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Senior Thesis Final Report

Penn State AE Senior Thesis

UMBC
Performing Arts &
Humanities Facility
Baltimore, MD

Courtney L Glaub
Construction Management
Dr. Chimay Anumba

UMBC Performing Arts & Humanities Facility

1000 Hilltop Circle, Baltimore, MD 21250

Project Overview:

Owner: University of Maryland, Baltimore County
Architect: Grimm & Parker Architects/William Rawn Associates, Architects, Inc.
MEP Engineer: Mueller Associates, Inc.
Structural Engineer: ReStl Designers, Inc./LeMessurier Consultants, Inc.
Civil Engineer: Site Resources, Inc.
General Contractor: Whiting-Turner Contracting Company
Total Height: 4 stories + basement
Building Area: 90,000 gsf
Cost: $67,000,000
Construction Dates: 07/01/2010 - 06/30/2012

Architectural Feature:

Building Façade:
Brick Veneer
Curtain Wall
Stainless Steel Wall Panels
Aluminum Composite Metal Panels

Space for Various Departments:
2 Theatres
Studios
Scene Shops
Academic Spaces

**LEED Certified—Silver Rating

Structural System:

Foundation:
Spread footing with allowable bearing capacity ranging 3-10 ksf
Structure:
1. Steel Framing System w/ W-shape steel members w/ load ranging from 25-490k
2. Concrete Framing System ; 2000-5000psi
3. Structural Masonry Block System - all concrete masonry units to be hollow weight w/ 2000psi minimum strength

Façade:
Brick Veneer
Curtain wall system with 8" aluminum framing w/ 1" insulating glass
Stainless steel wall panels
Aluminum composite metal wall panels w/ corrugated metals

Roof:
Built up roof with tapered rigid insulation
Built up roof without tapered insulation
Energy Star Thermoplastic roofing membrane

Construction Logistics:

Phase 1 - Opening Fall 2012
Performing Arts:
275 Seat Proscenium Theatre
120 Seat Black Box Theatre
Theatre Rehearsal and Acting Directing Studios
Scene Shops & Performance Support Spaces
Academic & Faculty Spaces for the Department of Theatre
Arts Management Offices
Humanities:
English Department Offices, Classrooms and Labs
James T. and Virginia M. Dresher Center for the Humanities
Linehan Artist Scholars Program
20 & 40 seat Academic Classrooms
Humanities Scholars Program

*Also upgrades to the existing Central Utility Plant and a concrete structure/tunnel connecting the existing Plant Tunnel to the new Performing Arts Facility.

Phase 2 - In Design Phase

Lighting/Electrical System:

General illumination Fluorescent lighting w/ T5 lamps
Main transformer is part of substation with 3000 KVA
(1) switchgear: 4000A, 480Y/277V, 3 phase, 4 wire
(2) switchboards: 3200A, 208Y/120V, 3 phase, 4 wire
1600A, 480Y/277V, 3 phase, 4 wire

Mechanical System:

23 Fancoil Units
8 Air Handling Units
VAV Systems
Energy Recovery Ventilators & AHU Energy Wheels
Radiant Panels & Finned Tube Radiation
Central Plant supplies heating and cooling

Courtney Glaub | Construction Management | http://www.engr.psu.edu/ae/thesis/portfolios/2011/clg5069/index.html

1.0 Executive Summary

This AE Capstone Senior Thesis Report is written to talk about the UMBC project and also discuss the three analyzed topics that were performed on the building. The UMBC Performing Arts & Humanities Facility is a $67 million, 90,000SF facility with four floors and a basement. In this building are a variety of performing arts amenities including theaters, studios, classrooms and offices. The topics performed are intended to improve the efficiency such as cost and schedule reduction on a construction job. The following are the analyses researched: the prefabrication of precast panels, the comparison between mobile cranes and a tower crane, and the study of PV roof panels.

Analysis #1 – Prefabrication of Precast System (Structural Breadth)

Since the university has certain goals for this project to be completed on time and efficiently for the students, the use of prefabrication may be very useful. Also, being that the building is made up of three different structural elements, this poses a challenge of erecting the building because adjacent work has to stop in order for a certain area to be completed. By performing this analysis of using prefabricated precast panels instead of the original masonry brick veneer system, it was found that the schedule was reduced by about 90 days and the amount of delays caused by trade coordination decreased. This was caused since the steel superstructure had to be fully complete before the precast would be erected. Also erecting on average 12 pieces of precast per day was a more efficient technique of reducing the time to build the façade. The only downfall is that, using these precast panels will add an extra $50,000 to the masonry cost.

Analysis #2 – Tower Crane vs. Mobile Crane (CM Depth)

Being that the site utilizes a tower crane positioned on the southwest corner of the building that has a very large swing radius for a smaller building footprint, it is proposed that it was not necessary to have such a large crane. There is enough space on site that the possibility of using a few mobile cranes instead may help save time and cost. This analysis showed that eliminating the tower crane would have a positive impact on the schedule. Unfortunately because the crane belonged to the concrete contractor, it saved them money initially compared to having to find other cranes to replace the production with.

Analysis #3 – Study on Photovoltaic Roof Panels (Electrical & Structural Breadth)

The UMBC Performing Arts & Humanities Facility had tried to look into utilizing PV panels on the roof being that this building is supposed to be the first building on campus to become LEED Certified. Due to financial implications, this sustainable technique was deleted from the plans early on. The purpose of this investigation is to design a PV roof system and show how much energy could be produced, and save the owner money after a certain payback period, despite the removal of this idea in the preconstruction phase. After performing this analysis, it shows that it is possible to add a specific PV roof system to the Humanities section of the building and that the PV's on that roof will be able to produce the total load of all the lights on those four floors of the Humanities section. After taking everything into consideration such as the structural impact and the electrical tie-in, the study of this photovoltaic roof panel system concluded that the owner would start receiving money back from the system after 6 years of paying for the initial cost.

2.0 Acknowledgments

Academic Acknowledgments:

Penn State AE Faculty
Dr. Chimay Anumba – CM Advisor

Industry Acknowledgments:

Special Thanks To:

The Whiting-Turner Contracting Company Project Team –
Patty Carper, Andrew Light, Tim Unrath, Steve Chesko
The UMBC Project Team – Mickey Miller
Grimm & Parker Architects – Sue Hains
Nitterhouse Concrete Products – Mark Taylor
Solar Gaines – John Hencken
My Family and Friends

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3.0 Project Overview

3.1 Introduction

The UMBC Performing Arts & Humanities Facility project includes a new state-of-the-art facility for the University of Maryland Baltimore County's Arts and Humanities departments that will enhance its teaching, research and public outreach programs while simultaneously improving the visibility of the arts and humanities as a major component of campus and community life.

The Performing Arts and Humanities Facility (PAHF) will be situated on 4.8 acres on the west side of Hilltop Road, adjacent to the existing Fine Arts, Engineering and ITE Buildings. The construction for this new $67 million building consists of a four story, 90,000sf facility providing a variety of performing arts amenities. The building includes a 275 Seat Proscenium Theater, a 100 Seat Black Box Theater, Scene Shop, Theater Rehearsal Studio, Acting/Directing Studio, Dressing Rooms, Support Spaces, Seminar Rooms, Classrooms, Conference Rooms and Administrative Offices. Another part of the project includes upgrades to the existing Central Utility Plant and a concrete structure/tunnel connecting the existing Plant Tunnel to the new Performing Arts Facility.

An interesting aspect of the PAHF is that it's comprised of multiple structural features. The exterior façade of the building consists of an assortment of materials creating a strong relationship with the current campus buildings. Although there are struggles throughout the construction of this building, the UMBC PAHF project is participating in the United States Green Building Council's Leadership in Energy and Environmental Design (LEED®) program and is striving for a LEED® Silver Certified rating. This project is expected to be the first building on campus to earn LEED® Certification.

BUILDING NAME	UMBC Performing Arts and Humanities Facility
LOCATION	1000 Hilltop Circle, Baltimore, MD 21250
PRIMARY OCCUPANCY NAME	University of Maryland
OCCUPANCY TYPE	Assembly Group A-1 (performing arts) & Business Group B
GROSS BUILDING AREA	90,000 gsf
NUMBER OF STORIES	4 stories + basement
DATES OF CONSTRUCTION	7/1/2010 - 6/30/2012
COST	$67,000,000
PROJECT DELIVERY METHOD	CM at risk

Table 1: General Building Statistics

3.2 Project Location

The site for the new Performing Arts & Humanities Facility is located adjacent to the existing Fine Arts, Engineering and ITE Buildings. The Fine Arts Building, located northeast of the proposed site, has served as the university's principal exhibition space – a forum for students, professors, and staff, as well as the general public to experience contemporary visual culture and to dialogue about important cultural and aesthetic issues. The existing Engineering Building, located directly east of the site, houses the Center for Photonics Technology, which conducts research in fiber optics. The ITE Building located southeast of the site, new in 2003, houses the Department of Computer Science and Electrical Engineering, the Department of Information Systems, the offices of the College of Engineering, the Center for Women and Information Technology and the Imaging Research Center, which is the state-of-the-art computer - based research and production facility specializing in high end computer animation and visualization. While public vehicular and pedestrian traffic is not a concern since the site is located on a private campus, the site is currently comprised of two parking lots providing 690 parking spaces for the campus and will need to be addressed during construction. Since the site consists of two parking lots, it will not be necessary to remove existing forested area. If improvements are necessary due to repair of the existing storm drain, clearing of forested area will be required to access the storm drain repair. Connections for water and sanitary sewer will need to be serviced from surrounding locations during construction. See APPENDIX A for the existing conditions site plan.

Figure 1: Aerial View of UMBC Campus

3.3 Client Information

The owner of this project is the University of Maryland, Baltimore, an Honors University in Maryland who is overseeing the construction of the facility for the campus of University of Maryland Baltimore County. Both fall under the global "University of Maryland System". UMBC combines the emphasis on teaching found at the best liberal arts colleges with the innovation of a research university. This university offers 39 undergraduate majors leading to the B.A., B.S., and B.F.A. degrees, 39 minors, 13 post-baccalaureates, 28 master's degree programs, and 22 doctoral programs through its five major academic units.

The facility is being built because the existing theatre and music facilities on campus are old and horribly inadequate. They are also building the PAHF because the programs are growing on campus and they need more space. UMB is also making a philosophical statement by combining the arts and the humanities into one facility; every student on campus must take humanities classes in this building requiring them to come face to face with the arts components of the building and the campus.

This project has many expectations that must be met in order to satisfy the owner's requirements. Costs are very tight on this project and the owner expects that the project comes in on budget without any additional costs. Numerous budget phases during preconstruction, including value engineering, were used to ensure the cost does not exceed the limit. Independent third party estimates were also done at every stage to double check the Construction Managers Budgets. Quality is expected to be very high and the schedule is considered aggressive but not expedited. Several mockups are planned for, to set the level of quality expectations on the job. The specifications are clear, outlining quality expectations and independent inspectors are required on critical items of work. All contracts are written with specific schedule information and there are liquidated damages assessed to all parties involved in the project if the schedule is not met. Safety is always a number one priority for everyone involved. There is a project specific safety plan with incentives for maintaining a safe workplace. Subcontractor EMR's (Experience Modification Ratings) were taken into consideration before awarding any contracts.

The main sequencing issues that are of interest to the owner are the utility tie-ins in the campus loop road and all of the work associated with the central utility plant. This project does not anticipate any joint, dual, or phased occupancy requirements. The major keys to completing the project to the owners' satisfaction are completing the project on time and on budget and producing a very high quality building. This project is expected to be the first building on campus to earn LEED® Certification.

3.4 Project Delivery Method

The project delivery system for the UMBC Performing Arts & Humanities Facility is a CM at Risk. This type of delivery method was chosen because it has the least risk to the funding amount. The state has a guaranteed amount that is required in order to make sure that the project will not exceed that amount before they will move forward with funding on any project.

The Whiting-Turner Contracting Company's contract for general contractor services is a guaranteed maximum price. This contractor was selected under a "best value" procurement process. First there was a submission of qualifications from all bidders on which they were all scored on based on their qualifications. Then there was a submission of general conditions and fees which they were also scored on based on those elements. Afterwards, interviews were held with the key personnel and the bidders were scored based on their interview. The three scores were added together and the construction manager with the best value was selected. For this type of contract with Whiting-Turner, there are 100% Performance and Payment Bonds required and the type of insurance required is Liability Insurance. University of Baltimore County will be carrying the required Builders Risk Insurance.

The contractual agreement between parties is shown below in Figure 2. The contract type between UMBC and Whiting-Turner is a GMP/CM at Risk. All of the subcontracts held by Whiting-Turner are lump sum contracts awarded to the lowest, prequalified bidder. The type of contract held between UMBC and the architect is a GMP with a Cost plus a Fee in case there are project delay

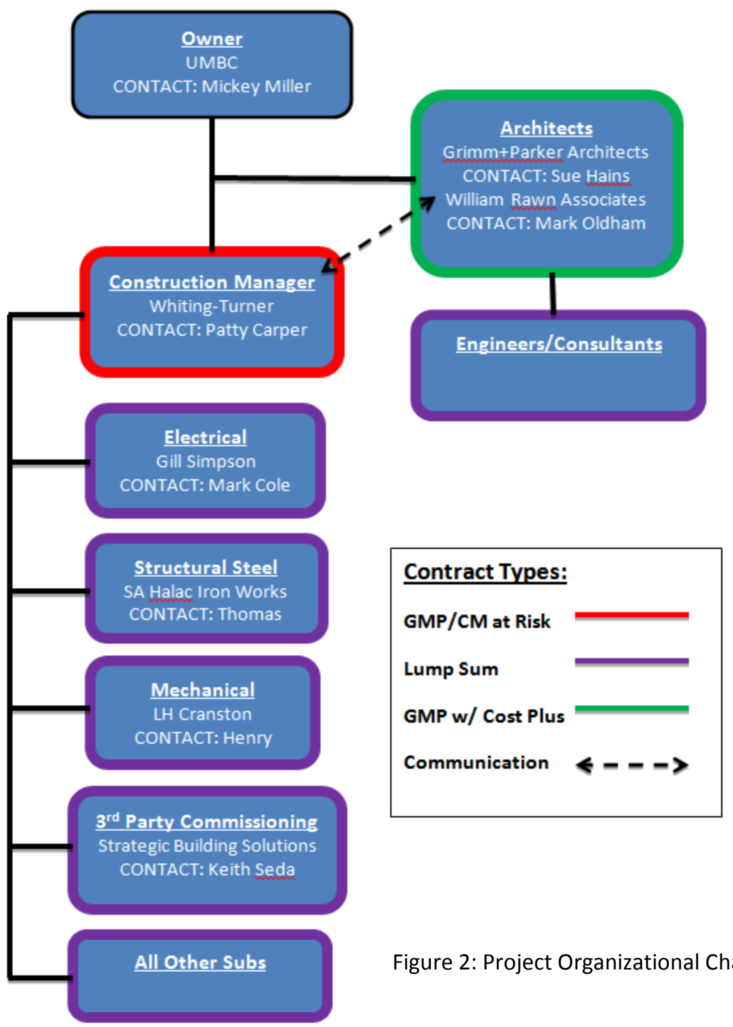

Figure 2: Project Organizational Chart

3.5 Project Team Staffing Plan

Whiting-Turner staffs their projects based on project size. As shown in Figure 3, the on-site field staff is managed by Project Manager, Patty Carper. She is in charge of handling the overall project control such as schedules, LEED oversight and owner invoicing. The other project managers are broken up into subdivisions. Each PM is responsible for their major building systems; mechanical, electrical, structural, and architectural. The entirety of this staff is overseen by a senior project manager and vice president. The senior PM's role consists of the site work, surveying, testing & inspection and the BIM Modeling. The vice president provides executive authority necessary to overcome the project team's obstacles and barriers, which are faced on the job. He is also ultimately responsible for this projects success.

On this project, the management staff and field staff are stationed at the jobsite in a field trailer. Typically, the architect visits the site weekly for Construction Administration and bi-weekly for certain meetings. As for safety, all of Whiting-Turner's project team is responsible to bring the attention to any hazardous construction activities that are seen on site. In addition, the superintendent is also the safety officer for the job.

