8/26/11	
76	Set Penthouse Pads and Framing	10 days	Fri 8/26/11	Thu 9/8/11
77	Set Penthouse Mechanical Equipment	10 days	Fri 9/9/11	Thu 9/22/11
78	Build Penthouse Walls	15 days	Fri 9/23/11	Thu 10/13/11
79	Rough-In Penthouse Ductwork	10 days	Fri 9/23/11	Thu 10/6/11
80	Rough-In Penthouse Mechanical Work	20 days	Fri 10/7/11	Thu 11/3/11
81	Rough-In Penthouse Electrical Work	10 days	Fri 11/4/11	Thu 11/17/11
82	Install Sprinklers	5 days	Fri 11/18/11	Thu 11/24/11
83	Penthouse Finishes	15 days	Fri 11/25/11	Thu 12/15/11
84	**BUILDING CORE FITOUTS**	131 days	Fri 8/26/11	Fri 2/24/12
85	Finish to Frame Garage Level	41 days	Fri 8/26/11	Fri 10/21/11
86	Finish to Frame Main Level	126 days	Fri 9/2/11	Fri 2/24/12



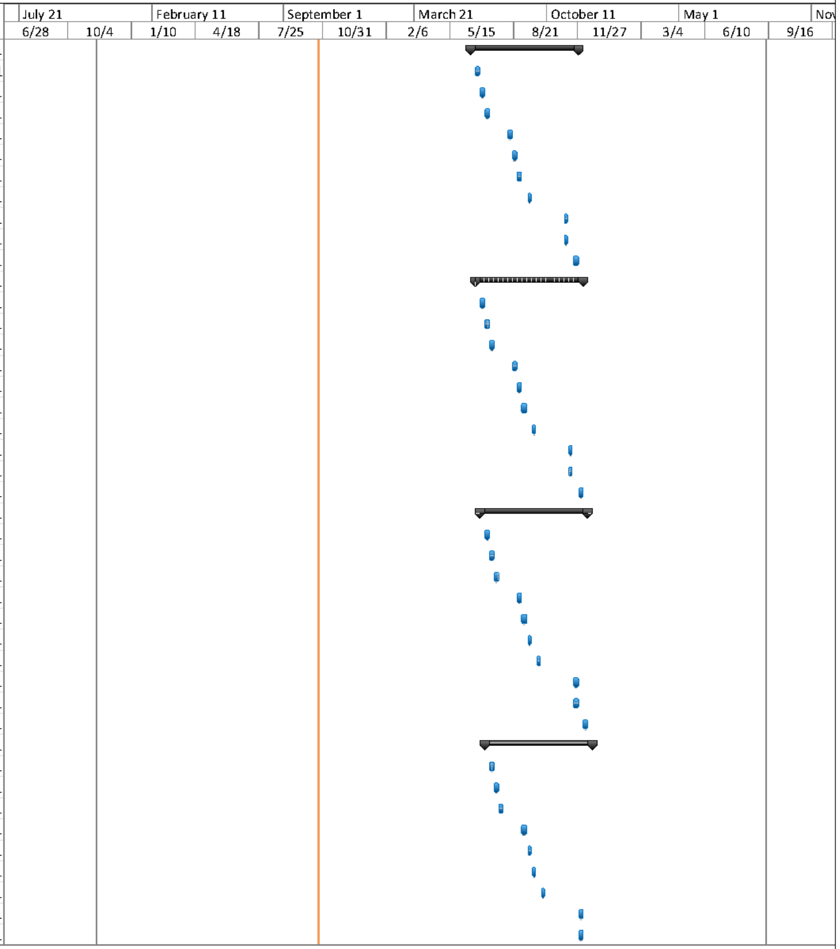
Project: Office Building - G
Technical Assignment Two

Task	▬	Project Summary	▬	Inactive Milestone	◇	Manual Summary Rollup	▬	Deadline	⇩
Split	┅	External Tasks	▬	Inactive Summary	▭	Manual Summary	▬	Progress	▬
Milestone	◆	External Milestone	◆	Manual Task	▬	Start-only	[		
Summary	▬	Inactive Task	▭	Duration-only	▬	Finish-only	]		

Dominic Coassolo
Construction Management
Dr. Robert Leicht

Office Building - G
Eastern United States
Detailed Project Schedule

ID	Task Name	Duration	Start	Finish
87	**2nd Floor Core Fitout**	118 days	Thu 6/16/11	/on 11/28/11
88	Duct Distribution	5 days	Thu 6/23/11	Wed 6/29/11
89	Electrical Distribution	6 days	Thu 6/30/11	Thu 7/7/11
90	Sprinkler Distribution	5 days	Fri 7/8/11	Thu 7/14/11
91	Mechanical Rough-In	5 days	Fri 8/12/11	Thu 8/18/11
92	Plumbing Rough-In	5 days	Fri 8/19/11	Thu 8/25/11
93	Electrical Rough-In	5 days	Fri 8/26/11	Thu 9/1/11
94	Core Drywall	5 days	Mon 9/12/11	Fri 9/16/11
95	MEP Fixtures and Trim	5 days	Mon 11/7/11	Fri 11/11/11
96	Electrical Trim Out	5 days	Mon 11/7/11	Fri 11/11/11
97	2nd Floor Finishes	6 days	Mon 11/21/11	/on 11/28/11
98	**3rd Floor Core Fitout**	118 days	Thu 6/23/11	Mon 12/5/11
99	Duct Distribution	6 days	Thu 6/30/11	Thu 7/7/11
100	Electrical Distribution	5 days	Fri 7/8/11	Thu 7/14/11
101	Sprinkler Distribution	5 days	Fri 7/15/11	Thu 7/21/11
102	Mechanical Rough-In	5 days	Fri 8/19/11	Thu 8/25/11
103	Plumbing Rough-In	5 days	Fri 8/26/11	Thu 9/1/11
104	Electrical Rough-In	6 days	Fri 9/2/11	Fri 9/9/11
105	Core Drywall	5 days	Mon 9/19/11	Fri 9/23/11
106	MEP Fixtures and Trim	5 days	Mon 11/14/11	Fri 11/18/11
107	Electrical Trim Out	5 days	Mon 11/14/11	Fri 11/18/11
108	3rd Floor Finishes	5 days	Tue 11/29/11	Mon 12/5/11
109	**4th Floor Core Fitout**	118 days	Thu 6/30/11	/on 12/12/11
110	Duct Distribution	5 days	Fri 7/8/11	Thu 7/14/11
111	Electrical Distribution	5 days	Fri 7/15/11	Thu 7/21/11
112	Sprinkler Distribution	5 days	Fri 7/22/11	Thu 7/28/11
113	Mechanical Rough-In	5 days	Fri 8/26/11	Thu 9/1/11
114	Plumbing Rough-In	6 days	Fri 9/2/11	Fri 9/9/11
115	Electrical Rough-In	5 days	Mon 9/12/11	Fri 9/16/11
116	Core Drywall	5 days	Mon 9/26/11	Fri 9/30/11
117	MEP Fixtures and Trim	6 days	Mon 11/21/11	/on 11/28/11
118	Electrical Trim Out	6 days	Mon 11/21/11	/on 11/28/11
119	4th Floor Finishes	5 days	Tue 12/6/11	/on 12/12/11
120	**5th Floor Core Fitout**	117 days	Fri 7/8/11	/on 12/19/11
121	Duct Distribution	5 days	Fri 7/15/11	Thu 7/21/11
122	Electrical Distribution	5 days	Fri 7/22/11	Thu 7/28/11
123	Sprinkler Distribution	5 days	Fri 7/29/11	Thu 8/4/11
124	Mechanical Rough-In	6 days	Fri 9/2/11	Fri 9/9/11
125	Plumbing Rough-In	5 days	Mon 9/12/11	Fri 9/16/11
126	Electrical Rough-In	5 days	Mon 9/19/11	Fri 9/23/11
127	Core Drywall	5 days	Mon 10/3/11	Fri 10/7/11
128	MEP Fixtures and Trim	5 days	Tue 11/29/11	Mon 12/5/11
129	Electrical Trim Out	5 days	Tue 11/29/11	Mon 12/5/11