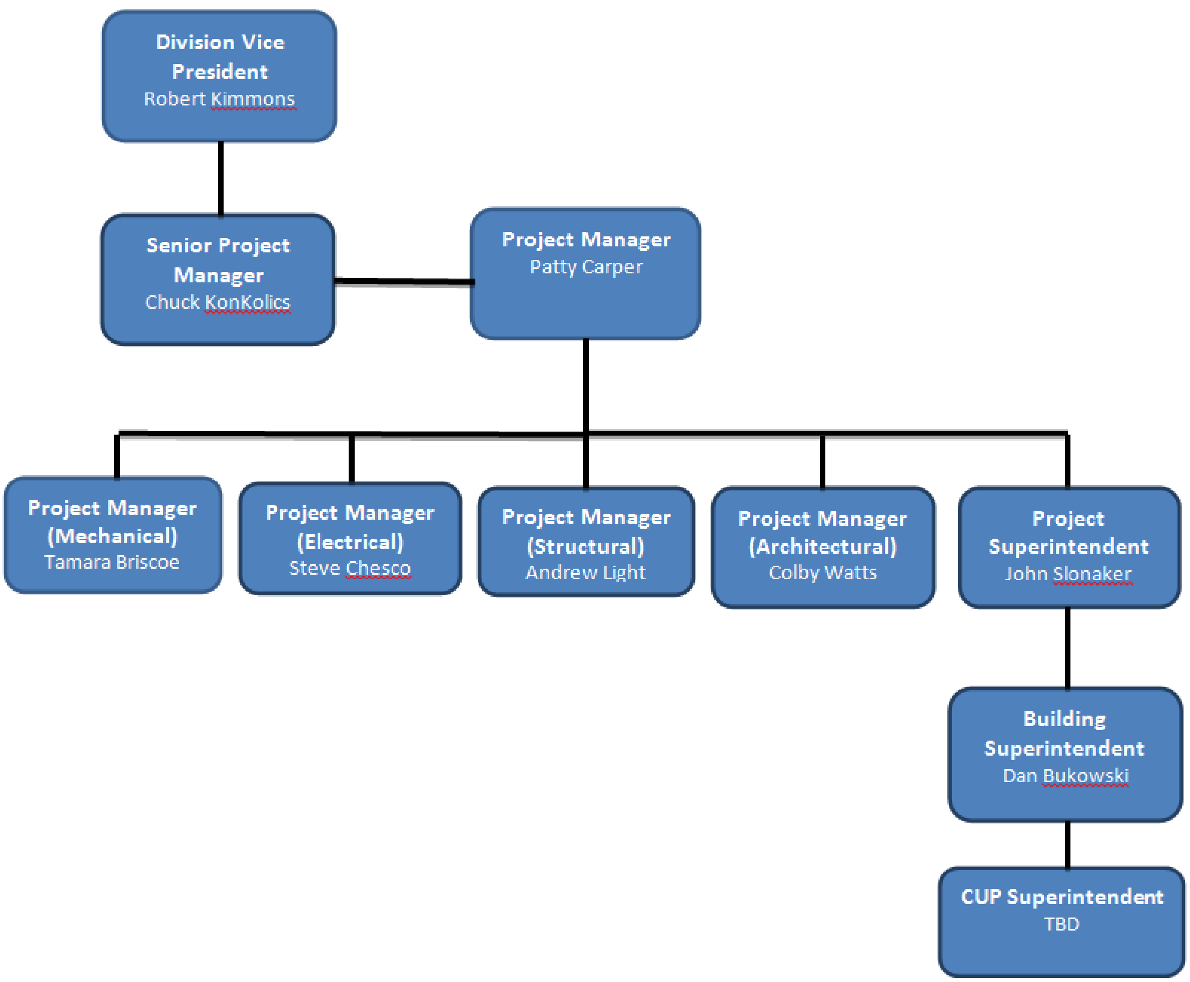

Figure 3: Staffing Plan

4.0 Design and Construction Overview

4.1 Building Systems

4.1.1 Demolition

The site of the UMBC Performing Arts & Humanities Facility was previously utilized by the university as a surface parking lot. Before any of the excavation work can begin, all of the asphalt, concrete curbs, utilities, site lighting, parking control gates, railings, stairs, etc. need to be cleared out. There are no hazardous materials expected to be in the demolition of the site. The materials being demolished are concrete and asphalt and other yard structures on the site. Boring logs provided by Schnabel Engineering Associates for one of the parking lots suggest more concern about citing basements relative to the water table and bedrock. Some unsuitable fills may exist across the site which may require removal and replacement.

4.1.2 Support of Excavation

A beam and lagging system is used for the structural excavation support of the basement and tunnel areas as well as for the installation of the underground rain water harvest tank. Other areas of excavation are standard cut/fill operations. The site does not anticipate a dewatering system because it is located at the edge of the groundwater elevations per the soils report and will only need spot watering.

4.1.3 Structural Steel

The complex is composed of a variety of spaces including the three performance spaces, a scene shop, studios, classrooms, offices and support. To respond to the variety of spatial and performance challenges, a composite structural steel frame is recommended. Floor slabs will generally be composed of 2" 20-gage galvanized steel deck plus 3-1/4" of lightweight concrete reinforced with WWF 6x6 x W2.9 X W2.9 creating a 2-hour floor system. The slab will be supported by composite steel beams ranging in depth from 12" at 20' to 18" at 40' spans. In general, column spacings have been planned to allow floor beams and girders not to exceed a total structural envelope of 2'-0". This will expand slightly at some spaces such as the dance studio when a built-up floor with a damping slab and floor vibration criteria may require a slightly deeper structure. There are 6 different roof elevations and many will have roof-top units supported thereon. Roof screen frames are also required. The baseline scheme suggests the use of composite steel construction for all roofs as the concrete is necessary for noise attenuation. Column sizes are generally W10s, although larger columns may be required at tall spaces such as the scene shop and theatre rehearsal spaces. A crane will be used to place the steel and the composite metal deck. I was unable to determine the location and size of the crane at this time however, a crawler crane would be logical to use because it could move around the building to different locations to reduce the number of movements by the crane.

4.1.4 Cast-In-Place Concrete

The Performance spaces require concrete walls which are isolated from the adjoining spaces. The concrete walls will support the floor and roof framing within the performance spaces. A combination of cast-in-place concrete and steel framing will support the floors and balconies of these spaces. The concrete walls surrounding the performance spaces will be 18" cast-in-place concrete walls which will serve as the lateral and vertical supports resisting wind and seismic forces and also providing noise and vibration isolation from the surrounding spaces. As these walls are isolated from the surrounding structure for acoustic reasons, the bordering columns of the steel frame will have diagonal braced frames to stabilize the surrounding structure. In general, the stepped and curved seating platforms for the proscenium theatre and concert hall are planned cast-in-place concrete construction. At the rear of the proscenium theatre, two pilasters will be required to supplement lateral support. Steel plates with headed shear connectors will be cast into the walls to support the steel framing. The mechanical room and Concert Hall required basement walls to be 16" thick with reinforcing to support the backfill. The concrete placement methods will be with a concrete truck and pump, but also the use of the crane and bucket will be utilized.

4.1.5 Façade

The masonry on this project consists of 8" CMU block as the exterior load bearing wall covered with a brick veneer façade as shown in Figure 3. The other side of this elevation is also brick veneer façade but there is not 8" CMU used as the backing. The connection is face brick with lipped bricks at lintels and relieving angles attached with masonry anchors. It is assumed that the brick veneer will be relieved at each floor. A relieving angle system is hung from the spandrel beam at the roof, 3rd and 2nd floors using galvanized relieving angles. The scaffolding will be erected for the first portion and then repositioned for the next. The curtain wall systems found on this project are located on the north and south elevations as shown in Figure 3. They are made up of 8" aluminum framing with 1" insulating glass and custom cap covers. All of the windows throughout the classrooms and offices, including the curtain wall system, have a Low-E coating on the surface. The windows are located in those particular spaces to allow for daylight to penetrate into the space. Aluminum storefront doors are also found where the vestibules and entrances are located.

4.1.6 MEP Systems

The mechanical rooms are located in the basement level of the new PAHF. A goal of the HVAC systems will be to minimize energy consumption while maintaining space design criteria. Some of the interesting features that contribute to LEED are an automatic shutdown of air handling systems during unoccupied hours subject to building low and high temperature and humidity limits. The controls isolate supply air flow to each floor served from centralized air handling systems based on the floor occupancy schedule. This will be accomplished through DDC system programming, to isolate airflow per floor and per AHU, by closing air terminal unit dampers or floor zone dampers during unoccupied mode. The occupancy sensor controls are reducing the air supply to each space during the day when not in use. There are variable airflow air handling systems with variable frequency controlled fans and variable water flow heating and chilled water distribution systems with variable frequency controls. There is energy recovered from exhaust air and temper outdoor air by the total energy recovery heat wheels. Cooling and dehumidification control for the building will be provided from the campus chilled water distribution system. A pair of 10" chilled water mains are proposed to serve the building. The chilled water system will utilize variable flow pumping within the building via three base-mounted, bronze fitted, end-suction pumps. The campus high temperature hot water system will be utilized as the energy source for heating and domestic hot water generation within the new facility. Preliminary load estimates of design day heating and domestic water requirements for the new facility indicate a peak hourly load of approximately 9100 MBH. The HTHW mains will extend to three shell and tube heat exchangers for low temperature hot water heating service. Chemical water treatment for the HTHW system will be provided at the central plant by UMBC. Humidity will be controlled year around throughout the facility due to its impact on the short term tuning and the long term preservation of musical instruments, and due to the intermittent high occupancy levels which will require the introduction of large amounts of outdoor air. Steam will be generated to humidify the building by point of used gas fired steam humidifiers generally for each AHU located within the building. The facility will be conditioned by fifteen air-handling units, providing each space with their own capacity. The AHU's airflow quantities will be controlled by VFCs, not inlet vanes or any other control device. Each system will have a dedicated roof mounted spark resistant exhaust fan, corrosion resistant exhaust ductwork, and automatic isolation dampers. An 8" combined (fire and domestic) water service will be provided. Once inside the building, the service will split into separate domestic water and fire suppression systems. Because of low water pressure in this portion of the campus distribution system, an electric fire pump will be provided in a dedicated fire pump room on the First Floor. Two fire department Siamese connections will be provided on the exterior of the building. An alarm bell will also be provided on the exterior of the building adjacent to the Siamese connections. Inside, the building will be protected throughout by hydraulically designed automatic wet pipe sprinkler systems. The electrical rooms are located in the basement level of the new PAHF. The electrical system has 15kv medium voltage feeders that come off of the substations. A unit substation consists of two 15kv, 600 amp switches (incoming); one 15kv, 600 amp switch (outgoing); 2500 KVA transformer; and 3200 Amp, 480Y/277 volt, 3 phase, 4 wire, 60 hertz switchgear. Power will be distributed at 480Y/277 volts and dry type transformers will be provided to supply 208Y/120 volt loads. Emergency power will be provided by a natural gas-fired engine generator with a 600KW, 480Y/277 volt, 3 phase, 4 wire set. The facility program required the switchgear to be a double-ended substation, but in the project team meetings, UMBC has decided that a single line up with one transformer is sufficient for this building and a double ended substation is not required.

4.2 Project Cost

The construction costs are based on the predicted costs provided by The Whiting-Turner Contracting Company. The amounts are slightly estimated for comparison purposes. All costs shown here do not correspond to actual bid costs for the project.

Project Parameters

Total Square Footage:	90,000 SF
Total Building Perimeter:	768 LF

Construction Cost

Actual:	$63,034,950
Per SF:	$700.39

Total Project Cost

Actual:	$67,735,293
Per SF:	$752.61

Major Building Systems Cost

Major Building Systems		
System	Actual	Per SF
Concrete	$5,484,200	$60.94
Masonry	$1,730,188	$19.22
Steel/Metals	$4,515,340	$50.17
Mechanical	$11,774,000	$130.82
Electrical	$8,285,510	$92.06

4.3 Local Conditions

UMBC Performing Arts & Humanities Facility is located at 1000 Hilltop Circle in Baltimore, MD. The PAHF will be situated on 4.8 acres on the west side of Hilltop Road adjacent to the existing Fine Arts, Engineering and ITE Buildings shown in Figure 4. The blue outline represents where the site will be and the red outline shows the adjacent buildings. The picture off to the right (Figure 5) is a view of the existing site from which the black arrow is facing in

Figure 4. This campus is located 15 minutes from Baltimore's Inner Harbor, 45 minutes from Washington, D.C. and four miles from BWI Airport. In this region of the mid-Atlantic, concrete structures are competitive with steel; that is not the case in most regions. PAHF uses both types of structures on this project, which does not adversely affect the costs to any great extent. The market conditions at the time, made the market very favorable from a cost perspective for the owner. Being that the construction is taking place on existing parking lots, campus parking was reduced and is extremely tight. This allows there to be no available construction parking on campus, making workers park at a neighboring Rt. 95 Park & Ride and be shuttled into the site.

Along with the LEED certification, recycling is available and is being used on this project. The recycling/waste management requirement is to divert 50% of construction debris from disposal and the tipping fees are $400 per 5 ton cans plus $65/ton over the original 5 tons. The types of soils on this site in Baltimore, MD are suitable per the soils report (n/a). Significant rock was encountered during excavation which was not evident on the soils report. Also the subsurface water conditions are not a concern on this construction site.

Figure 4: UMBC Campus Map

Figure 5: Camera View of the Existing Parking Lot and Adjacent Buildings

4.4 Detailed Project Schedule

The Whiting-Turner Contracting Company was awarded the General Contracting responsibilities for the UMBC Performing Arts & Humanities Facility. The funding was approved in May 2010 followed by the Notice to Proceed in June 2010. These milestones are the beginning of the attached detailed project schedule in Appendix B.

UMBC Performing Arts & Humanities Facility Milestones	
Milestone	Date
Notice to Proceed	6/2/2010
Mobilization Approval	6/4/2010
Start Construction	7/2/2010
Proscenium Water Tight	5/4/2011
Black Box/BOH Water Tight	8/3/2011
Humanities Water Tight	8/17/2011
Mech Start up for finishes Humanities	8/19/2011
Mech Start up for finishes BB/Proscenium	10/1/2011
Project Completion	7/17/2012

Table 3: Project Milestones

In order to develop a detailed project schedule for the PAHF, it was important to establish some important dates and activities that needed to take place in order for the project to be completed. The projected completion date is July 17, 2012 and staying on schedule is important being that this is a campus and the traffic flow is a critical factor. Refer to Table 3 for a list of the important milestone dates found within the schedule.

Upon mobilization, construction activities began with installing temporary utilities, the excavation of the site including the demolition of the parking lots, and installing the excavation support systems. Following the excavation activities, the foundation activities will fall directly in line with the critical path. These activities include forming, reinforcing, and pouring all concrete walls and slabs within the basement of the building and also the tunnel that will tie into the new PAHF. The structure-to-grade is scheduled to start around December 2010. There is a complicated relationship between the site excavations, structural excavation, foundations and structural elements. There are multiple structural systems being used on this project. The different systems incorporated into this building are concrete structures, masonry bearing structures, structural steel, and some areas have a combination of all three. Certain areas are isolated structurally from adjacent areas and since there are varying depths of excavation and areas of structural foundation, this will cause a hold up in the progression of the adjacent foundation work. This process needs to be carefully organized to ensure that all trades are performing the proper work at the right time. While work is taking place on the structure above grade, interior work below grade will be starting to take place such as MEP rough-ins and equipment installation. Shown below in Figure 6 is the building footprint which indicates the theater and some of the rooms that are located on the first level.

Figure 6: Building Footprint

The Proscenium Theatre shown on the right will be enclosed with aluminum composite metal panels and the Humanities area of the building, which includes classrooms, offices, etc., will be surrounded by brick veneer façade. The curtain wall installation will be following closely behind in the proper sequence of events. These enclosures will provide the entire facility with a water tight status in May of 2011 August of 2011, respectively. At the time the work is taking place outside to enclose the building, work inside will be progressing through the MEP rough-in stages. Once the structures have the water tight status, the finish work can begin, eventually leading to substantial completion of the project.

4.5 Site Layout Planning

The site for the new Performing Arts & Humanities Facility is located on the campus of the University of Maryland, Baltimore County (UMBC). There is limited on-site parking for construction personnel and everyone else is required park of campus and then shuttle to the site. Based on the detailed schedule, the project consists of two major phases: Excavation and Superstructure.

Figure 7: Aerial View of UMBC PAHF Construction Site

Excavation

The excavation phase of UMBC's Performing Arts & Humanities Facility primarily consists of demolishing the existing parking lot, curbs, utilities, site lighting, railings, etc. before excavation can even begin. The soil that will be excavated for the foundation of the building will be kept in soil piles on site before it is hauled off to other locations, which can be found on the excavation site utilization plan in Appendix C. The project sits near the perimeter of the Hilltop Circle road and there are three adjacent buildings near the site. A beam and lagging system is used for the structural excavation support of the basement and tunnel areas as well as for the installation of the underground rain water harvest tank. Other areas of excavation are standard cut and fill operations.

Superstructure

During the superstructure phase of the project, the site is more congested than any other point during construction. The concrete, steel, masonry, mechanical and electrical subcontractors are all present on site with field trailers and storage facilities. A 140' boom tower crane is stationed within the perimeter of the building footprint and will be utilized to construct the structure of the building and unload materials and equipment associated with the structure. There will also be specified crane paths for the crawler cranes on site shown in Appendix C.

4.6 General Conditions Estimate

The estimate summarized in Table 4 below shows a representation of the costs for the general condition line items on the UMBC Performing Arts & Humanities Facility. These numbers are an approximation between the cost data and the industry standards provided by The Whiting-Turner Contracting Company.

General Conditions Summary

Line Item	Quantity	Unit	Unit Cost	Cost
Staff Reimbursable	$20,928.92	Week	104	$2,176,608
Total Construction Phase Non-Personnel	$30,308.65	Week	104	$3,152,100
CM-GMP Contingency	$9,615.38	Week	104	$1,000,000
TOTAL CM REIMBURSABLE COSTS	$60,852.95	Week	104	$6,328,708

Table 4 – General Conditions Estimate

The estimate was broken down into three categories: Staff Reimbursable, Non-Personnel, and CM-GMP Contingency. Staff Reimbursable includes the management and support staff for the project, such as the Project Managers, Superintendents, and Project Engineers. The Total Construction Phase Non-Personnel category incorporates items such as mobilization, temporary facilities, tools/equipment, safety, etc. Finally, the CM-GMP Contingency accounts for the GMP Contingency.

As shown below in Figure 8, the Non-Personnel costs account for nearly 50% of the general conditions estimate, which is evident given the amount of items listed under this line item. If these items were broken up into more categories, the Staff costs would be the largest. The overall general conditions amount of $6,328,708 is just over 9% of the total project cost of $67 million. Additionally, the 9% falls just below the industry average of 10% for general conditions. See Appendix D for the general conditions estimate.