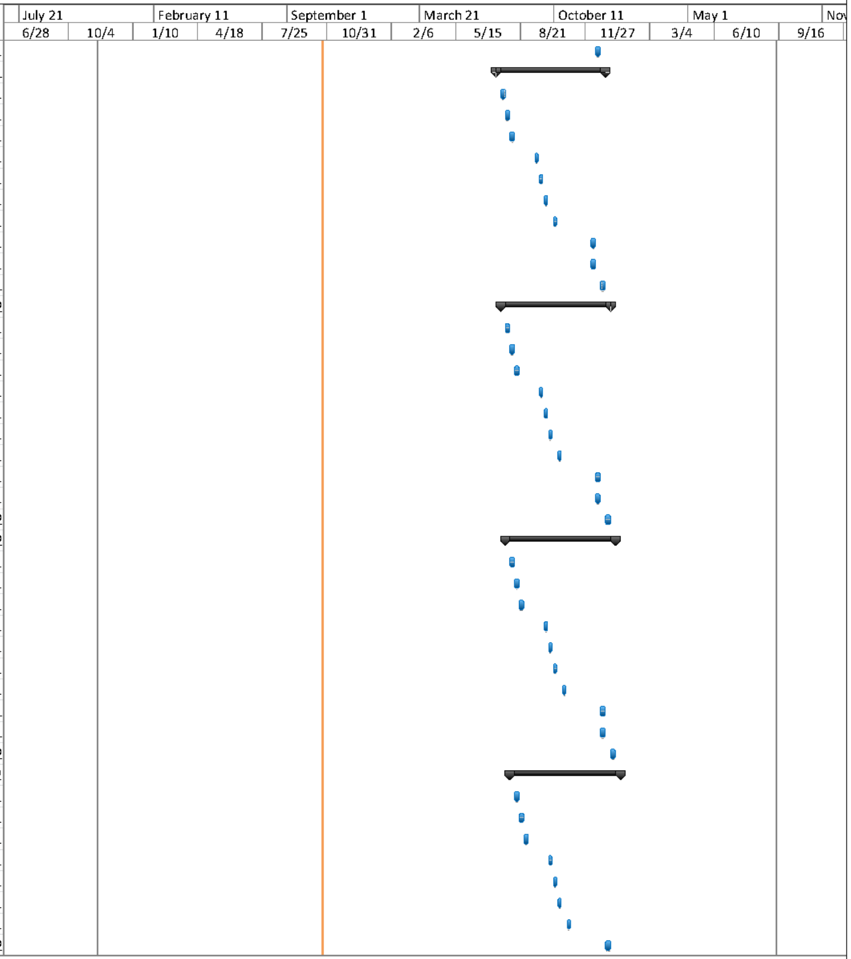
Project: Office Building - G
Technical Assignment Two

Task	Project Summary	Inactive Milestone	Manual Summary Rollup	Deadline
Split	External Tasks	Inactive Summary	Manual Summary	Progress
Milestone	External Milestone	Manual Task	Start-only	
Summary	Inactive Task	Duration-only	Finish-only	

Dominic Coassolo
Construction Management
Dr. Robert Leicht

Office Building - G
Eastern United States
Detailed Project Schedule

ID	ℹ	Task Name	Duration	Start	Finish
130		5th Floor Finishes	5 days	Tue 12/13/11	/on 12/19/11
131		**6th Floor Core Fitout**	118 days	Fri 7/15/11	Tue 12/27/11
132		Duct Distribution	5 days	Fri 7/22/11	Thu 7/28/11
133		Electrical Distribution	5 days	Fri 7/29/11	Thu 8/4/11
134		Sprinkler Distribution	5 days	Fri 8/5/11	Thu 8/11/11
135		Mechanical Rough-In	5 days	Mon 9/12/11	Fri 9/16/11
136		Plumbing Rough-In	5 days	Mon 9/19/11	Fri 9/23/11
137		Electrical Rough-In	5 days	Mon 9/26/11	Fri 9/30/11
138		Core Drywall	5 days	Mon 10/10/11	Fri 10/14/11
139		MEP Fixtures and Trim	5 days	Tue 12/6/11	/on 12/12/11
140		Electrical Trim Out	5 days	Tue 12/6/11	/on 12/12/11
141		6th Floor Finishes	6 days	Tue 12/20/11	Tue 12/27/11
142		**7th Floor Core Fitout**	119 days	Fri 7/22/11	Wed 1/4/12
143		Duct Distribution	5 days	Fri 7/29/11	Thu 8/4/11
144		Electrical Distribution	5 days	Fri 8/5/11	Thu 8/11/11
145		Sprinkler Distribution	5 days	Fri 8/12/11	Thu 8/18/11
146		Mechanical Rough-In	5 days	Mon 9/19/11	Fri 9/23/11
147		Plumbing Rough-In	5 days	Mon 9/26/11	Fri 9/30/11
148		Electrical Rough-In	5 days	Mon 10/3/11	Fri 10/7/11
149		Core Drywall	5 days	Mon 10/17/11	Fri 10/21/11
150		MEP Fixtures and Trim	5 days	Tue 12/13/11	/on 12/19/11
151		Electrical Trim Out	5 days	Tue 12/13/11	/on 12/19/11
152		7th Floor Finishes	6 days	Wed 12/28/11	Wed 1/4/12
153		**8th Floor Core Fitout**	119 days	Fri 7/29/11	Wed 1/11/12
154		Duct Distribution	5 days	Fri 8/5/11	Thu 8/11/11
155		Electrical Distribution	5 days	Fri 8/12/11	Thu 8/18/11
156		Sprinkler Distribution	5 days	Fri 8/19/11	Thu 8/25/11
157		Mechanical Rough-In	5 days	Mon 9/26/11	Fri 9/30/11
158		Plumbing Rough-In	5 days	Mon 10/3/11	Fri 10/7/11
159		Electrical Rough-In	5 days	Mon 10/10/11	Fri 10/14/11
160		Core Drywall	5 days	Mon 10/24/11	Fri 10/28/11
161		MEP Fixtures and Trim	6 days	Tue 12/20/11	Tue 12/27/11
162		Electrical Trim Out	6 days	Tue 12/20/11	Tue 12/27/11
163		8th Floor Finishes	5 days	Thu 1/5/12	Wed 1/11/12
164		**9th Floor Core Fitout**	120 days	Fri 8/5/11	Thu 1/19/12
165		Duct Distribution	5 days	Fri 8/12/11	Thu 8/18/11
166		Electrical Distribution	5 days	Fri 8/19/11	Thu 8/25/11
167		Sprinkler Distribution	5 days	Fri 8/26/11	Thu 9/1/11
168		Mechanical Rough-In	5 days	Mon 10/3/11	Fri 10/7/11
169		Plumbing Rough-In	5 days	Mon 10/10/11	Fri 10/14/11
170		Electrical Rough-In	5 days	Mon 10/17/11	Fri 10/21/11
171		Core Drywall	5 days	Mon 10/31/11	Fri 11/4/11
172		MEP Fixtures and Trim	6 days	Wed 12/28/11	Wed 1/4/12