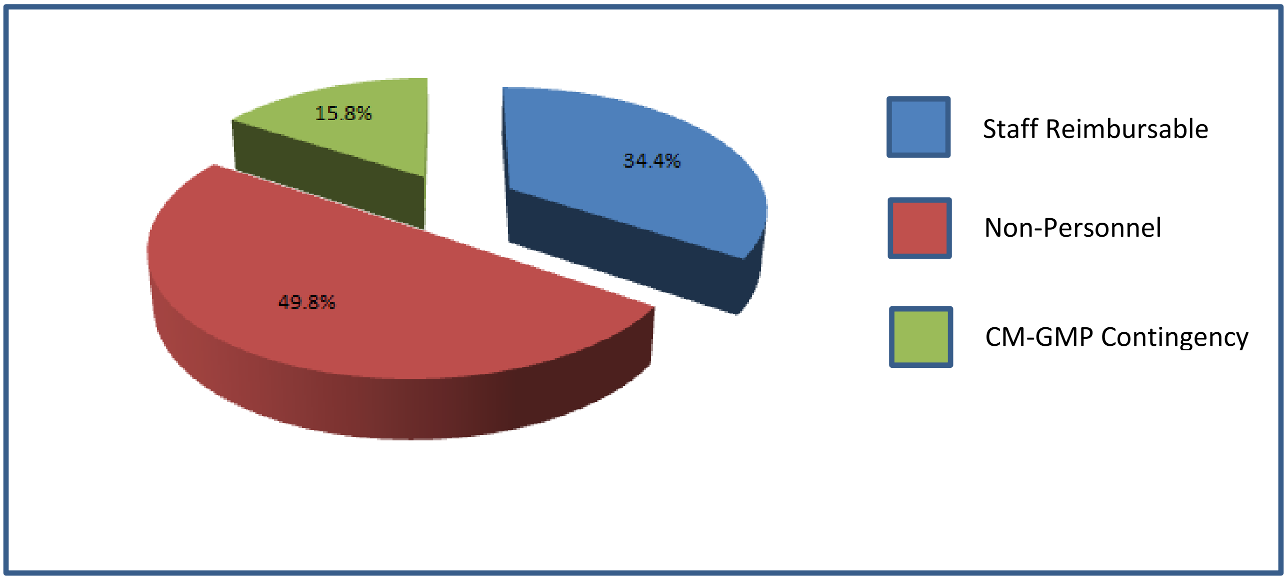

Figure 8: Percent Break Down

5.0 The Use of Precast Brick through Prefabrication

5.1 Problem Identification

Since the university has certain goals for this project to be completed on time and efficiently for the students, the use of prefabrication may be very useful. Also, being that the building is made up of three different structural elements, this poses a challenge of erecting the building because adjacent work has to stop in order for a certain area to be completed. The confusion of the sequence of elements will also lead into the masonry having difficulties erecting the brick veneer façade in the same manner. Their work will have to stop if other work adjacent to it is not complete, causing major delays.

5.2 Research Goal

The goal of this analysis is to design a precast wall system in place of the masonry wall system and see how the use of prefabrication will impact the trade coordination delays on site, the schedule, and the cost.

5.3 Methodology

- Research precast masonry wall panel systems
- Contact a manufacturer for design consultation
- Design a precast system for the exterior façade
- Analyze the impact to the structure from the precast system loads
- Determine transportation requirements to ship the precast
- Analyze the impact to the cost, schedule and constructability

5.4 Background Information

The UMBC Performing Arts & Humanities Facility facade was originally designed with a special brick veneer backed by structural reinforced masonry bearing walls (8" CMU) in certain areas and backed by steel studs in other areas. The color of this type of brick consists of 70% Driftwood Grey, and 30% Light Autumn by Cloud Ceramics, Roman Modular type. The original masonry package for this project was estimated to be complete in about 115 days and the proposed cost was about $900,000. The issue with this area of the project is that the building is made up of three different structural elements which causes delays when erecting the structure; when one structure is being erected, the other adjacent work has to stop until it's complete, which is a major efficiency concern. Being that erecting the structure was such a concern, it was proposed that prefabricated precast panels be used to help decrease the amount of delays. Prefabricated panels are becoming more and more efficient and will help save time on a project because these panels are constructed in a factory away from any site congestion; while the structure is being put up, the panels are being made at the same time. Since the superstructure has to be completed before the panels are attached, this helps reduce delays with different trades. Once the steel is complete, the panels can be shipped to the site and lifted straight off the truck onto the building for quick and effective constructability.

Some drawbacks to precast wall systems are that they are normally less flexible in design and aesthetic quality compared to a hand-laid brick wall. This means the proper selection of a system which can offer a high level of aesthetic quality is important. The design for the Performing Arts Facility required a match of the existing building features with an emphasis on a quality appearance and an exceedingly watertight enclosure. The joints between the precast panels and exterior curtain walls require close attention and quality control. Precast systems have control joints between the panels, which require quality control inspections in the field during construction. If the joints of the precast are not sealed/caulked far enough back, water will seep through the thin face brick and reach behind the panel causing water issues. To ensure these joints are properly closed with a quality seal, a successful mock-up would need to be constructed and tested for watertight assurance and quality aesthetic appeal. Figure 9 below is the mock-up design for the original face brick designed for this building.

Figure 9: Mock-up of Original Face Brick

5.5 Precast Design

Upon reviewing the type of building structure this project consists of and talking with contacts about what type of precast design is best for this system, it was most logical to connect the precast panels at the exterior beam and span from column to column above and below the windows and also have different size panels fit in between the window spaces; different type of connections could be used at the beam area. The precast design will consist of 341 pieces of precast that will range from different sizes. Some of the sizes were up to 12-foot high and could span from 35-40 feet max. The consultant at Nitterhouse Concrete Products also stated that they could accommodate for the special design pattern the owner/architect proposed. See Appendix E for the precast take-off charts for each elevation. In the elevation shown below in Figure 10, the different color sections represent the different panels which span from column to column above and below the windows and in between each window.

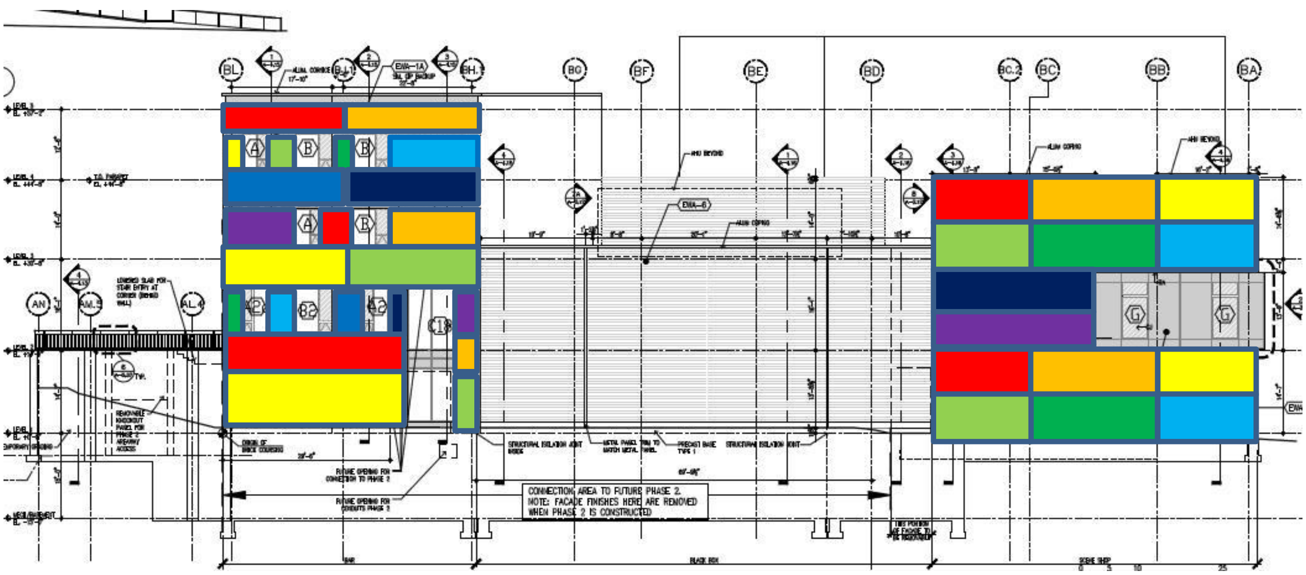

Figure 10: Elevation of Precast Design

5.6 Structural Impact

The precast wall panels will change the load to the structure which means checking the existing structure is important, and re-sizing the members might be necessary. When a new exterior building enclosure system is proposed over the originally designed system, it is important to take into consideration the structural implications this change has on the structural design. Calculations can determine whether the size of the structure is sufficient or if it needs to be increased based on the alternative system weight. As stated before, the precast panels were designed to span from column to column above and below the windows and have a separate panel made for in between the windows.

In most cases, precast panels will be heavier than that of normal brick tied into the structure. With this being said, the structure may have some slight impacts in deflections. Based on Table 5, the 6” thick precast panel weighs more than the originally designed brick veneer. Since that’s the case, the beams carrying the weight of the precast panels may need to be up-sized to be able to withstand the new weight.

STRUCTURAL WEIGHTS			
MASONRY WALL		PRECAST	
MATERIAL	WEIGHT (PSF)	MATERIAL	WEIGHT (PSF)
Brick	40	6" Thick Panel	75

Table 5: Structural Weights

The most common exterior beams that will be holding the new precast panel weights are W16x26, W14x22, and W21x44 beams. These beams were analyzed for the new proposed precast panel load cases and also for the existing masonry wall system. Table 6 shows the deflections for the existing masonry wall loads and also for the precast panel loads.

BEAM DEFLECTION		
BEAM SIZE	LOAD CASE	MAX DEFLECTION
W16X26	Masonry Wall Loads	0.374
	Precast Panel Loads	0.537
W14X22	Masonry Wall Loads	0.546
	Precast Panel Loads	0.783
W21X44	Masonry Wall Loads	0.538
	Precast Panel Loads	0.772

Table 6: Max Deflections on the Exterior Beams

The maximum deflection for the existing beam sizes for the masonry wall is slightly less than that of the precast loads, but after performing the calculations to check the composite beam design and deflection over a typical composite beam, it is determined that all three beam sizes are adequate to carry the load of the precast panels. Usually when precast panels are connected to a steel structure they will connect to clips that are located on the columns. In this situation, it is possible to connect clips/angles to the exterior beam using a fixed tie back connection or a bearing adjustable tie back connection; either will be suitable for the connection of these precast panels. See Appendix G for a detailed section of the two types of connections possible. Therefore, it will be assumed by this structural analysis that no changes to the structural system will be implemented for supporting the weight of the precast panels. See Appendix F for the structural breadth calculations determining if the existing beams can hold the new precast panel weight.

5.7 Trade Coordination

As stated numerous times above, trade coordination is an issue on this project because of the difficulties while erecting the three different structural systems. By using the prefabricated precast panels, this was supposed to decrease the amount of delays caused by the different trades on site. It is calculated in the upcoming section that utilizing the precast panels will reduce the masonry schedule by a significant amount of days. This means that the amount of delays will decrease because the structure will have to be completed first while the panels are being made in the factory. Since the panels cannot be attached to the structure until it is 100% complete this eliminates the issue that partially contributed to some of the delays on the project. Since the façade and the structure will no longer overlap, utilizing the designed precast panel system proves that there will be fewer delays caused by adjacent work trying to be completed at the same time.

Even though site congestion is not a concern being that there is so much laydown space on site, the site logistics have to be reviewed so that a precast erecting sequence plan is established. There are two accessible gate entrances for the precast trucks to enter through. Once the trucks arrive on site, they will be located in areas that have direct access to the cranes so that the precast panels can be lifted right off the truck and onto the building structure. Figure 11 shows the gate entrances, the locations for the precast trucks, and also the crane locations for erecting the panels onto the building. The precast erection will start on the East elevation with crane 1 which is represented by the orange rectangle; this crane will erect not only the east façade but also half of the south façade for the Humanities section. From there, the precast placement will move around the building in a counterclockwise direction, finishing up with the south façade at the loading dock area with crane 4. For a complete precast erection plan, see Appendix H for full detail.

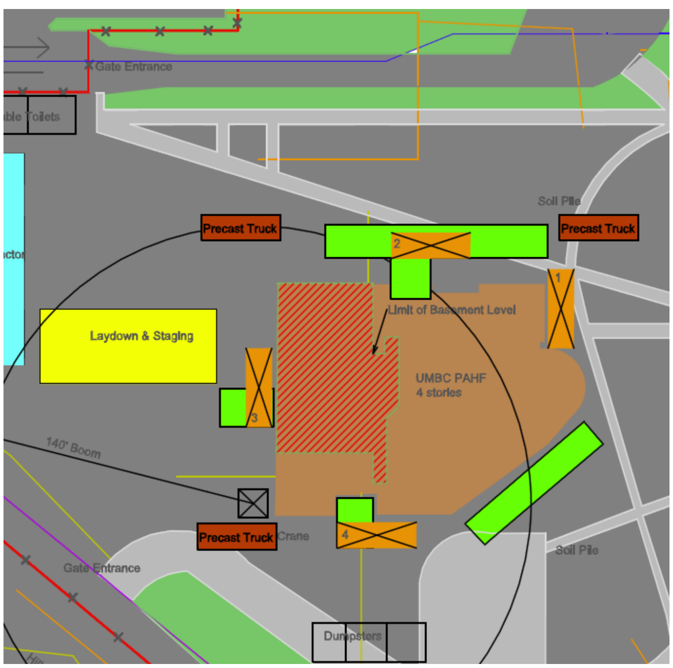

Figure 11: Precast Erection Plan

5.8 Schedule Reduction

Being that the masonry schedule was proposed to take 115 days to complete all the brick veneer façade and since there was trade coordination issues, the precast panels were designed in order to help improve efficiency on the job and reduce the amount of time it takes to erect the masonry system. After analyzing the new designed precast system, it was assumed from a previous conversation that it would take approximately 29 days to erect the precast panels. To determine this number of days, the amount of 341 precast panels was divided by the average erection time of 12 pieces of precast per day to get a number just under 29 days. Table 7 below shows the schedule savings on each elevation, totaling to about 90 days to build up the precast façade.

SCHEDULE REDUCTION DUE TO PRECAST FAÇADE						
ELEVATION	FAÇADE SF	MASONRY DURATION (DAYS)	TOTAL # OF PRECAST PANELS	PANELS/DAY	PRECAST DURATION (DAYS)	SCHEDULE SAVINGS (DAYS)
South	7126.12	40.00	103	12	8.58	(31.42)
North	6307.5	30.00	109	12	9.08	(20.92)
East	1923.87	15.00	42	12	3.50	(11.50)
West	4378.75	30.00	43	12	3.58	(26.42)
Corners	1098.8	0.00	44	12	3.67	3.67
TOTAL	**20835.04**	**115.00**	**341**	**12**	**28.42**	**(86.59)**

Table 7: Schedule Reduction Due to Precast Facade

Even though the schedule is being reduced by 90 days, remember that the superstructure still has to be fully complete before the precast panels get attached. The structures of the different parts of the building (Black Box, Proscenium Theatre and the Humanities classroom) all still go up simultaneously which may still cause some delays for the adjacent work. By implementing precast panels for the facade instead of the brick veneer, speeds up the exterior wall finish schedule and allows for the windows and curtain wall to be installed immediately after the precast is attached. The effect of fast tracking the schedule by almost 90 days will allow the project to be completed faster and the students can use the building sooner.

Keep in mind with that being said and looking back at the original schedule, the façade unfortunately does not run through the critical path for this building. The critical path runs through the proscenium theatre including tasks such as the foundations, rigging, specialties, and the finishes. The most important challenge on the project is getting the structure up in a timely fashion with the least amount of delays. Even though the façade is not a part of the critical path, it will still help by completing the precast ahead of schedule so that more time can be spent on the more difficult activities that may cause delays.

5.9 Cost Reduction

Performing a detailed cost analysis of the two differing systems is crucial in determining the cost impacts. The cost of the original brick veneer was estimated to be around $41.50 per SF; this included the cost of the back-up system provided. When conversing with the Nitterhouse representative, it was determined for this designed precast system that the cost is $37.00 per SF when there is CMU wall back up and $50.50 per SF where there is stud back up; also the precast corners were estimated to cost $37.00 per SF. The $37.00 per SF cost was all inclusive which meant that traveling, erecting, and prefabrication was all included in that specific cost. Below, Table 8 shows the differing prices between the two systems and it also shows the cost savings with using precast panels instead of brick veneer. As shown, there will not be cost savings for this project but there will be an added cost increase of about 17% after comparing the brick veneer with the precast panels.

COST DIFFERENCE DUE TO PRECAST FAÇADE				
ELEVATION	FAÇADE SF	MASONRY TOTAL COST	PRECAST TOTAL COST	COST SAVINGS
South	7126.121	$ 295,734.02	$ 299,682.71	-$3,948.69
North	6307.499	$ 261,761.21	$ 318,528.67	-$56,767.47
East	1923.87	$ 79,840.61	$ 86,942.69	-$7,102.08
West	4378.75	$ 181,718.13	$ 162,013.75	$19,704.38
Corners	1098.803	$ 45,600.32	$ 48,190.11	-$2,589.79
TOTAL	**20835.043**	**$ 864,654.29**	**$ 915,357.93**	**-$50,703.64**

Table 8: Precast Façade Cost Savings

5.10 Architectural Impacts

One issue that may arise when using precast panels is the leaking at the joints in between each piece of precast. The numerous joints in a precast concrete envelope are an important aspect of the façade design. The joints between precast units or between precast and other building components must be maintained to prevent leakage through the precast wall system. For an example, if the joint is caulked to close to the front face of the thin brick, then water may seep into the pores of the face brick and move behind the caulk joint, causing moisture and leakage behind the panel. The caulk at the joints should be designed far enough back to keep moisture out and also be able to withstand movement at the joint.

5.11 Conclusion

After performing this analysis, it is proved that utilizing the prefabricated precast system instead of the hand-built brick veneer is an effective way on improving the constructability on a project that has time requirements. As discussed in the analysis, one of the goals was to reduce the delays caused by trades trying to erect the structure at the same time. In section 5.7 it shows that using the precast system does eliminate some of the delays because in order to erect the precast panels, the structure has to be completed prior to erection. This newly designed precast system also proves to reduce the masonry schedule by almost 90 days; even though the façade is not a part of the critical path reducing the schedule will help fast track the following events that occur after the façade. A downside to using the precast panels is the small additional fee that needs to be added on to the project budget. As per discussed with the owner representative, he thought that utilizing precast panels was a good idea based on the schedule reduction and he mentioned that the small amount of money needed to erect the panels was affordable. The only issue that was not necessarily a concern with him, but would potentially be a problem with the overall campus, is the aesthetic look of the precast panels; it would take a lot of convincing and analyzing the precast before the campus would approve. In conclusion, based on the following results concerning the trades, schedule and cost implications, utilizing the designed precast system demonstrates to be a beneficial substitute in place of the brick veneer system.

6.0 Mobile Crane vs. Tower Crane Comparison

6.1 Problem Identification

As mentioned above, it is critical for the project to stay on schedule and get completed by a certain date for the students to start using the new facility. Being that the site utilizes a tower crane positioned on the southwest corner of the building that has a very large swing radius for a smaller building footprint, it is not necessary to have such a large crane. This type of crane takes numerous trucks to transport it to the site and then have to erect the crane when it arrives. There is enough space on site that the possibility of using a few mobile cranes instead may help save time and cost. This would allow the project to stay below the budget and on time for school to start.

6.2 Research Goal

The goal of this analysis will be to investigate the production, cost, schedule and site logistic impacts associated with utilizing mobile cranes instead of a tower crane.

6.3 Methodology

- Determine what size mobile cranes must be used to make all the picks
- Determine a new site logistics plan
- Contact Whiting Turner & suppliers to determine the overall costs of the tower crane and mobile crane
- Analyze the productivity of the mobile cranes compared to the tower cranes
- Determine the schedule impacts of a mobile crane instead of a tower crane
- Perform cost comparison

6.4 Background Information

As mentioned above in the problem identification, there is a tower crane being utilized during the erection of the structure for the new Performing Arts Facility, along with some mobile cranes. Being that the site is on a smaller scale compared to most jobs that use a tower crane, the need for such a large piece of equipment is not economical. Numerous mobile cranes, depending on the size and type, can be used to produce the same amount of work instead of having both types of cranes on site. Tower cranes take a lot longer to install and erect compared to mobile cranes and it is critical for the project to stay on schedule. Being that this project is only four stories and approximately 90,000SF a tower crane doesn't seem reasonable when comparing mobile cranes with this tower crane.

6.5 Crane Comparison

6.5.1 Mobile Crane

There are numerous types of mobile cranes that can be implemented, depending on the type of job and the max load it can lift. Some of the more popular mobile cranes that could be utilized on this project would be truck mounted cranes or hydraulic truck cranes, and/or crawler cranes. Some advantages of a mobile crane are that they can move around the site with or without a load attached, they perform each lift with very little set up required, they are flexible when it comes to handling different types of loads, and there are different tractions for a variety of jobs. A few disadvantages about these types of cranes are that they are very heavy in weight, cost a lot to be traveled around to different sites, and they also move slower from one location to the next on a project, especially if they need something that is on the opposite side of the site. The UMBC PAHF utilizes a few different mobile cranes for multiple areas of erection, while yet also using the tower crane. There is a 60 ton Hydraulic Truck Crane Grove (TMS700E) that will erect areas one through four, a 60 ton HTC Linkbelt (HT8660) that will erect areas five and nine and lastly there is a 80 ton HTC Grove (TMS800E) that will erect areas seven and eight. Below in Figure 12 is an image of a typical hydraulic truck crane. See Appendix I for the data sheets for those specific cranes.

Figure 12: Hydraulic Truck Crane

6.5.2 Tower Crane

A tower crane on the other hand is not mobile at all and is fixed to the ground on a concrete slab and sometimes even attached to the sides of the structure, but it can work in multiple areas at the same time. Tower cranes often provide the best combination of height and lifting capacity, which are beneficial in taller construction buildings (skyscrapers). Some of the disadvantages of a tower crane include the time it takes to erect the crane and the cost difference between a tower crane and a mobile crane. A tower crane takes much longer to install than a mobile crane on site because there has to be a foundation poured and set just to support the crane and then there is the need for a smaller crane just to assemble the rest of the tower crane. On top of already taking a long time to erect just the tower, it may take the operator another hour just to get to the seat depending on how high up the crane worker will be. Figure 13 shows the existing tower crane on the UMBC Performing Arts & Humanities Facility project; this picture is shot facing the north wall elevation.

Figure 13: Tower Crane

The tower crane that is used on this project is a BK 412-10 tower crane having maximum capacity at 22,000 pounds. The jib is 246 feet long and the crane can reach nearly everywhere on the site. See Appendix J for this tower cranes data sheet.

6.6 Site Logistics

As previously mentioned, the tower crane is located at the southwest corner of the building. This allows the swing radius of the crane to have accessibility to everywhere on site for picking up and laying down items. Using a tower crane allows there to be only one set area for staging and laydown materials off to the west side of the project site. If the new proposed site eliminated the tower crane and had only mobile cranes, then the contractor would have to come up with a new site logistics plan with multiple laydown areas. The mobile cranes would need space to move and also make sure they can reach where the material will be staged. Figure 14 shows a snapshot of the new proposed site plan without the tower crane. The green areas are the cranes paths and the yellow area shows the new multiple laydown areas for the cranes to have access to and from. See Appendix K for the new full site logistics plan without the tower crane.

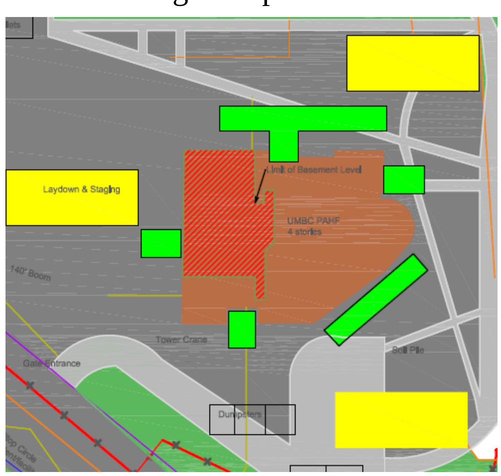

Figure 14: Site Plan w/o Tower Crane

6.7 Schedule Impact

The goal of eliminating the tower crane and utilizing just a few mobile cranes was to reduce the schedule time and length it took to install the overall crane. Once the tower crane was shipped to the site, it took 8 days to build up the foundation for the crane and then also another 3 days just to install the crane. Not only is this process lengthy, another mobile crane is needed to help install the tower of the crane causing more delays and cost.

Looking at the UMBC Superstructure Sequence Schedule in Appendix L, the overall time it took to unload steel, set the steel, weld and bolt, and lay the decking and studs was 318 days. Table 9 shows the specific crane per area and how many days it took for that area.

Crane Lift Areas		Days
HTC - TMS700E	Erect areas 1-4	187
HTC - HT8660	Erect areas 5 & 9	55
HTC - TMS800E	Erect areas 7 & 8	35
Tower Crane BK 412	Erect area 6	41

Table 9: Days per Crane Area

By eliminating the tower crane from this chart, another mobile crane would have to be added to take into account area 6. It would have to be a 90 ton hydraulic crane for the purpose that area 6 has the largest pick and the other cranes on site would not be able to carry that load. This may add a few extra days to erect all of the material but fortunately this crane will not need 11 days to install a foundation and a tower.

6.8 Cost Impact

In order to compare the cost implications of the initial crane costs with the new costs having eliminated the tower crane, RS Means Costworks was used. The total with the 3 mobile cranes and the tower crane come to a total of $1,317,069.09 as shown below in Table 10.

Quantity	LineNumber	Description	Crew	Daily Output	Labor Hours	Unit	Material	Labor	Equipment	Total	Ext. Total	Total O&P	Ext. Total O&P
242	015419500400	Crane crew, daily use for small jobs, 55-ton truck-mounted hydraulic crane, portal to portal	A3K	1	16	Day	$ -	$ 610.00	$ 1,525.00	$ 2,135.00	$ 516,670.00	$ 2,595.00	$ 627,990.00
35	015419500500	Crane crew, daily use for small jobs, 80-ton truck-mounted hydraulic crane, portal to portal	A3L	1	16	Day	$ -	$ 610.00	$ 1,700.00	$ 2,310.00	$ 80,850.00	$ 2,795.00	$ 97,825.00
9.7	015433602600	Rent crane truck mounted, hydraulic, 55 ton capacity, Incl. Hourly Oper. Cost.				Month	$ -	$ -	$19,677.00	$ 19,677.00	$ 190,866.90	$ 21,644.70	$ 209,953.59
1.25	015433602700	Rent crane truck mounted, hydraulic, 80 ton capacity, Incl. Hourly Oper. Cost.				Month	$ -	$ -	$22,764.00	$ 22,764.00	$ 28,455.00	$ 25,040.40	$ 31,300.50
Total											**$ 816,841.90**		**$ 967,069.09**
												Tower Crane	$ 350,000.00
													$ 1,317,069.09

Table 10: Initial Crane Costs

The reason the tower crane cost wasn't from RS Means is because the tower crane was actually a part of the concrete contractors bid. The concrete contractor utilized this tower crane because they own their own crane, making the cost a lot cheaper.

By eliminating the tower crane, a pump truck and another mobile crane must be added to cover the work that the tower crane produced. Again RS Means was implemented and the new cost of the cranes is a total of $6,649,107.65 as shown in Table 11. This cost is much higher than the initial cost because of adding two more types of cranes. The initial cost had an advantage using the tower crane since the concrete contractor owns the crane.

Quantity	LineNumber	Description	Crew	Daily Output	Labor Hours	Unit	Material	Labor	Equipment	Total	Ext. Total	Total O&P	Ext. Total O&P
9.7	015433602600	Rent crane truck mounted, hydraulic, 55 ton capacity, Incl. Hourly Oper. Cost.				Month	$ -	$ -	$19,677.00	$ 19,677.00	$ 190,866.90	$ 21,644.70	$ 209,953.59
1.25	015433602700	Rent crane truck mounted, hydraulic, 80 ton capacity, Incl. Hourly Oper. Cost.				Month	$ -	$ -	$22,764.00	$ 22,764.00	$ 28,455.00	$ 25,040.40	$ 31,300.50
242	015419500400	Crane crew, daily use for small jobs, 55-ton truck-mounted hydraulic crane, portal to portal	A3K	1	16	Day	$ -	$ 610.00	$ 1,525.00	$ 2,135.00	$ 516,670.00	$ 2,595.00	$ 627,990.00
35	015419500500	Crane crew, daily use for small jobs, 80-ton truck-mounted hydraulic crane, portal to portal	A3L	1	16	Day	$ -	$ 610.00	$ 1,700.00	$ 2,310.00	$ 80,850.00	$ 2,795.00	$ 97,825.00
3	015419500600	Crane crew, daily use for small jobs, 100-ton truck-mounted hydraulic crane, portal to portal	A3M	1	16	Day	$ -	$ 610.00	$ 3,375.00	$ 3,985.00	$ 11,955.00	$ 4,620.00	$ 13,860.00
0.1	015433602720	Rent crane truck mounted, hydraulic, 100 ton capacity, Incl. Hourly Oper. Cost.				Month	$ -	$ -	$30,704.00	$ 30,704.00	$ 3,070.40	$ 33,774.40	$ 3,377.44
10.6	015433102140	Rent pump concrete truck mounted 5" line 110' boom, Incl. Hourly Oper. Cost.	C-14D			Month	$ -	$ -	$15,672.00	$ 15,672.00	$ 166,123.20	$ 17,239.20	$ 182,735.52
318	015433102140	Crew C-14D for pump concrete truck.				Days	$ -	$9,337.40		$9,337.40	$2,969,293.20	$ 17,239.20	$5,482,065.60
Total											**$3,967,283.70**		**$6,649,107.65**

Table 11: Crane Costs w/o Tower Crane

6.9 Conclusion

As shown in section 6.7 and 6.8, it was proven wrong to eliminate the tower crane. Even though the schedule would be reduced by a few days of foundation work and installation, the advantage the concrete contractor had over the tower crane cost was very beneficial. Not only was it beneficial for the contractor to supply his own crane, but also it was shared with other trades as well.

Ultimately, the decision to keep the tower crane was based on the schedule, cost and production detailed in this analysis.

7.0 Study on PV Roof Panels

7.1 Problem Identification

The UMBC Performing Arts & Humanities Facility had looked into utilizing PV panels on the roof being that is building is supposed to be the first building on campus to become LEED certified. Due to financial implications this technique was removed early on. Using PV panels not only to provide more LEED points but also the energy produced will be used to power the Humanities portion of the building and if there is extra power it will be sold back to the grid and eventually save the university money in the long run.

7.2 Research Goal

The goal of this analysis is to design a PV roof system and calculate how much energy is produced and saved annually to reduce the energy costs for the owner over a certain payback period.

7.3 Methodology

- Research information about PV panels
- Determine the number of panels to be used on the roof
- Contact a PV panel manufacturer
- Calculate additional loads to see if the structure is affected
- Calculate life cycle cost and payback period

7.4 Background Information

As mentioned above, PV panels were thought of when pursuing a LEED certification but the financial budget for this job just wouldn't support this addition to the scope of work. If UMBC plans on using this building for a long time, the addition of PV panels overtime would show the owner how much energy and cost they could actually save. Being that the price of everything is rising, the use of a PV system could have some major benefits in the future. Not everyone is used to the thought of sustainability yet but the research has shown that there are sustainable techniques that are growing and being widely used. When implementing PV's on this project, it is assumed that there is not enough space to provide for the amount of PV's needed for a theater building but when using the panels in a certain area, will in the end, result in a reduction of the cost of energy. Each state has different incentives which would help with the cost of the system, which seemed to be the problem on this job. Utilizing a PV roof system would not only make the job more efficient but it would provide a great renewable energy source which benefits the owner after the project is complete.

7.5 PV Array Design

Based on the design parameters for Baltimore, MD shown in Table 12 and also looking at the available roof space, the layout and orientation for the PV system was determined. The large rectangle space is the Humanities rooftop which faces southwest and is the best available space for the PV system. To make sure the PV design was the most accurate so that there will be no shading on the panels at any time of day or year, a Google SketchUp model was made to produce the sun angles. The solar shading on the model occurred at 9AM and 3PM during the four different solstices shown in Figures 15-17. As shown in the model, the design was created so that the panels did not have any shade on their surfaces to cause negative effects on the energy production.