Project: Office Building - G
Technical Assignment Two

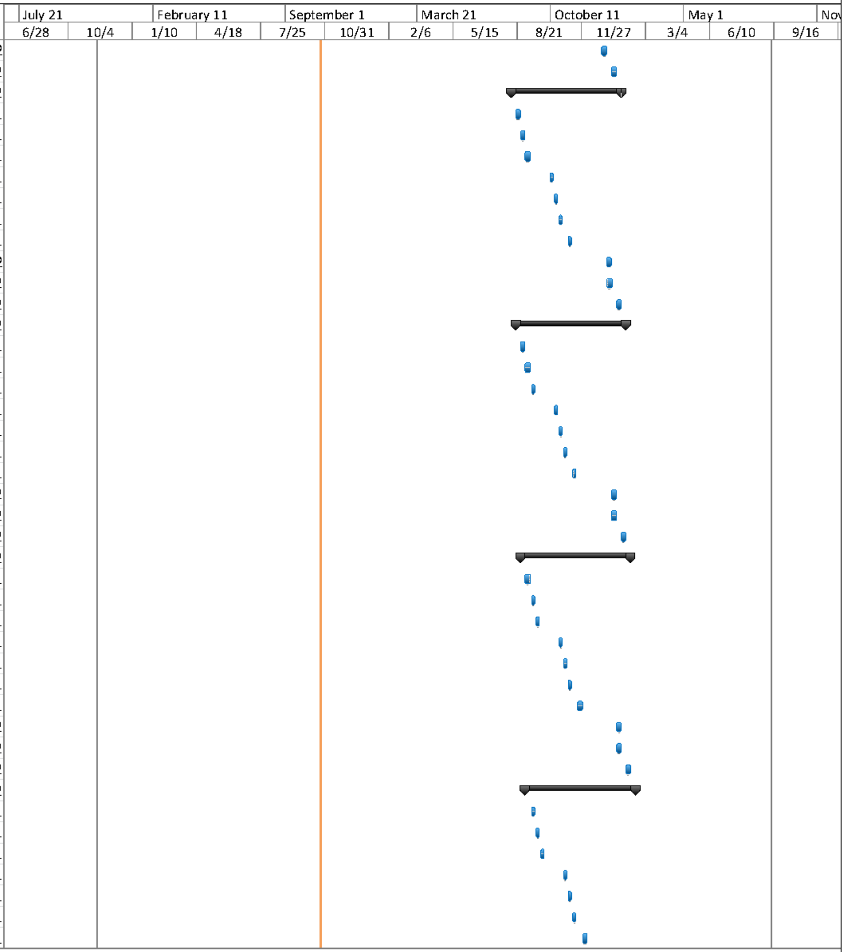
Task	▬	Project Summary	▬	Inactive Milestone	◇	Manual Summary Rollup	▬	Deadline	⇩
Split	┈	External Tasks	▬	Inactive Summary	▭	Manual Summary	▬	Progress	▬
Milestone	◆	External Milestone	◆	Manual Task	▬	Start-only	[		
Summary	▬	Inactive Task	▭	Duration-only	▬	Finish-only	]		

4

Dominic Coassolo
Construction Management
Dr. Robert Leicht

Office Building - G
Eastern United States
Detailed Project Schedule

ID	Task Name	Duration	Start	Finish
173	Electrical Trim Out	6 days	Wed 12/28/11	Wed 1/4/12
174	9th Floor Finishes	6 days	Thu 1/12/12	Thu 1/19/12
175	**10th Floor Core Fitout**	120 days	Fri 8/12/11	Thu 1/26/12
176	Duct Distribution	5 days	Fri 8/19/11	Thu 8/25/11
177	Electrical Distribution	5 days	Fri 8/26/11	Thu 9/1/11
178	Sprinkler Distribution	6 days	Fri 9/2/11	Fri 9/9/11
179	Mechanical Rough-In	5 days	Mon 10/10/11	Fri 10/14/11
180	Plumbing Rough-In	5 days	Mon 10/17/11	Fri 10/21/11
181	Electrical Rough-In	5 days	Mon 10/24/11	Fri 10/28/11
182	Core Drywall	5 days	Mon 11/7/11	Fri 11/11/11
183	MEP Fixtures and Trim	5 days	Thu 1/5/12	Wed 1/11/12
184	Electrical Trim Out	6 days	Thu 1/5/12	Thu 1/12/12
185	10th Floor Finishes	5 days	Fri 1/20/12	Thu 1/26/12
186	**11th Floor Core Fitout**	120 days	Fri 8/19/11	Thu 2/2/12
187	Duct Distribution	5 days	Fri 8/26/11	Thu 9/1/11
188	Electrical Distribution	6 days	Fri 9/2/11	Fri 9/9/11
189	Sprinkler Distribution	5 days	Mon 9/12/11	Fri 9/16/11
190	Mechanical Rough-In	5 days	Mon 10/17/11	Fri 10/21/11
191	Plumbing Rough-In	5 days	Mon 10/24/11	Fri 10/28/11
192	Electrical Rough-In	5 days	Mon 10/31/11	Fri 11/4/11
193	Core Drywall	5 days	Mon 11/14/11	Fri 11/18/11
194	MEP Fixtures and Trim	6 days	Thu 1/12/12	Thu 1/19/12
195	Electrical Trim Out	6 days	Thu 1/12/12	Thu 1/19/12
196	11th Floor Finishes	5 days	Fri 1/27/12	Thu 2/2/12
197	**12th Floor Core Fitout**	120 days	Fri 8/26/11	Thu 2/9/12
198	Duct Distribution	6 days	Fri 9/2/11	Fri 9/9/11
199	Electrical Distribution	5 days	Mon 9/12/11	Fri 9/16/11
200	Sprinkler Distribution	5 days	Mon 9/19/11	Fri 9/23/11
201	Mechanical Rough-In	5 days	Mon 10/24/11	Fri 10/28/11
202	Plumbing Rough-In	5 days	Mon 10/31/11	Fri 11/4/11
203	Electrical Rough-In	5 days	Mon 11/7/11	Fri 11/11/11
204	Core Drywall	6 days	Mon 11/21/11	Mon 11/28/11
205	MEP Fixtures and Trim	5 days	Fri 1/20/12	Thu 1/26/12
206	Electrical Trim Out	5 days	Fri 1/20/12	Thu 1/26/12
207	12th Floor Finishes	5 days	Fri 2/3/12	Thu 2/9/12
208	**13th Floor Core Fitout**	121 days	Fri 9/2/11	Fri 2/17/12
209	Duct Distribution	5 days	Mon 9/12/11	Fri 9/16/11
210	Electrical Distribution	5 days	Mon 9/19/11	Fri 9/23/11
211	Sprinkler Distribution	5 days	Mon 9/26/11	Fri 9/30/11
212	Mechanical Rough-In	5 days	Mon 10/31/11	Fri 11/4/11
213	Plumbing Rough-In	5 days	Mon 11/7/11	Fri 11/11/11
214	Electrical Rough-In	5 days	Mon 11/14/11	Fri 11/18/11
215	Core Drywall	5 days	Tue 11/29/11	Mon 12/5/11