DESIGN PARAMETERS FOR PV SYSTEM	
Location	Baltimore, MD
Latitude	39.26°N
Longitude	76.71°W
Elevation	47m
Roof Orientation	South-Southwest
Roof Space	9075.78sf
Slope of Roof	0°
Optimum Tilt Angles:	
Summer	24°
Fall/Spring	35°
Winter	54°
Sun hours/day (yearly avg)	12

Table 12: Design Parameters

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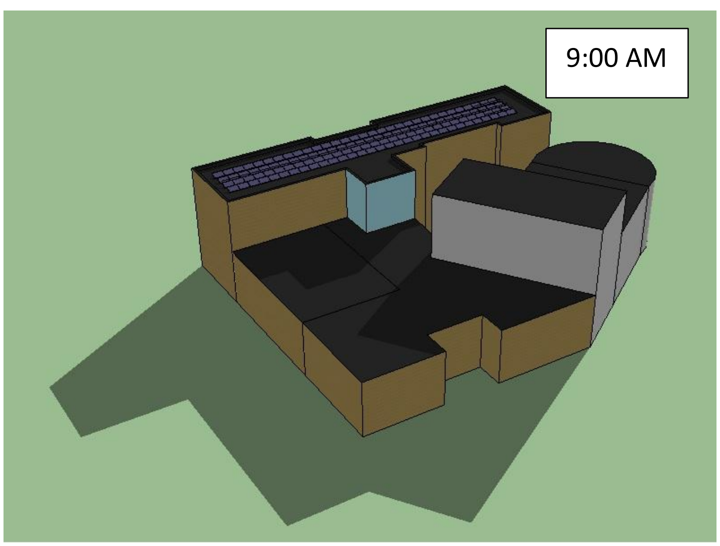

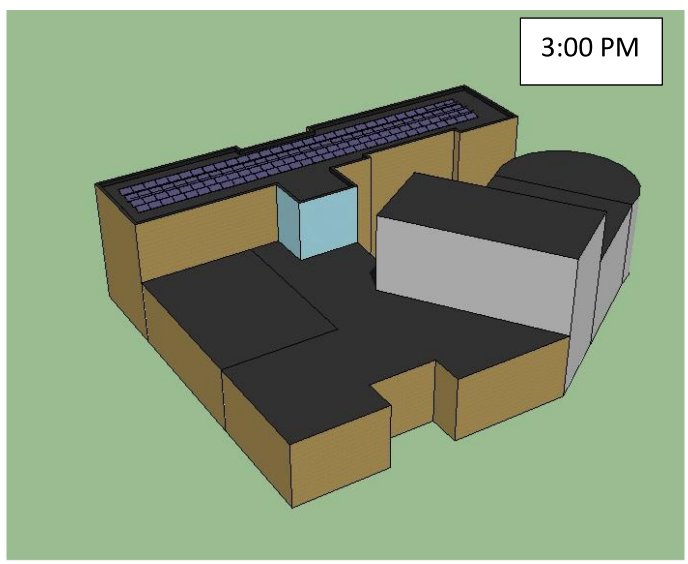

Figure 15: Summer Solstice (June 20)

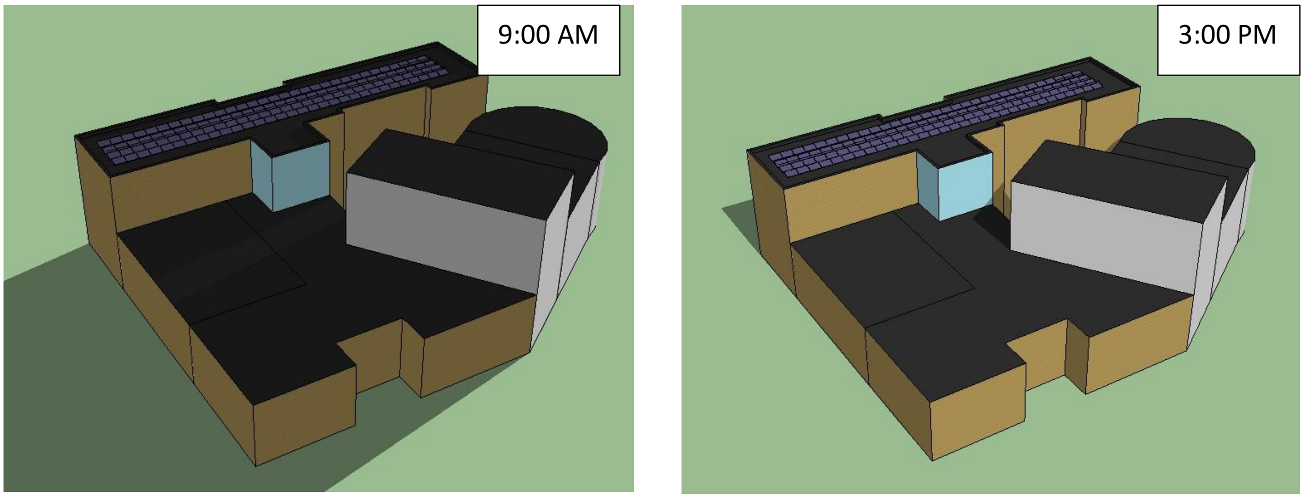

Figure 16: Fall & Spring Equinox (March 20, September 22)

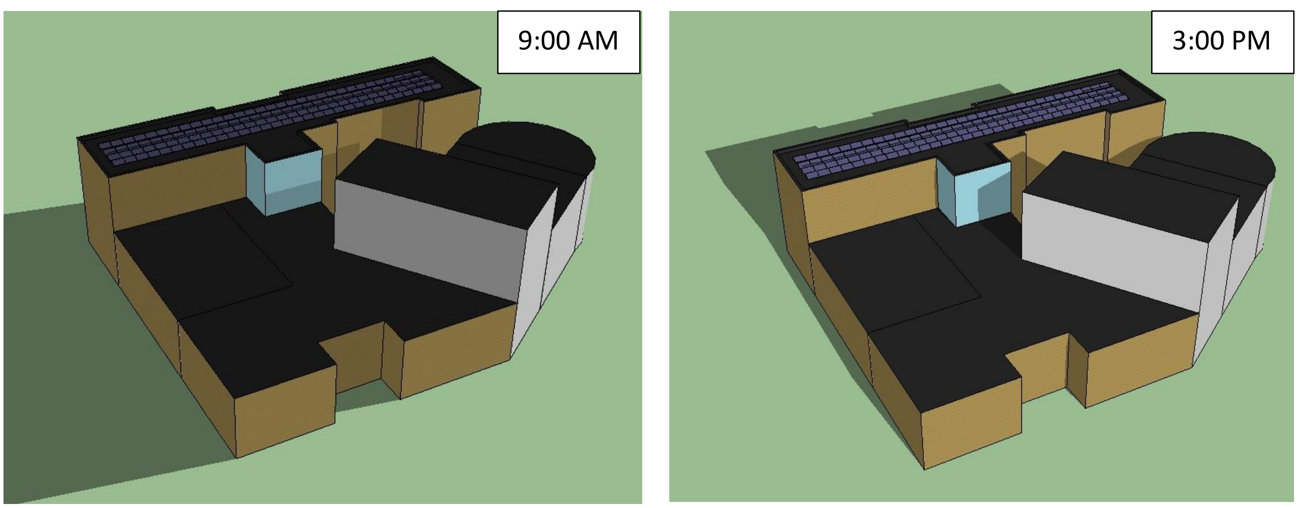

Figure 17: Winter Solstice (December 21)

Assuming that the PV system would not be able to produce enough energy for the entire building since the theater load is massive within itself, it was obvious to concentrate one area of the buildings energy and design the system to meet that certain load for that section of the building. The lighting in the Humanities section of the building consists of multiple lights on each floor which makes up a good portion of the total load of the buildings energy usage. So in order to design a specific PV system to account for the energy used by the lights in the Humanities section, a load take-off was performed to determine the energy load from these lights per floor. Table 13 shows the total energy used by the Humanities section lights.

ENERGY LOADS - HUMANITIES LIGHTS		
FLOOR LEVEL	QUANTITY	WATTS
Level 1	173	6751.7
Level 2	175	8292.85
Level 3	187	6744.1
Level 4	165	5412.9
TOTAL	700	27201.55

Table 13: Estimated Energy Load for Humanities Lights

As shown above, the total watts that the Humanities lights produced is approximately 27kW, and using the wattage of each panel to be 235W based on the panel spec sheet, the required number of panels is at least 116 panels to account for the lights in the Humanities section of the building. To take full advantage of the leftover space on the roof, 24 more panels were added for a total of 140 PV panels. The extra energy these panels produce will run right back into the grid, and will be useful for other buildings on campus. The PV array system is then designed to have 140 panels, each panel producing 235 watts of power. The type of panel chosen is a Sharp NU-U235F1 that will be mounted on a ballasted roof mounting system with a fixed tilt to receive optimum sunlight at all times. Since the entire Humanities roof section is being utilized, there will be 4 rows of 35 panels with about 5.5' spacing between each row so that one panel does not shadow onto another panel. This panel layout shown in Figure 18 not only optimizes the sunlight, but it suffices the requirements of having maintenance access on the rooftop. For more information about the product data used, see Appendix M.

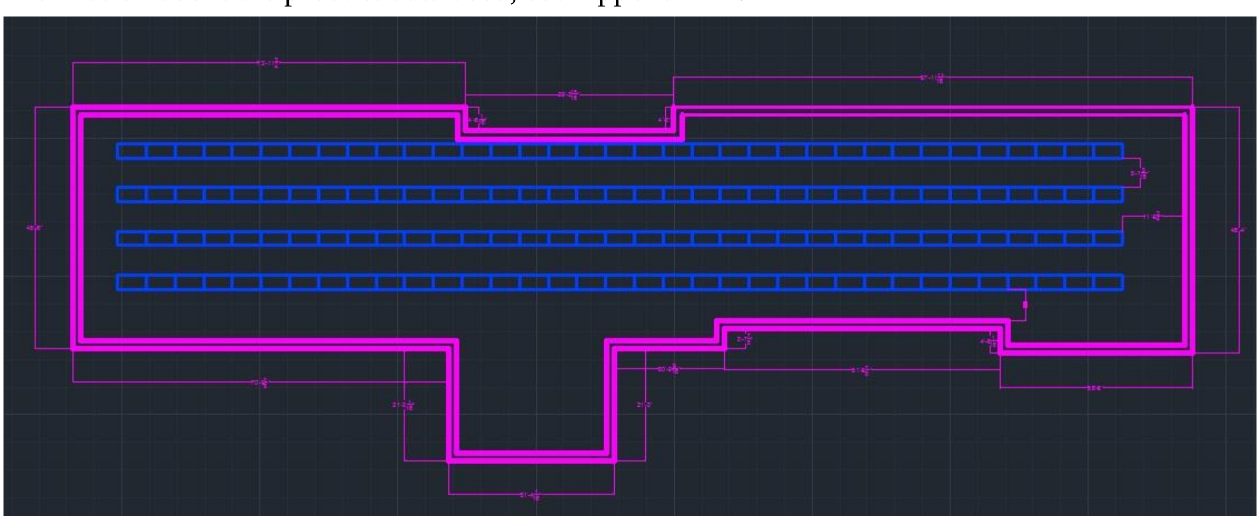

Figure 18: PV Array Layout

7.6 Energy Production & Electrical Impact

Based on the given parameters for Baltimore, MD (Table 14), the yearly value of energy was produced using the PVWatts calculator. As shown in Table 15, the yearly energy value of $3129.40 was calculated; this table also shows the total production results from the PVWatts calculator for that area.

STATION IDENTIFICATION	
City:	Baltimore
State:	Maryland
Latitude:	39.18° N
Longitude:	76.67° W
Elevation:	47 m
PV SYSTEM SPECIFICATIONS	
DC Rating:	32.9 kW
DC to AC Derate Factor:	0.77
AC Rating:	25.3 kW
Array Type:	Fixed Tilt
Array Tilt:	35.0°
Array Azimuth:	200.0°
ENERGY SPECIFICATIONS	
Cost of Electricity:	7.8 ¢/kWh

Table 14: Station Identification

PV WATTS ENERGY PRODUCTION RESULTS			
MONTH	SOLAR RADIATION ($kWh/m^2/day$)	AC ENERGY (kWh)	ENERGY VALUE ($)
1	3.30	2649	206.62
2	4.20	3030	236.34
3	4.74	3630	283.14
4	5.14	3756	292.97
5	5.38	3901	304.28
6	5.83	3917	305.53
7	5.78	4004	312.31
8	5.38	3734	291.25
9	4.91	3362	262.24
10	4.75	3497	272.77
11	3.42	2528	197.18
12	2.70	2112	164.74
Year	4.63	40121	3129.4
PV WATTS FACTOR = Annual AC Energy/System DC Rating = 40121/32.9 = 1219.5			

Table 15: Energy Production Results

In order to determine the required electrical components for the PV system, the system tie-in needs to be identified first. This PV system designed for the Humanities rooftop must have a tie-in system with a supply-side connection. When a supply-side connection is necessary it has both the PV power coming into a meter box and also the existing utility grid coming into the meter box. Once inside the meter box, both loads meet and only one feed is sent to the main panel board in the electrical room which then distributes the power to the Humanities section. Figure 19 shows the specific supply-side connection for this PV array design. When using a supply-side connection system for a PV system to connect to the existing electrical system, certain components are needed for operation. Some of the components include the DC and AC wires and disconnects, the inverter, and the tap required to tie into the meter box.

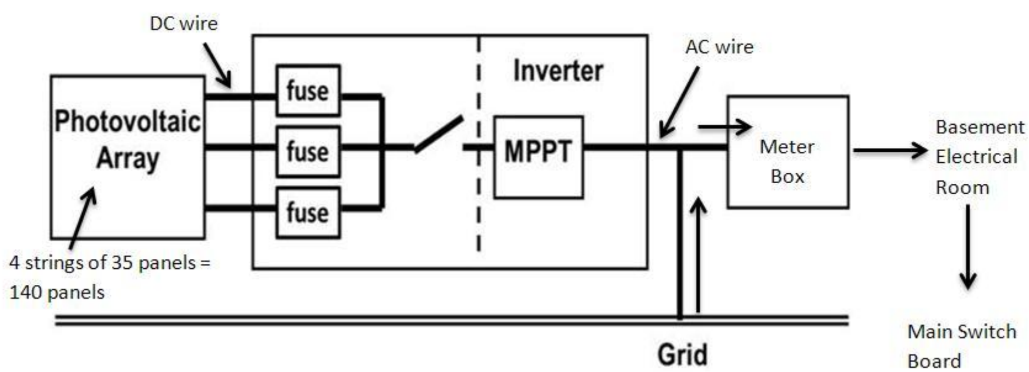

Figure 19: Supply-Side Connection Diagram

Because the electrical room is located in the basement of the Humanities Building, there is potential for large voltage drops. As a result, it was determined that the inverter would be placed on the roof to minimize these voltage drops. DC wire is also more expensive than AC wire so locating the inverters on the roof would be less expensive than locating them in the electrical room in the basement. For determining the sizing of the DC wire for this particular system, see Appendix N. The selected inverter for these PV panels was a Sunny Tower-US which contains six, Sunny Boy 6000-US inverters producing 45.0 kW; this was more economical to select a tower which already contained everything needed for this system compared to buying individual inverters. This size inverter was chosen because the next size down is 30.0 kW and this isn't large enough to cover the PV array design. The complete product data for this inverter is located in Appendix M. Figure 20 below shows the exact location of the inverter; the inverter is placed in the northwest corner since the main electrical room is located on the west side of the basement. The AC wire would run down the building into the electrical room, where as previously shown, will meet the existing utility grid power.

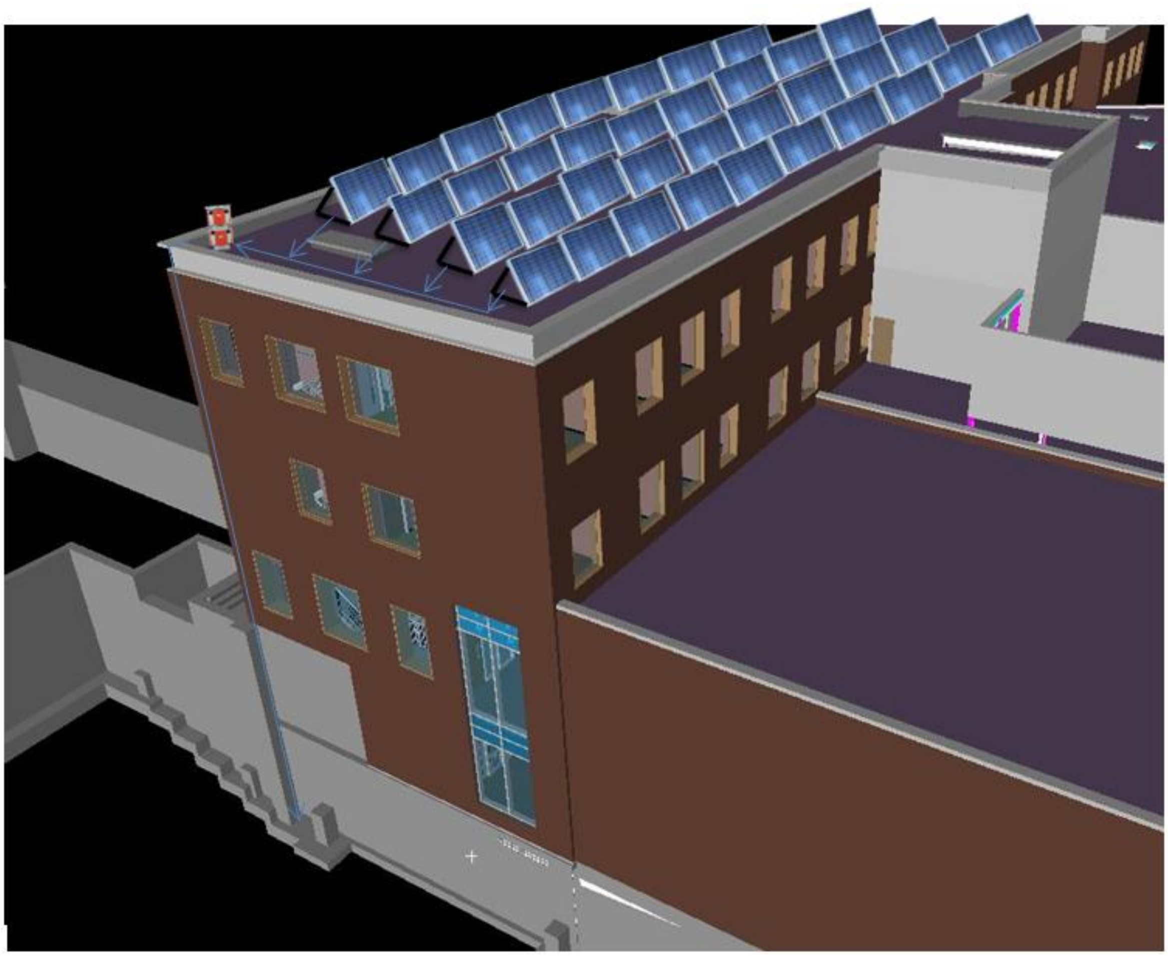

Figure 20: Inverter and Wire Location for the PV System

7.7 Structural Impact

With the installation of this system, it is prevalent that the photovoltaic array will possibly present structural problems that would need to be addressed with modifying the types of beams used for the roof support. The selected mounting structure, Power-Fab Ballasted Roof Mounts, for the rooftop PV panels will not require roof penetrations. The structure is held in place by the weight of concrete blocks that each weigh 14.5 lbs. that sit in ballast trays. Also, there is EPDM rubber on the bottom of the rack surface to increase friction and protect the roofing. The NU-U235F1 panel selected for this PV design weighs 44 lbs each based on the product data supplied in Appendix M. To determine the structural impact of the system, the tributary area of the roof steel members had to be calculated, which would reveal the quantity of PV panels supported by each steel beam/girder. Figure 21 shows the designed structure for a typical bay on the fifth floor roof level.

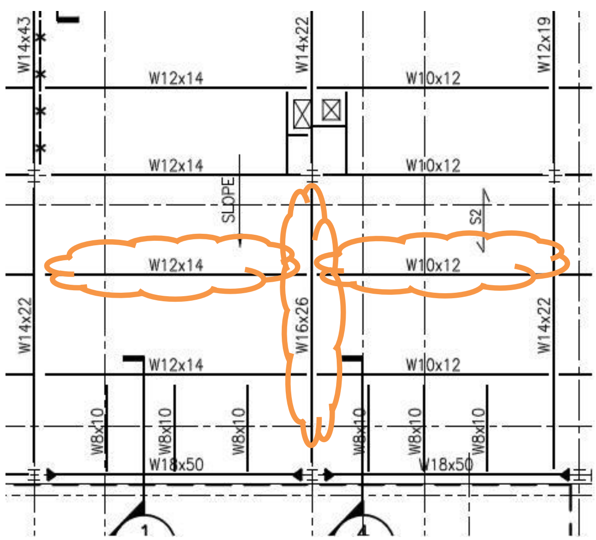

Figure 21: Typical Bay – Roof Level

For this analysis, the W12x14 beam, the W10x12 beam, and the W16x26 girder were checked for loads and deflections from the PV array. See Appendix O for the structural calculations of these beams and girders. After calculating the loads and deflections on these steel members from the PV system, it was determined that this minor additional load on the roof would not require any design change and the current steel structure would be sufficient to handle the loads from the PV array.

7.8 System Cost

To determine the system cost of the photovoltaic array, an approximate cost estimate for the system was determined from a price quote done by a Solar Gaines representative. The summary shows that the average pre-incentive cost to install this specific system in Baltimore, Maryland is approximately $200,000. Table 16 below shows the estimated cost proposed by Solar Gaines for the 32.9 kW PV array system specifically designed for the UMBC Performing Arts & Humanities Facility before and after incentives were taken into account.

Proposed System Cost and Incentives	
Pre-Incentive System Cost	$197,291
Federal Grant	($59,187)
Maryland Grant	($16,450)
Net Cost After One-Time Incentives	**$121,654**
Average electrical savings/yr over payback period	$7,482
Average per year SREC payment over payback period	$12,491
Total average yearly benefit over payback period	$19,973
Payback Period	6.09
Average Yearly ROI	14%

Table 16: Estimated PV Array Cost

The following are the credits found available to the state of Maryland for the installation of a PV system. These incentives are used to determine the payback period of installing such a system. One incentive is the Maryland State Energy Program which offers $500 per kW of system size. Another is the Maryland Energy Credit which is $0.40 per kWh produced. Last is the Federal Tax Credit which offers 30% of the installation cost.

The main reason behind installing a photovoltaic array is not only to reduce energy costs but to find out the acceptable payback period. At this time, the electric cost per kilowatt hour in the state of Maryland is $0.156 with an expected market inflation rate of 3.00% each year. To show the cumulative benefit of the system, the payback period was calculated for the option of 0% of the initial system cost borrowed and paying the upfront cost all at once. See Appendix P for the complete feasibility analysis calculated by Solar Gaines. This option implies that UMBC will completely fund the PV array system at the time of installation. This option includes an initial cost of $121,654 after rebates and incentives are taken into consideration. There will be a yearly energy savings of about $20,000 per year which produces a positive net of $293,146 throughout a 25-year system life cycle. Figure 22 shows that the PV system recovers all upfront costs by year 6, which is very beneficial to UMBC given that the campus had financial implications that steered them away from using such a system.

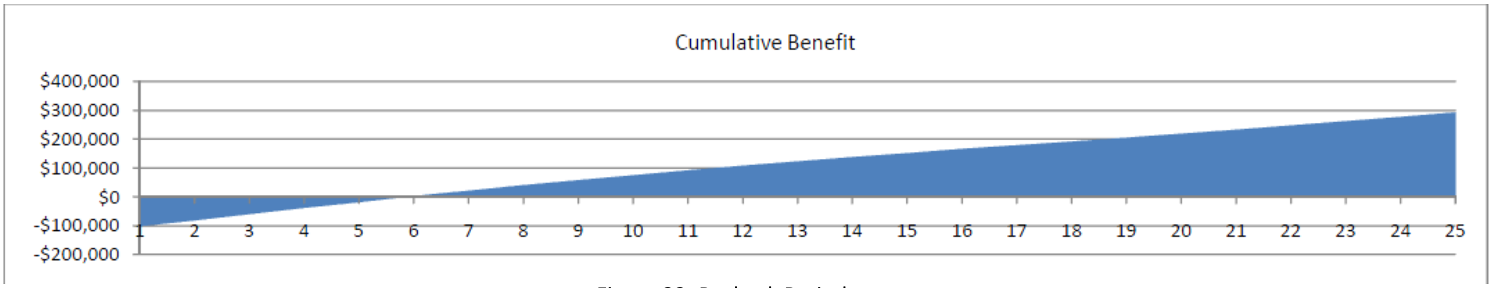

Figure 22: Payback Period

7.9 Conclusion

After performing this analysis, it is proved that installing the designed PV array system on the Humanities rooftop was ideal to produce power for that section of the building. For the 32.9 kW system, it was optimal to use 140 panels and all available roof space as long as there wasn't any shading effects. The recommended tie-in system was a supply-side connection with the inverter tower located on the roof to minimize the DC wire run. As shown in the analysis, there were no structural impacts by placing these panels and mounting systems on the Humanities rooftop. Per the discussion with the owner representative, UMBC had looked into pursuing the use of photovoltaic panels on the roof while this project was still in the preconstruction phase but it was determined that adding them would make the project over budget and the State does not allow the project to go over the budget even if the panels have a payback period. The total cost of the PV system after incentives was estimated to be about $121,654 with a 6 year payback period. If the state does not allow a project to go over budget, it can be proposed that a loan be utilized to cover the costs without actually adding them to the project cost. This option would not only allow the UMBC to use PV panels and consume energy for the building but being that the payback period is early on, that proves to be beneficial to the campus since then plan on operating this facility for at least 50 years round about.

8.0 Conclusions

Throughout the entire year in the AE Capstone Thesis course, the UMBC Performing Arts & Humanities Facility project was looked at in much detail after becoming familiar with the building statistics during the fall semester. After the building was evaluated, certain aspects of the construction process that could be altered to benefit the efficiency on this job were proposed for this report. This senior thesis report was used to show the findings of the three topics analyzed: the prefabrication of precast panels, the comparison between mobile cranes and a tower crane, and the study of PV panels. These topics discussed were not actually implemented onto this project and the research done was strictly performed based on the senior thesis requirements.

Analysis one attempted to eliminate the delays caused by the different trades and also reduce the schedule and cost. The major problem that caused delays in work was the structure having three different components and when one portion was being erected, the adjacent work had to stop. Because of this issue a precast wall system was designed since the superstructure had to be complete first before the precast panels could be attached. This would help save time and reduce the amount of delays that the different trades produced. The design of this prefabricated precast system saves almost three months off the schedule that the masons would be working to put up the brick veneer. Unfortunately, not only does this system reduce the schedule, this wall system also adds an additional cost of about $50,000 to the project budget. Implementing the prefabricated precast panels on this building proved to reduce the schedule and make the project more efficient by reducing the amount of delays on site with the trades even though there was a small cost added on. So in conclusion, the precast panel façade proves to be a practicable option to incorporate into the Performing Arts & Humanities Facility.

Analysis two attempted to eliminate the tower crane which seemed not economical and save cost and time. Even though taking away the tower crane decreased the schedule time, there was still a major downfall. By removing the crane means there needs to be other cranes in place of the tower crane, made the cost of the total cranes increase by a lot. The reason behind this is because the concrete contractor supplied his own tower crane which came at a reasonably lower cost than a normal tower crane. Since the analysis showed an increase in crane cost, the best idea is to just keep using the tower crane.

Analysis three attempted to reduce the energy costs of the building and help save the owner money by designing a PV system on the rooftop. The photovoltaic array system was designed for the Humanities roof and the total energy the system would produce is 32.9 kW, using 140 panels; four rows of 35 panels. The array of panels would be connected to an inverter placed on the roof which would transfer power from DC wires to AC wires down into the electrical room located in the basement. The total cost of the system is $121,654 after taking out for the Maryland incentive programs. Using this system would save the owner about $20,000 a year in energy and by paying for the system up front and not using any loans, the system would have a 6 year payback period. In conclusion, it is recommended to install this system on the rooftop since this analysis proves to have financial benefits to the university. Also if the campus intends to utilize this building for at least 50 years the impact on energy savings is tremendous.

In general after looking into all three analyses topics, it is shown that the proposed ideas for this building based on the existing information, will help make the construction of this building more efficient and effective. By implementing the prefabricated precast design for the façade proves to be an efficient way of reducing the schedule and reducing the amount of delays caused by the trades, even though there is a minor additional cost for the system. The removal of the tower crane was thought to have a positive impact on the cost and schedule, but numbers show it only increased the cost. Finally, by designing a PV system for the rooftop of the Humanities section, showed how much energy could actually be saved by using a renewable energy system. Not only is energy being saved but this system is also financially practical for the owner. In conclusion, each topic that was researched within this report just shows how the construction of buildings can improve with efficiency and quality.

9.0 Resources

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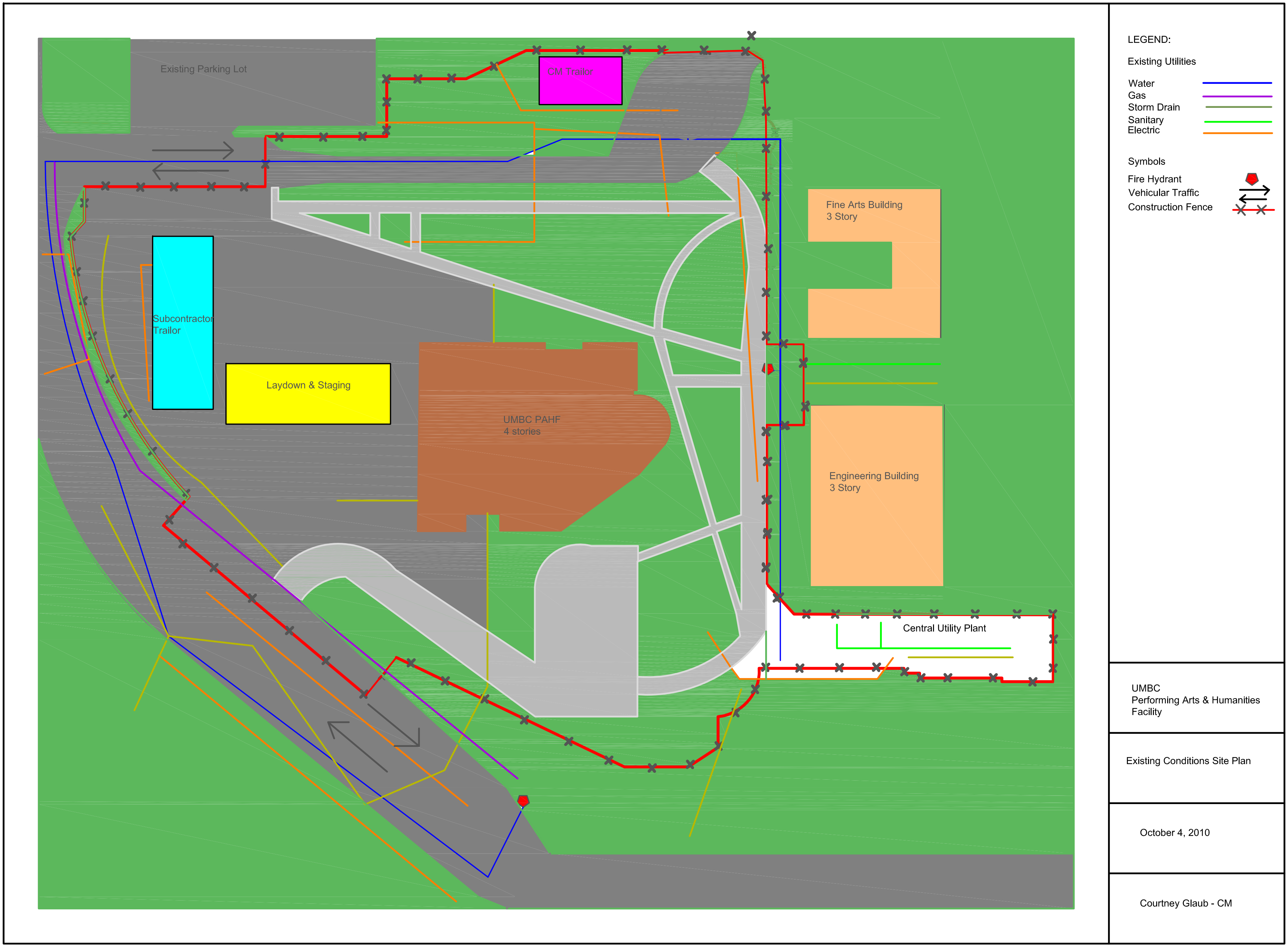
APPENDIX A – Existing Conditions Site Plan