Project: Office Building - G
Technical Assignment Two

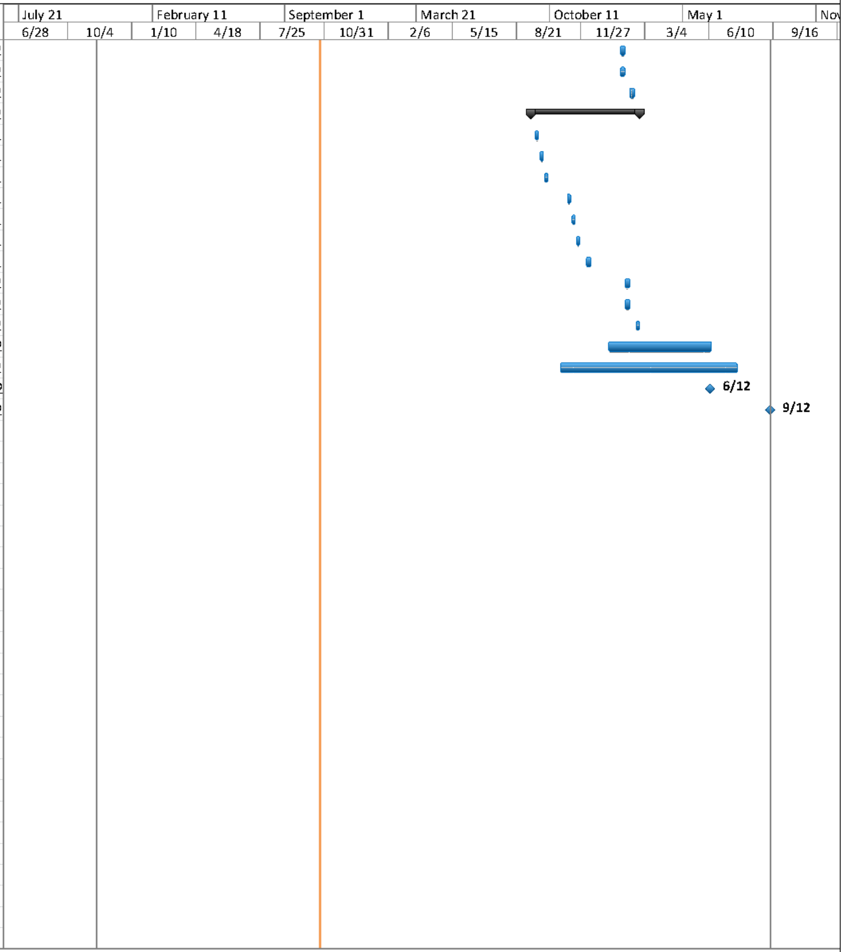
Task ▬	Project Summary ▬	Inactive Milestone ◇	Manual Summary Rollup ▬	Deadline ⇩
Split ┅	External Tasks ▬	Inactive Summary ▭	Manual Summary ▬	Progress ▬
Milestone ◆	External Milestone ◆	Manual Task ▬	Start-only ⊏	
Summary ▬	Inactive Task ▭	Duration-only ▬	Finish-only ⊐	

5

Dominic Coassolo
Construction Management
Dr. Robert Leicht

Office Building - G
Eastern United States
Detailed Project Schedule

ID	ℹ	Task Name	Duration	Start	Finish
216		MEP Fixtures and Trim	5 days	Fri 1/27/12	Thu 2/2/12
217		Electrical Trim Out	5 days	Fri 1/27/12	Thu 2/2/12
218		13th Floor Finishes	6 days	Fri 2/10/12	Fri 2/17/12
219		**14th Floor Core Fitout**	120 days	Mon 9/12/11	Fri 2/24/12
220		Duct Distribution	5 days	Mon 9/19/11	Fri 9/23/11
221		Electrical Distribution	5 days	Mon 9/26/11	Fri 9/30/11
222		Sprinkler Distribution	5 days	Mon 10/3/11	Fri 10/7/11
223		Mechanical Rough-In	5 days	Mon 11/7/11	Fri 11/11/11
224		Plumbing Rough-In	5 days	Mon 11/14/11	Fri 11/18/11
225		Electrical Rough-In	5 days	Mon 11/21/11	Fri 11/25/11
226		Core Drywall	5 days	Tue 12/6/11	‌Mon 12/12/11
227		MEP Fixtures and Trim	5 days	Fri 2/3/12	Thu 2/9/12
228		Electrical Trim Out	5 days	Fri 2/3/12	Thu 2/9/12
229		14th Floor Finishes	5 days	Mon 2/20/12	Fri 2/24/12
230		**Commissioning & Final Inspections**	113 days	Mon 1/9/12	Wed 6/13/12
231		**Tenant Fitout**	193 days	Thu 10/27/11	Mon 7/23/12
232		**Tenant Occupancy**	0 days	Tue 6/12/12	Tue 6/12/12
233		**Project Completion (Tenative Date)**	0 days	Wed 9/12/12	Wed 9/12/12
234					
235					
236					
237					
238					
239					
240					
241					
242					
243					
244					
245					
246					
247					
248					
249					
250					
251					
252					
253					
254					
255					
256					
257					
258					