UMBC
Performing Arts & Humanities Facility

Existing Conditions Site Plan

October 4, 2010

Courtney Glaub - CM

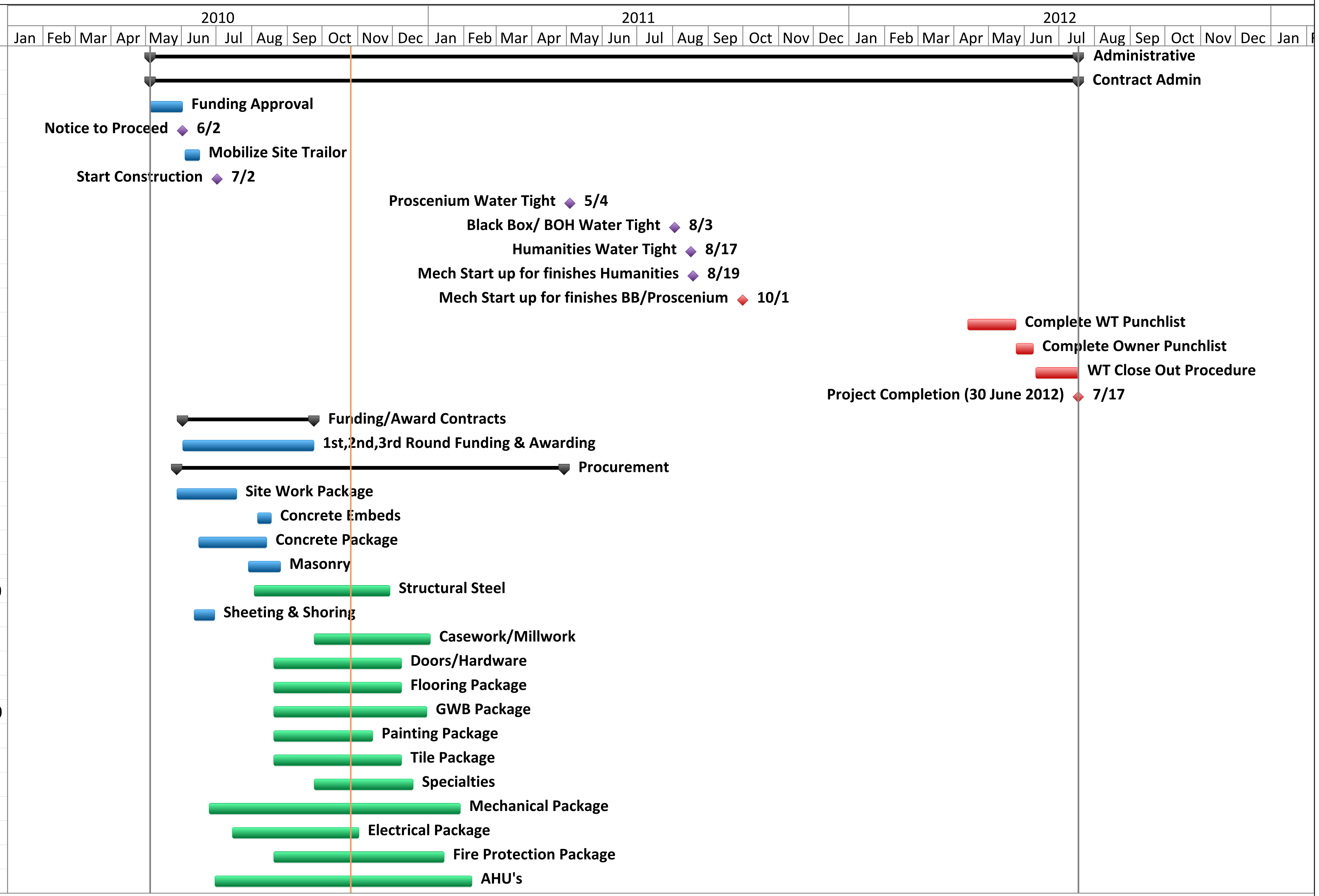
APPENDIX B – Detailed Project Schedule

WT 100 YEARS

Courtney Glaub
Construction Management

Detailed Project Schedule - Tech 2
October 27, 2010

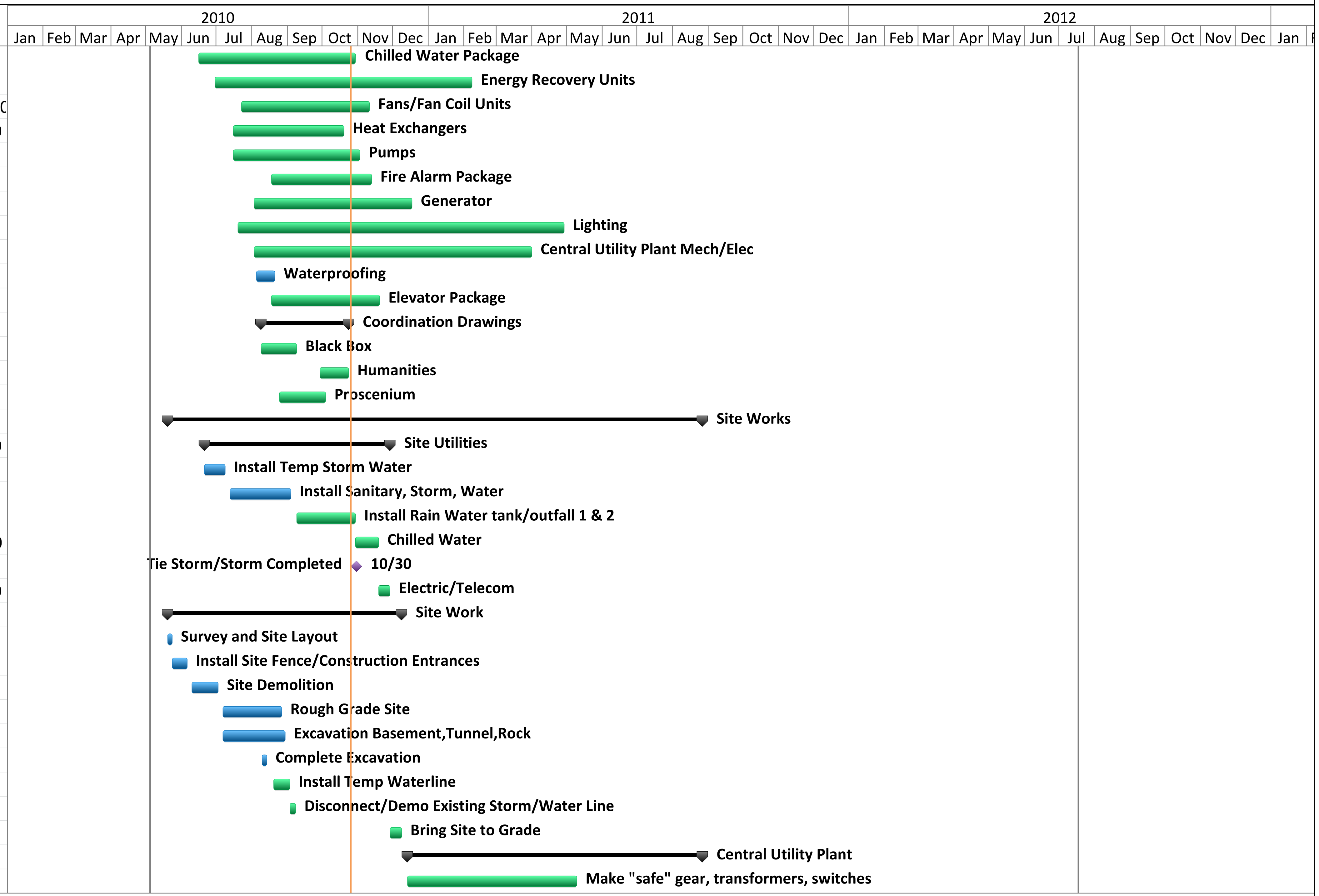
Task Name	Duration	Start	Finish
Administrative	575 days	Wed 5/5/10	Tue 7/17/12
Contract Admin	575 days	Wed 5/5/10	Tue 7/17/12
Funding Approval	20 days	Wed 5/5/10	Tue 6/1/10
Notice to Proceed	0 days	Wed 6/2/10	Wed 6/2/10
Mobilize Site Trailor	9 days	Fri 6/4/10	Wed 6/16/10
Start Construction	0 days	Fri 7/2/10	Fri 7/2/10
Proscenium Water Tight	0 days	Wed 5/4/11	Wed 5/4/11
Black Box/ BOH Water Tight	0 days	Wed 8/3/11	Wed 8/3/11
Humanities Water Tight	0 days	Wed 8/17/11	Wed 8/17/11
Mech Start up for finishes Humanities	0 days	Fri 8/19/11	Fri 8/19/11
Mech Start up for finishes BB/Proscenium	0 days	Sat 10/1/11	Sat 10/1/11
Complete WT Punchlist	30 days	Fri 4/13/12	Thu 5/24/12
Complete Owner Punchlist	11 days	Fri 5/25/12	Fri 6/8/12
WT Close Out Procedure	27 days	Mon 6/11/12	Tue 7/17/12
Project Completion (30 June 2012)	0 days	Tue 7/17/12	Tue 7/17/12
Funding/Award Contracts	82 days	Wed 6/2/10	Thu 9/23/10
1st,2nd,3rd Round Funding & Awarding	82 days	Wed 6/2/10	Thu 9/23/10
Procurement	240 days	Fri 5/28/10	Thu 4/28/11
Site Work Package	37 days	Fri 5/28/10	Sun 7/18/10
Concrete Embeds	8 days	Fri 8/6/10	Tue 8/17/10
Concrete Package	43 days	Wed 6/16/10	Fri 8/13/10
Masonry	20 days	Thu 7/29/10	Wed 8/25/10
Structural Steel	85 days	Tue 8/3/10	Sun 11/28/10
Sheeting & Shoring	13 days	Sat 6/12/10	Tue 6/29/10
Casework/Millwork	72 days	Fri 9/24/10	Sun 1/2/11
Doors/Hardware	79 days	Fri 8/20/10	Wed 12/8/10
Flooring Package	79 days	Fri 8/20/10	Wed 12/8/10
GWB Package	95 days	Fri 8/20/10	Thu 12/30/10
Painting Package	62 days	Fri 8/20/10	Sat 11/13/10
Tile Package	79 days	Fri 8/20/10	Wed 12/8/10
Specialties	62 days	Fri 9/24/10	Sat 12/18/10
Mechanical Package	156 days	Fri 6/25/10	Fri 1/28/11
Electrical Package	78 days	Thu 7/15/10	Mon 11/1/10
Fire Protection Package	106 days	Fri 8/20/10	Fri 1/14/11
AHU's	159 days	Wed 6/30/10	Mon 2/7/11



Project: DETAILED PROJECT SCHED
Date: Tue 10/26/10

Early Bar | Milestone | Summary | Progress Bar | Critical Activity

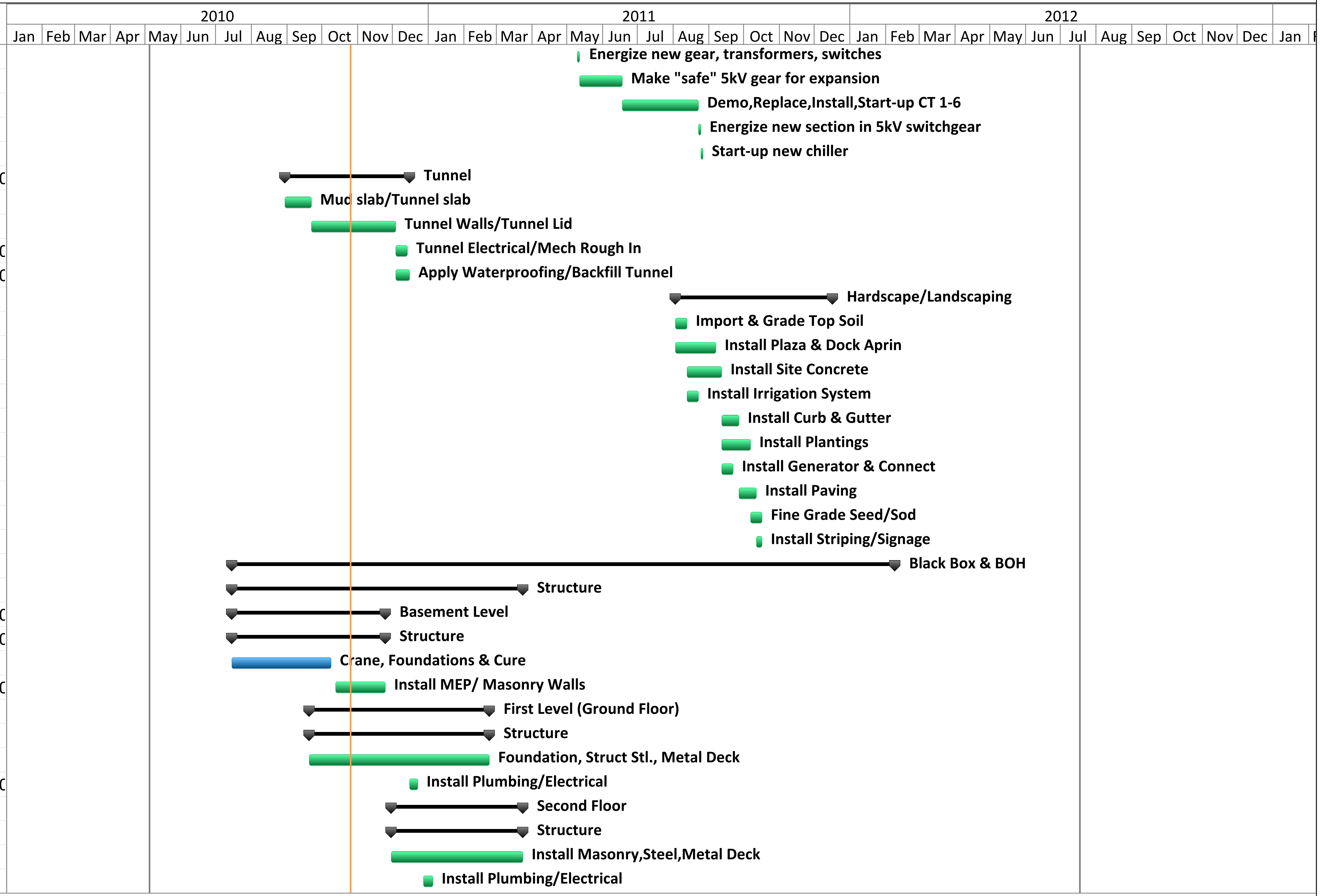
Task Name	Duration	Start	Finish
Chilled Water Package	98 days	Wed 6/16/10	Fri 10/29/10
Energy Recovery Units	159 days	Wed 6/30/10	Mon 2/7/11
Fans/Fan Coil Units	79 days	Fri 7/23/10	Wed 11/10/10
Heat Exchangers	68 days	Fri 7/16/10	Tue 10/19/10
Pumps	78 days	Fri 7/16/10	Tue 11/2/10
Fire Alarm Package	63 days	Wed 8/18/10	Fri 11/12/10
Generator	99 days	Tue 8/3/10	Fri 12/17/10
Lighting	203 days	Tue 7/20/10	Thu 4/28/11
Central Utility Plant Mech/Elec	173 days	Tue 8/3/10	Thu 3/31/11
Waterproofing	12 days	Thu 8/5/10	Fri 8/20/10
Elevator Package	68 days	Wed 8/18/10	Fri 11/19/10
Coordination Drawings	56 days	Mon 8/9/10	Sat 10/23/10
Black Box	23 days	Mon 8/9/10	Wed 9/8/10
Humanities	19 days	Wed 9/29/10	Sat 10/23/10
Proscenium	29 days	Wed 8/25/10	Sun 10/3/10
Site Works	332 days	Thu 5/20/10	Fri 8/26/11
Site Utilities	116 days	Mon 6/21/10	Sun 11/28/10
Install Temp Storm Water	14 days	Mon 6/21/10	Thu 7/8/10
Install Sanitary, Storm, Water	39 days	Tue 7/13/10	Fri 9/3/10
Install Rain Water tank/outfall 1 & 2	37 days	Thu 9/9/10	Fri 10/29/10
Chilled Water	15 days	Sat 10/30/10	Thu 11/18/10
Tie Storm/Storm Completed	0 days	Sat 10/30/10	Sat 10/30/10
Electric/Telecom	7 days	Fri 11/19/10	Sun 11/28/10
Site Work	145 days	Thu 5/20/10	Wed 12/8/10
Survey and Site Layout	3 days	Thu 5/20/10	Sun 5/23/10
Install Site Fence/Construction Entrances	11 days	Mon 5/24/10	Sat 6/5/10
Site Demolition	17 days	Thu 6/10/10	Fri 7/2/10
Rough Grade Site	37 days	Wed 7/7/10	Thu 8/26/10
Excavation Basement,Tunnel,Rock	39 days	Wed 7/7/10	Sun 8/29/10
Complete Excavation	4 days	Tue 8/10/10	Fri 8/13/10
Install Temp Waterline	10 days	Fri 8/20/10	Thu 9/2/10
Disconnect/Demo Existing Storm/Water Line	3 days	Fri 9/3/10	Tue 9/7/10
Bring Site to Grade	8 days	Mon 11/29/10	Wed 12/8/10
Central Utility Plant	184 days	Tue 12/14/10	Fri 8/26/11
Make "safe" gear, transformers, switches	105 days	Tue 12/14/10	Mon 5/9/11



Project: DETAILED PROJECT SCHED
Date: Tue 10/26/10

Early Bar | Milestone | Summary | Progress Bar | Critical Activity

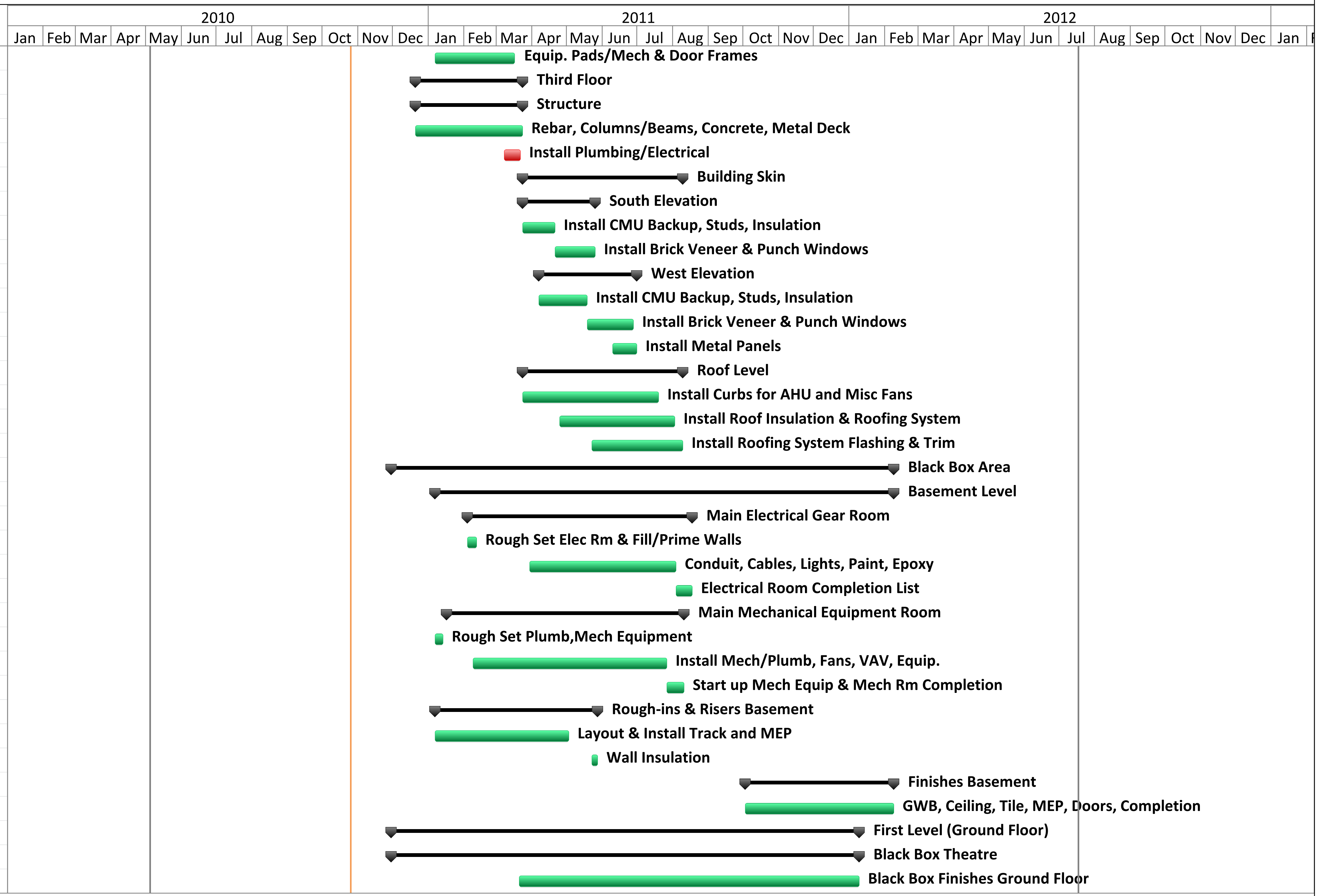
Task Name	Duration	Start	Finish
Energize new gear, transformers, switches	2 days	Tue 5/10/11	Wed 5/11/11
Make "safe" 5kV gear for expansion	27 days	Thu 5/12/11	Fri 6/17/11
Demo,Replace,Install,Start-up CT 1-6	47 days	Sat 6/18/11	Mon 8/22/11
Energize new section in 5kV switchgear	2 days	Tue 8/23/11	Wed 8/24/11
Start-up new chiller	2 days	Thu 8/25/11	Fri 8/26/11
Tunnel	78 days	Mon 8/30/10	Wed 12/15/10
Mud slab/Tunnel slab	17 days	Mon 8/30/10	Tue 9/21/10
Tunnel Walls/Tunnel Lid	53 days	Wed 9/22/10	Fri 12/3/10
Tunnel Electrical/Mech Rough In	7 days	Sat 12/4/10	Mon 12/13/10
Apply Waterproofing/Backfill Tunnel	9 days	Sat 12/4/10	Wed 12/15/10
Hardscape/Landscaping	98 days	Wed 8/3/11	Fri 12/16/11
Import & Grade Top Soil	8 days	Wed 8/3/11	Fri 8/12/11
Install Plaza & Dock Aprin	25 days	Wed 8/3/11	Tue 9/6/11
Install Site Concrete	22 days	Sat 8/13/11	Sun 9/11/11
Install Irrigation System	7 days	Sat 8/13/11	Mon 8/22/11
Install Curb & Gutter	11 days	Mon 9/12/11	Mon 9/26/11
Install Plantings	19 days	Mon 9/12/11	Thu 10/6/11
Install Generator & Connect	8 days	Mon 9/12/11	Wed 9/21/11
Install Paving	11 days	Tue 9/27/11	Tue 10/11/11
Fine Grade Seed/Sod	7 days	Fri 10/7/11	Sun 10/16/11
Install Striping/Signage	4 days	Wed 10/12/11	Sun 10/16/11
Black Box & BOH	410 days	Thu 7/15/10	Wed 2/8/12
Structure	180 days	Thu 7/15/10	Wed 3/23/11
Basement Level	95 days	Thu 7/15/10	Wed 11/24/10
Structure	95 days	Thu 7/15/10	Wed 11/24/10
Crane, Foundations & Cure	62 days	Thu 7/15/10	Fri 10/8/10
Install MEP/ Masonry Walls	31 days	Wed 10/13/10	Wed 11/24/10
First Level (Ground Floor)	112 days	Mon 9/20/10	Tue 2/22/11
Structure	112 days	Mon 9/20/10	Tue 2/22/11
Foundation, Struct Stl., Metal Deck	112 days	Mon 9/20/10	Tue 2/22/11
Install Plumbing/Electrical	5 days	Thu 12/16/10	Wed 12/22/10
Second Floor	82 days	Tue 11/30/10	Wed 3/23/11
Structure	82 days	Tue 11/30/10	Wed 3/23/11
Install Masonry,Steel,Metal Deck	82 days	Tue 11/30/10	Wed 3/23/11
Install Plumbing/Electrical	6 days	Tue 12/28/10	Tue 1/4/11