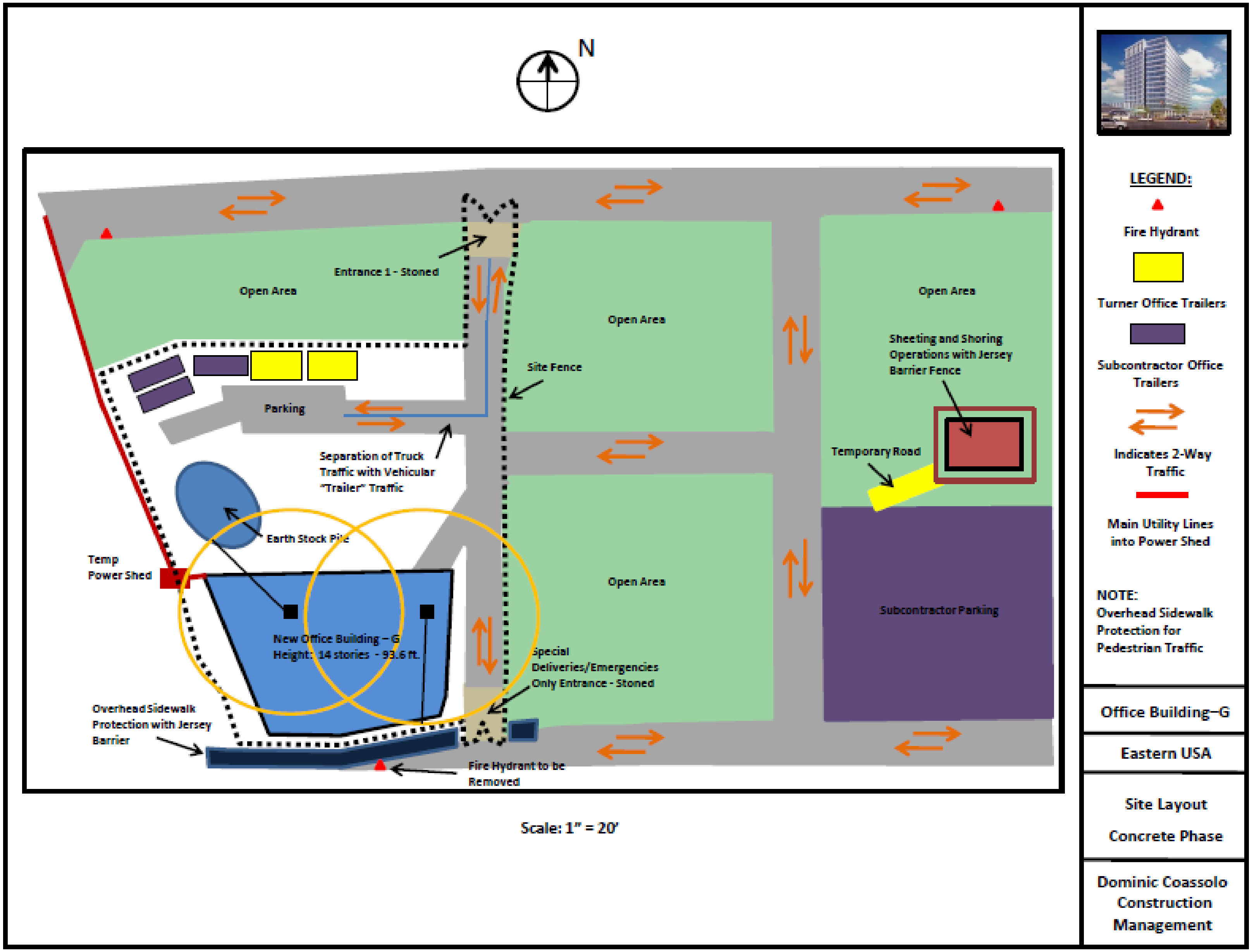


Project: Office Building - G
Technical Assignment Two

Task	Project Summary	Inactive Milestone	Manual Summary Rollup
Split	External Tasks	Inactive Summary	Manual Summary
Milestone	External Milestone	Manual Task	Start-only
Summary	Inactive Task	Duration-only	Finish-only
Deadline	Progress		

6

APPENDIX D: SITE LAYOUT PLAN



N
Open Area
Entrance 1 - Stoned
Open Area
Site Fence
Open Area
Sheeting and Shoring Operations with Jersey Barrier Fence
Temporary Road
Parking
Separation of Truck Traffic with Vehicular "Trailer" Traffic
Earth Stock Pile
Temp Power Shed
New Office Building – G
Height: 14 stories - 93.6 ft.
Open Area
Subcontractor Parking
Special Deliveries/Emergencies Only Entrance - Stoned
Overhead Sidewalk Protection with Jersey Barrier
Fire Hydrant to be Removed
Scale: 1" = 20'
LEGEND:
Fire Hydrant
Turner Office Trailers
Subcontractor Office Trailers
Indicates 2-Way Traffic
Main Utility Lines into Power Shed
NOTE: Overhead Sidewalk Protection for Pedestrian Traffic
Office Building–G
Eastern USA
Site Layout
Concrete Phase
Dominic Coassolo Construction Management

APPENDIX E: STRUCTURAL BREADTH ANALYSIS

Soil Loading Diagram

	Elev.	Soil Type	Soil Density	Friction Angle	Active Press. Coeff.	Vert. Stress	Active Press. Top	Active Press. Bottom	Pressure Area
Layer 1	406	Fill	120	26	0.39	0	0	258	709
Layer 2	400.5	Sandy Silt	130	34	0.283	660	187	1675	37699
Subgrade	360					5925			

Design Factors

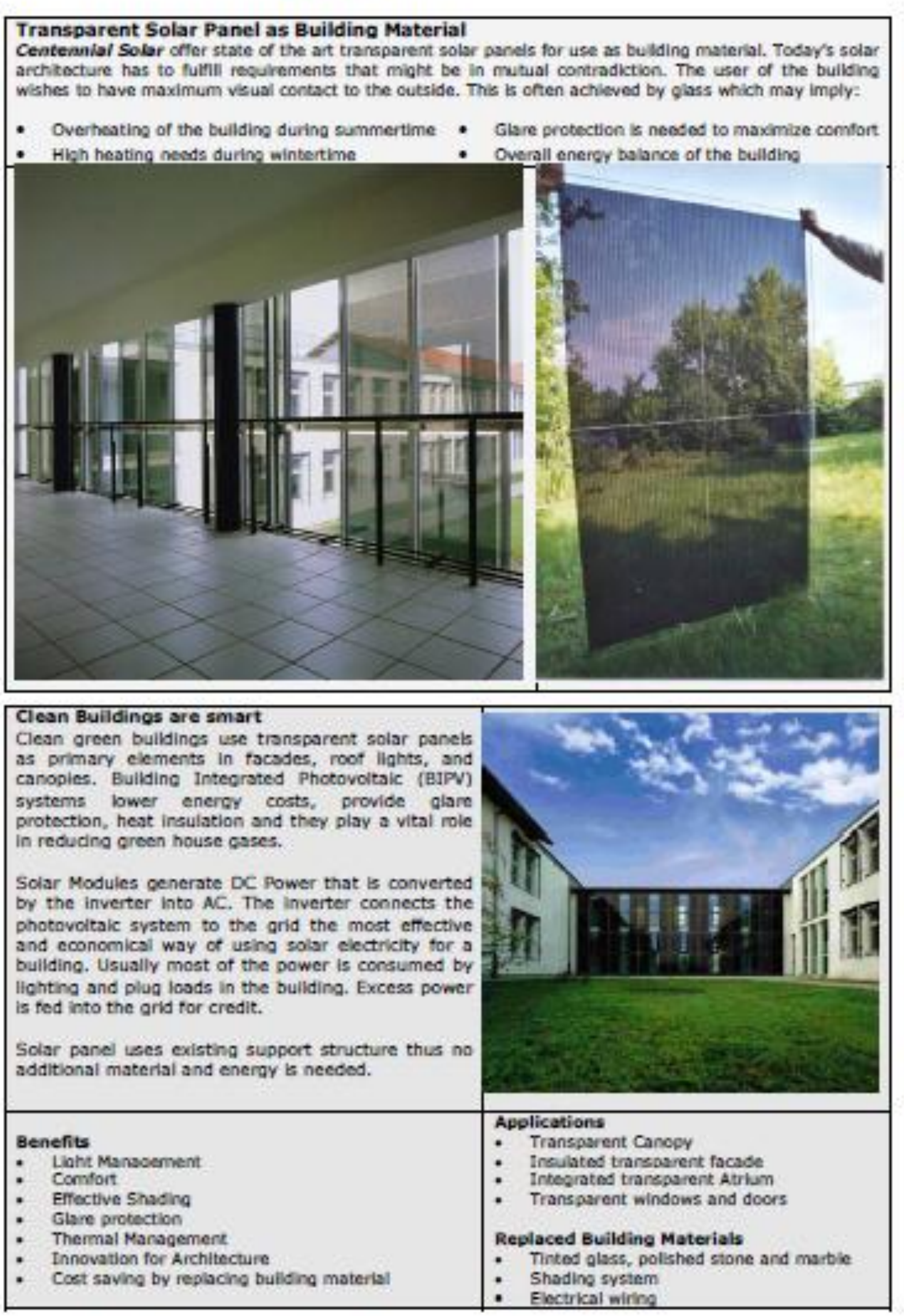
Stiffness Factor	1.25
Total Pressure	38408
Ave. Soil Density	128.8
Eq. Active Coeff.	0.282
Eq. Friction Angle	34.1

Equations

Vertical Stress	$\sigma = \sigma(0) + \gamma(\text{layer}) \text{ x delta } H$
Active Pressure	$p = \sigma \text{ x } K(a)$
Active Pressure Coeff.	$K(a) = (2 \text{ x } p(\text{tot})) / (\gamma(\text{ave}) \text{ x } H^2)$
Metro Trapazoid Pressure	$p(\max) = (\beta \text{ x } p(\text{tot})) / (0.8 \text{ x } H)$

APPENDIX F: CENTENNIAL SOLAR PANEL SPECIFICATIONS

CentennialSolar



Transparent Solar Panel as Building Material

Centennial Solar offer state of the art transparent solar panels for use as building material. Today's solar architecture has to fulfill requirements that might be in mutual contradiction. The user of the building wishes to have maximum visual contact to the outside. This is often achieved by glass which may imply:

- Overheating of the building during summertime
- High heating needs during wintertime
- Glare protection is needed to maximize comfort
- Overall energy balance of the building

Clean Buildings are smart

Clean green buildings use transparent solar panels as primary elements in facades, roof lights, and canopies. Building Integrated Photovoltaic (BIPV) systems lower energy costs, provide glare protection, heat insulation and they play a vital role in reducing green house gases.

Solar Modules generate DC Power that is converted by the inverter into AC. The inverter connects the photovoltaic system to the grid the most effective and economical way of using solar electricity for a building. Usually most of the power is consumed by lighting and plug loads in the building. Excess power is fed into the grid for credit.

Solar panel uses existing support structure thus no additional material and energy is needed.

Benefits

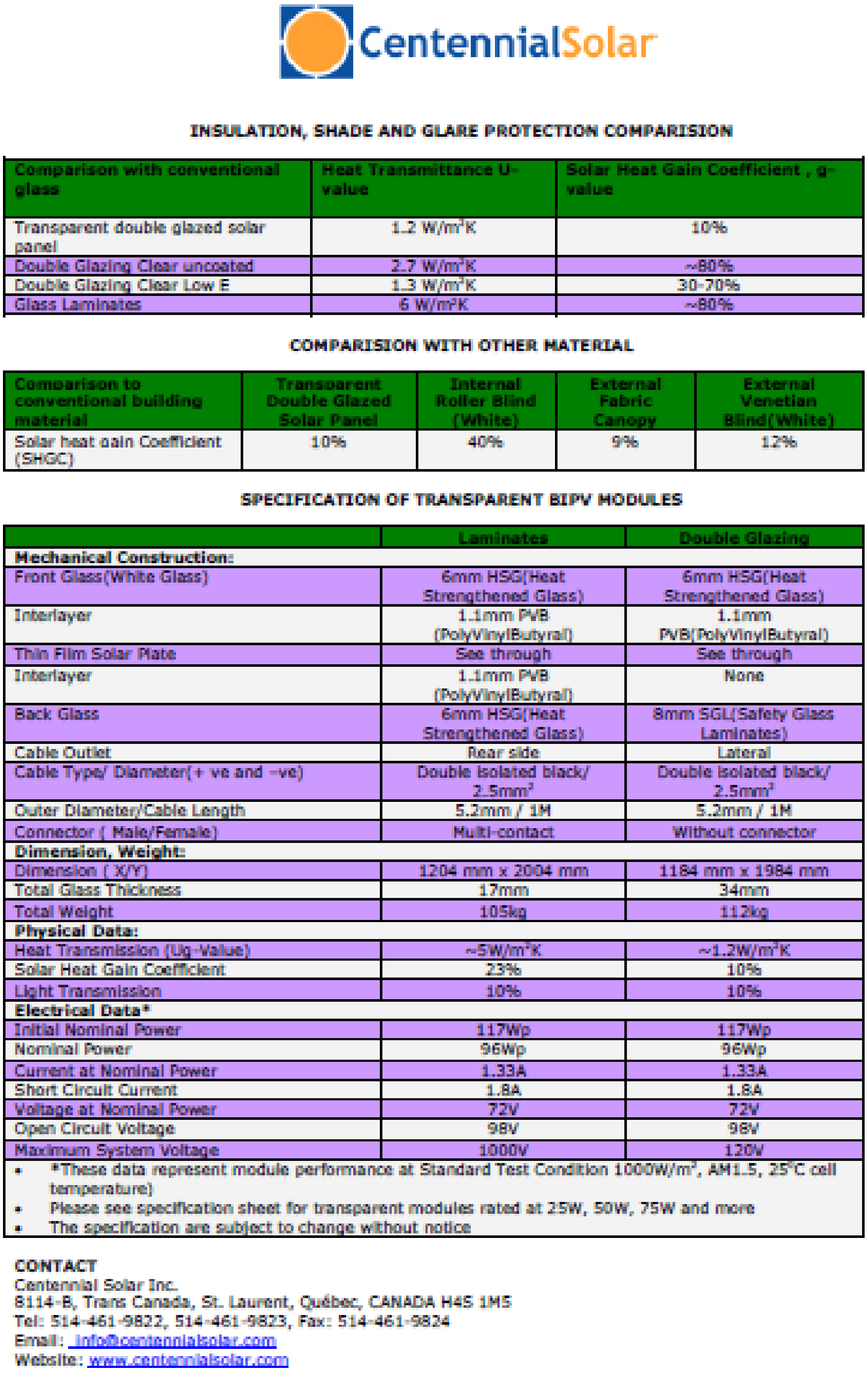
- Light Management
- Comfort
- Effective Shading
- Glare protection
- Thermal Management
- Innovation for Architecture
- Cost saving by replacing building material

Applications

- Transparent Canopy
- Insulated transparent facade
- Integrated transparent Atrium
- Transparent windows and doors

Replaced Building Materials

- Tinted glass, polished stone and marble
- Shading system
- Electrical wiring



CentennialSolar

INSULATION, SHADE AND GLARE PROTECTION COMPARISION

Comparison with conventional glass	Heat Transmittance U-value	Solar Heat Gain Coefficient , g-value
Transparent double glazed solar panel	1.2 W/m^{2}K	10%
Double Glazing Clear uncoated	2.7 W/m^{2}K	~80%
Double Glazing Clear Low E	1.3 W/m^{2}K	30-70%
Glass Laminates	6 W/m²K	~80%

COMPARISION WITH OTHER MATERIAL

Comparison to conventional building material	Transparent Double Glazed Solar Panel	Internal Roller Blind (White)	External Fabric Canopy	External Venetian Blind(White)
Solar heat gain Coefficient (SHGC)	10%	40%	9%	12%

SPECIFICATION OF TRANSPARENT BIPV MODULES

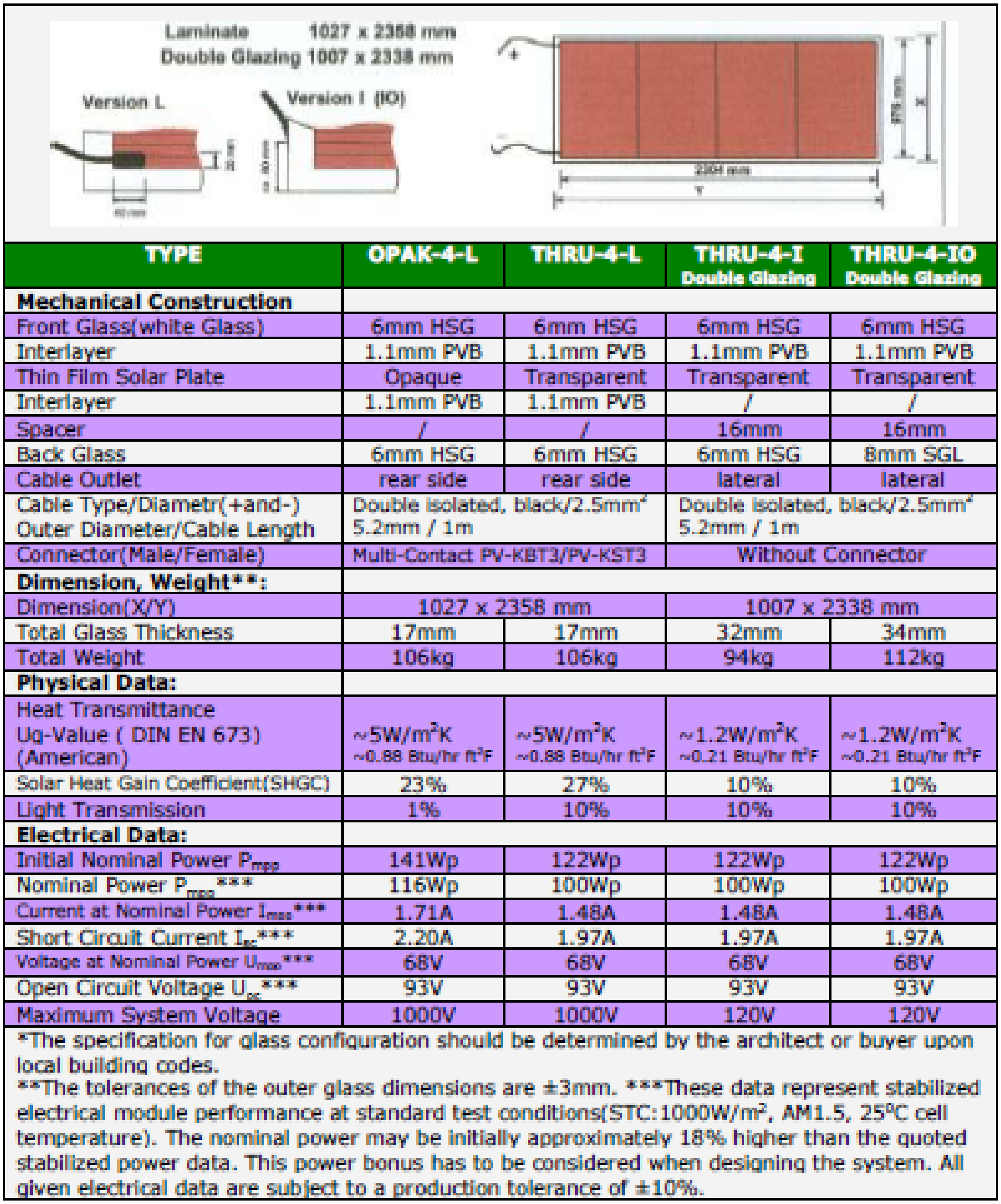
	Laminates	Double Glazing
Mechanical Construction:		
Front Glass(White Glass)	6mm HSG(Heat Strengthened Glass)	6mm HSG(Heat Strengthened Glass)
Interlayer	1.1mm PVB (PolyVinylButyral)	1.1mm PVB(PolyVinylButyral)
Thin Film Solar Plate	See through	See through
Interlayer	1.1mm PVB (PolyVinylButyral)	None
Back Glass	6mm HSG(Heat Strengthened Glass)	8mm SGL(Safety Glass Laminates)
Cable Outlet	Rear side	Lateral
Cable Type/ Diameter(+ ve and –ve)	Double isolated black/ 2.5mm^2	Double isolated black/ 2.5mm^2
Outer Diameter/Cable Length	5.2mm / 1M	5.2mm / 1M
Connector (Male/Female)	Multi-contact	Without connector
Dimension, Weight:		
Dimension (X/Y)	1204 mm x 2004 mm	1184 mm x 1984 mm
Total Glass Thickness	17mm	34mm
Total Weight	105kg	112kg
Physical Data:		
Heat Transmission (Ug-Value)	~5W/m^{2}K	~1.2W/m^{2}K
Solar Heat Gain Coefficient	23%	10%
Light Transmission	10%	10%
Electrical Data*		
Initial Nominal Power	117Wp	117Wp
Nominal Power	96Wp	96Wp
Current at Nominal Power	1.33A	1.33A
Short Circuit Current	1.8A	1.8A
Voltage at Nominal Power	72V	72V
Open Circuit Voltage	98V	98V
Maximum System Voltage	1000V	120V

- *These data represent module performance at Standard Test Condition 1000W/m^2, AM1.5, 25^{0}C cell temperature)
- Please see specification sheet for transparent modules rated at 25W, 50W, 75W and more
- The specification are subject to change without notice

CONTACT
Centennial Solar Inc.
8114-B, Trans Canada, St. Laurent, Québec, CANADA H4S 1M5
Tel: 514-461-9822, 514-461-9823, Fax: 514-461-9824
Email: info@centennialsolar.com
Website: www.centennialsolar.com

CentennialSolar

BIPV THIN FILM MODULES



TYPE	OPAK-4-L	THRU-4-L	THRU-4-I Double Glazing	THRU-4-IO Double Glazing
Mechanical Construction				
Front Glass(white Glass)	6mm HSG	6mm HSG	6mm HSG	6mm HSG
Interlayer	1.1mm PVB	1.1mm PVB	1.1mm PVB	1.1mm PVB
Thin Film Solar Plate	Opaque	Transparent	Transparent	Transparent
Interlayer	1.1mm PVB	1.1mm PVB	/	/
Spacer	/	/	16mm	16mm
Back Glass	6mm HSG	6mm HSG	6mm HSG	8mm SGL
Cable Outlet	rear side	rear side	lateral	lateral
Cable Type/Diametr(+and-) Outer Diameter/Cable Length	Double isolated, black/2.5mm^2 5.2mm / 1m		Double isolated, black/2.5mm^2 5.2mm / 1m	
Connector(Male/Female)	Multi-Contact PV-KBT3/PV-KST3		Without Connector	
Dimension, Weight:**				
Dimension(X/Y)	1027 x 2358 mm		1007 x 2338 mm	
Total Glass Thickness	17mm	17mm	32mm	34mm
Total Weight	106kg	106kg	94kg	112kg
Physical Data:				
Heat Transmittance Ug-Value (DIN EN 673) (American)	~5W/m^{2}K ~0.88 Btu/hr ft^{2}F	~5W/m^{2}K ~0.88 Btu/hr ft^{2}F	~1.2W/m^{2}K ~0.21 Btu/hr ft^{2}F	~1.2W/m^{2}K ~0.21 Btu/hr ft^{2}F
Solar Heat Gain Coefficient(SHGC)	23%	27%	10%	10%
Light Transmission	1%	10%	10%	10%
Electrical Data:				
Initial Nominal Power P_{mpp}	141Wp	122Wp	122Wp	122Wp
Nominal Power P_{mpp}***	116Wp	100Wp	100Wp	100Wp
Current at Nominal Power I_{mpp}***	1.71A	1.48A	1.48A	1.48A
Short Circuit Current I_{sc}***	2.20A	1.97A	1.97A	1.97A
Voltage at Nominal Power U_{mpp}***	68V	68V	68V	68V
Open Circuit Voltage U_{oc}***	93V	93V	93V	93V
Maximum System Voltage	1000V	1000V	120V	120V

*The specification for glass configuration should be determined by the architect or buyer upon local building codes.

**The tolerances of the outer glass dimensions are ±3mm. ***These data represent stabilized electrical module performance at standard test conditions(STC:1000W/m^2, AM1.5, 25^{0}C cell temperature). The nominal power may be initially approximately 18% higher than the quoted stabilized power data. This power bonus has to be considered when designing the system. All given electrical data are subject to a production tolerance of ±10%.

APPENDIX G: PAYBACK PERIOD ANALYSIS

Payback Period

Year	Cost + 1.00% Inc. Each Year ($)	Total kWh Produced Per Year	Tax Savings Per Year ($)	Total Each Year ($)	
1	0.12680	53469	33,800	40579.87	40579.87
2	0.12810	53469	33,800	40649.38	81229.25
3	0.12930	53469	33,800	40713.54	121942.79
4	0.13059	53469	33,800	40782.68	162725.47
5	0.13190	53469	33,800	40852.50	203577.97
6	0.13322	53469	33,800	40923.03	244501.00
7	0.13455	53469	33,800	40994.26	285495.26
8	0.13590	53469	33,800	41066.20	326561.46
9	0.13725	53469	33,800	41138.86	367700.32
10	0.13863	53469	33,800	41212.25	408912.58
11	0.14001	53469	33,800	41286.37	450198.95
12	0.14141	53469	33,800	41361.24	491560.19
13	0.14283	53469	33,800	41436.85	532997.04
14	0.14426	53469	33,800	41513.22	574510.26
15	0.14570	53469	33,800	41590.35	616100.61
16	0.14716	53469	33,800	41668.26	657768.87
17	0.14863	53469	33,800	41746.94	699515.81
18	0.15011	53469	33,800	41826.41	741342.21
19	0.15161	53469	33,800	41906.67	783248.89
20	0.15313	53469	33,800	41987.74	825236.62
21	0.15466	53469	33,800	42069.62	867306.24
22	0.15621	53469	33,800	42152.31	909458.55
23	0.15777	53469	33,800	42235.83	951694.39
24	0.15935	53469	33,800	42320.19	994014.58
25	0.16094	53469	33,800	42405.40	1036419.97
				25 Year Total	**$1,036,420.00**

APPENDIX H: INVERTER SPECIFICATIONS

PVPowered™

PVP75kW and PVP100kW

The new industry standard for reliability and ease of installation

The new PV Powered 75kW and 100kW inverters set the industry standard for high reliability, ease of installation and lifetime maintainability. Their 20-plus year design-life is enabled by an array of new market-leading reliability features including bus bars for all power connections, a sealed electronics module and an instrumented cooling system. The highly-integrated system was designed to save commercial installers time and money with load-rated AC & DC service disconnects, ETL-approval for installation without a neutral conductor, cable landing points sized for maximum NEC-compliant cables and a well-planned cable bending radius for top, bottom and side cable entry options.

PV Powered commercial inverters offer best-in-class 96% efficiency* and a voltage window of 295-600VDC. This is the widest operating range with the lowest standard MPPT voltage of any three-phase inverter in the industry. This provides exceptional stringing capability with all PV modules currently available including new thin film modules. Serviceability is enhanced by a modular design that divides the inverter into easy-to-maintain subsystems. PV Powered backs all their inverters with an industry-leading 10-year nationwide warranty and an unprecedented optional 20-year warranty, plus the best service and support team in the business.

Performance Monitoring

Performance monitoring solutions are available on all PV Powered inverters and include low cost, secure web-based access to PV system status and performance history.

FEATURES

Superior Reliability

- Engineered power connections eliminate failure points
- Advanced, high-reliability circuit board system
- Innovative cooling system ensures long IGBT life
- Industrial-grade power supply for long-life and high quality control power

Exceptional Installability

- Bottom, top and side cable entry
- Generous cable bending area and oversized cable landings
- Complete range of fused DC sub-combiner options
- Exterior mounting flange for fast and easy anchoring
- Error-free AC auto-phasing

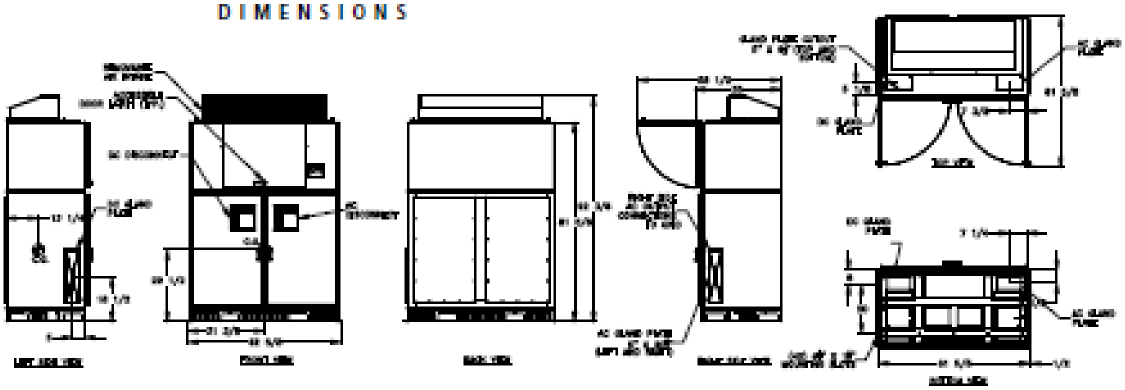
Easy to Maintain

- All maintenance and service via front access
- Load-rated AC and DC service disconnects
- Positive-locking, tool-free circuit board cage
- Optional preventative maintenance program and extended warranty

150 SW Scalehouse Loop
Bend OR 97702

1-541-312-3832
WWW.PVPOWERED.COM

DIMENSIONS



(complete design documentation including seismic calculations available upon request)

ELECTRICAL SPECIFICATIONS

MODEL	PVP75kW	PVP100kW
Continuous Output Power (kW)	75	100
Weighted CEC Efficiency (%)	95.5% (208 V), 96.0% (480V) [est.]	95.5% (208 V), 96.0% (480V)
Maximum DC Input Voltage (VOC)	600	600
DC Peak Power Tracking Range (V)	295 - 500	295 - 500
DC Imp Nominal Current (A)	267	356
AC Nominal Voltage (V)	208, 480 and 208/480	208, 480 and 208/480
AC Operating Range (V)		
208	183 - 228	183 - 228
480	422 - 528	422 - 528
AC Frequency Range (Hz)	59.3 - 60.5	59.3 - 60.5
AC Maximum Continuous Current (A)	208 (208V), 90 (480V)	278 (208V), 120 (480V)
Standby Losses (W)	45	45
Harmonic Distortion (%THD)	1.5% at 75% (est)	1.5% at 75% (est)
Power Factor	1.0	1.0

MECHANICAL SPECIFICATIONS

MODEL	PVP75kW	PVP100kW
Enclosure	NEMA 4	NEMA 4
Construction	Powder Coated Steel	Powder Coated Steel
Mounting	Pad Mount	Pad Mount
Weight (lbs)	2,750	3,000
Cooling	Forced Convection	Forced Convection
Temperate Range (°C)	-30 to 50	-30 to 50
Isolation Transformer	Yes	Yes

OPTIONS

- Complete range of integrated fused sub-array combiners from one to nine fuses and from 75 to 600 Amps
- Positive ground
- Factory integrated data monitoring solutions
- Preventative maintenance program
- 20-year warranty

STANDARDS APPROVALS

UL 1741, IEEE519, IEEE929, IEEE1547, FCC Class A

* PVP100kW 480V