Project: DETAILED PROJECT SCHED
Date: Tue 10/26/10

Early Bar | Milestone | Summary | Progress Bar | Critical Activity

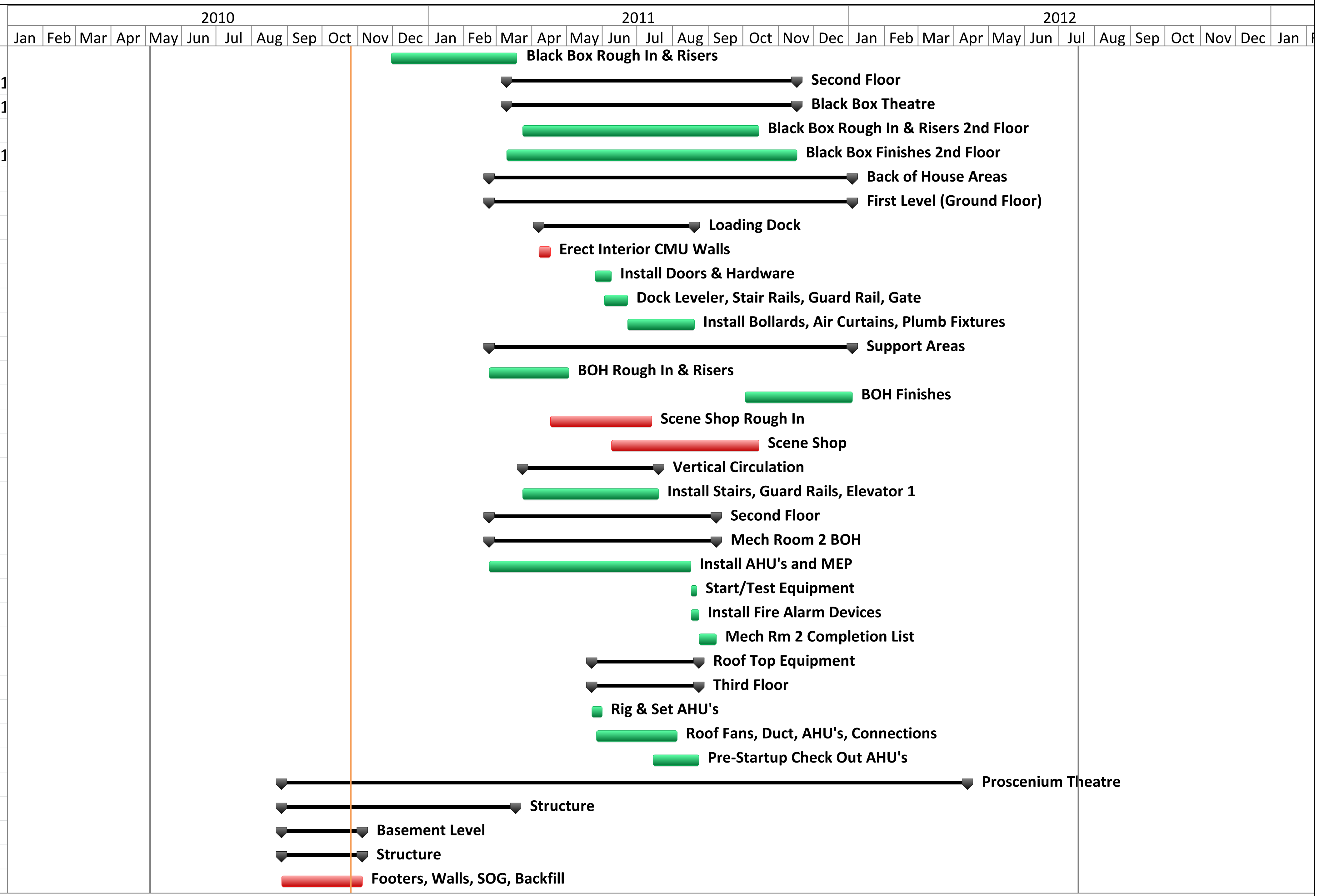
Task Name	Duration	Start	Finish
Equip. Pads/Mech & Door Frames	49 days	Fri 1/7/11	Wed 3/16/11
Third Floor	67 days	Tue 12/21/10	Wed 3/23/11
Structure	67 days	Tue 12/21/10	Wed 3/23/11
Rebar, Columns/Beams, Concrete, Metal Deck	67 days	Tue 12/21/10	Wed 3/23/11
Install Plumbing/Electrical	10 days	Tue 3/8/11	Mon 3/21/11
Building Skin	99 days	Thu 3/24/11	Tue 8/9/11
South Elevation	45 days	Thu 3/24/11	Wed 5/25/11
Install CMU Backup, Studs, Insulation	20 days	Thu 3/24/11	Wed 4/20/11
Install Brick Veneer & Punch Windows	25 days	Thu 4/21/11	Wed 5/25/11
West Elevation	61 days	Thu 4/7/11	Thu 6/30/11
Install CMU Backup, Studs, Insulation	30 days	Thu 4/7/11	Wed 5/18/11
Install Brick Veneer & Punch Windows	28 days	Thu 5/19/11	Mon 6/27/11
Install Metal Panels	15 days	Fri 6/10/11	Thu 6/30/11
Roof Level	99 days	Thu 3/24/11	Tue 8/9/11
Install Curbs for AHU and Misc Fans	84 days	Thu 3/24/11	Tue 7/19/11
Install Roof Insulation & Roofing System	72 days	Mon 4/25/11	Tue 8/2/11
Install Roofing System Flashing & Trim	57 days	Mon 5/23/11	Tue 8/9/11
Black Box Area	312 days	Tue 11/30/10	Wed 2/8/12
Basement Level	284 days	Fri 1/7/11	Wed 2/8/12
Main Electrical Gear Room	139 days	Fri 2/4/11	Wed 8/17/11
Rough Set Elec Rm & Fill/Prime Walls	6 days	Fri 2/4/11	Fri 2/11/11
Conduit, Cables, Lights, Paint, Epoxy	91 days	Wed 3/30/11	Wed 8/3/11
Electrical Room Completion List	10 days	Thu 8/4/11	Wed 8/17/11
Main Mechanical Equipment Room	148 days	Mon 1/17/11	Wed 8/10/11
Rough Set Plumb,Mech Equipment	5 days	Fri 1/7/11	Thu 1/13/11
Install Mech/Plumb, Fans, VAV, Equip.	120 days	Wed 2/9/11	Tue 7/26/11
Start up Mech Equip & Mech Rm Completion	11 days	Wed 7/27/11	Wed 8/10/11
Rough-ins & Risers Basement	101 days	Fri 1/7/11	Fri 5/27/11
Layout & Install Track and MEP	82 days	Fri 1/7/11	Mon 5/2/11
Wall Insulation	5 days	Mon 5/23/11	Fri 5/27/11
Finishes Basement	93 days	Mon 10/3/11	Wed 2/8/12
GWB, Ceiling, Tile, MEP, Doors, Completion	93 days	Mon 10/3/11	Wed 2/8/12
First Level (Ground Floor)	290 days	Tue 11/30/10	Mon 1/9/12
Black Box Theatre	290 days	Tue 11/30/10	Mon 1/9/12
Black Box Finishes Ground Floor	211 days	Mon 3/21/11	Mon 1/9/12



Project: DETAILED PROJECT SCHED
Date: Tue 10/26/10

Early Bar | Milestone | Summary | Progress Bar | Critical Activity

Task Name	Duration	Start	Finish
Black Box Rough In & Risers	79 days	Tue 11/30/10	Fri 3/18/11
Second Floor	180 days	Thu 3/10/11	Wed 11/16/11
Black Box Theatre	180 days	Thu 3/10/11	Wed 11/16/11
Black Box Rough In & Risers 2nd Floor	147 days	Thu 3/24/11	Fri 10/14/11
Black Box Finishes 2nd Floor	180 days	Thu 3/10/11	Wed 11/16/11
Back of House Areas	225 days	Wed 2/23/11	Tue 1/3/12
First Level (Ground Floor)	225 days	Wed 2/23/11	Tue 1/3/12
Loading Dock	97 days	Thu 4/7/11	Fri 8/19/11
Erect Interior CMU Walls	8 days	Thu 4/7/11	Sat 4/16/11
Install Doors & Hardware	10 days	Thu 5/26/11	Wed 6/8/11
Dock Leveler, Stair Rails, Guard Rail, Gate	14 days	Fri 6/3/11	Wed 6/22/11
Install Bollards, Air Curtains, Plumb Fixtures	42 days	Thu 6/23/11	Fri 8/19/11
Support Areas	225 days	Wed 2/23/11	Tue 1/3/12
BOH Rough In & Risers	49 days	Wed 2/23/11	Mon 5/2/11
BOH Finishes	67 days	Mon 10/3/11	Tue 1/3/12
Scene Shop Rough In	64 days	Sun 4/17/11	Wed 7/13/11
Scene Shop	92 days	Thu 6/9/11	Fri 10/14/11
Vertical Circulation	84 days	Thu 3/24/11	Tue 7/19/11
Install Stairs, Guard Rails, Elevator 1	84 days	Thu 3/24/11	Tue 7/19/11
Second Floor	141 days	Wed 2/23/11	Wed 9/7/11
Mech Room 2 BOH	141 days	Wed 2/23/11	Wed 9/7/11
Install AHU's and MEP	125 days	Wed 2/23/11	Tue 8/16/11
Start/Test Equipment	4 days	Wed 8/17/11	Sun 8/21/11
Install Fire Alarm Devices	5 days	Wed 8/17/11	Tue 8/23/11
Mech Rm 2 Completion List	11 days	Wed 8/24/11	Wed 9/7/11
Roof Top Equipment	67 days	Mon 5/23/11	Tue 8/23/11
Third Floor	67 days	Mon 5/23/11	Tue 8/23/11
Rig & Set AHU's	7 days	Mon 5/23/11	Tue 5/31/11
Roof Fans, Duct, AHU's, Connections	50 days	Fri 5/27/11	Thu 8/4/11
Pre-Startup Check Out AHU's	28 days	Fri 7/15/11	Tue 8/23/11
Proscenium Theatre	425 days	Fri 8/27/10	Thu 4/12/12
Structure	145 days	Fri 8/27/10	Thu 3/17/11
Basement Level	50 days	Fri 8/27/10	Thu 11/4/10
Structure	50 days	Fri 8/27/10	Thu 11/4/10
Footers, Walls, SOG, Backfill	50 days	Fri 8/27/10	Thu 11/4/10



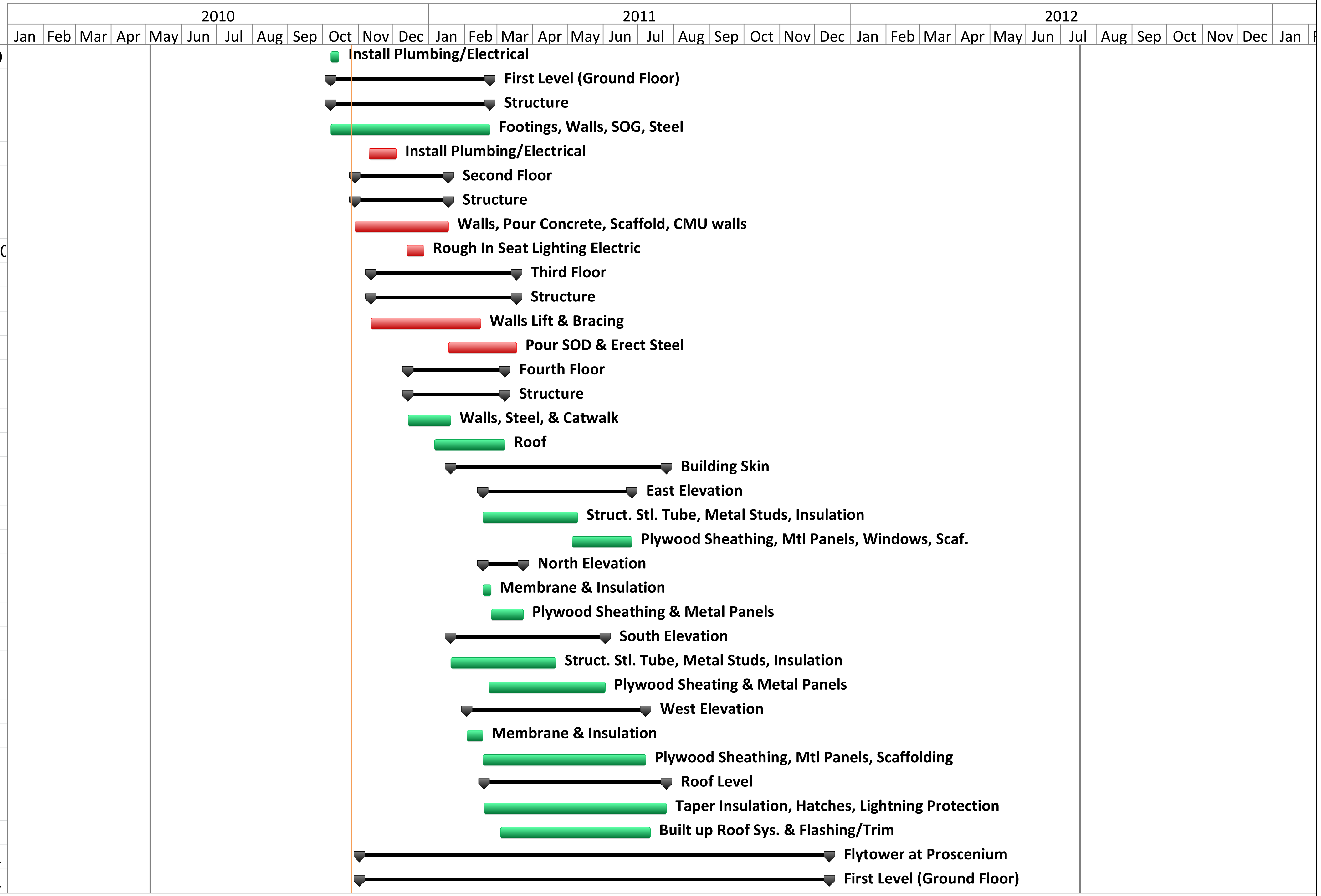
Project: DETAILED PROJECT SCHED
Date: Tue 10/26/10

Early Bar | Milestone | Summary | Progress Bar | Critical Activity

Courtney Glaub
Construction Management

Detailed Project Schedule - Tech 2
October 27, 2010

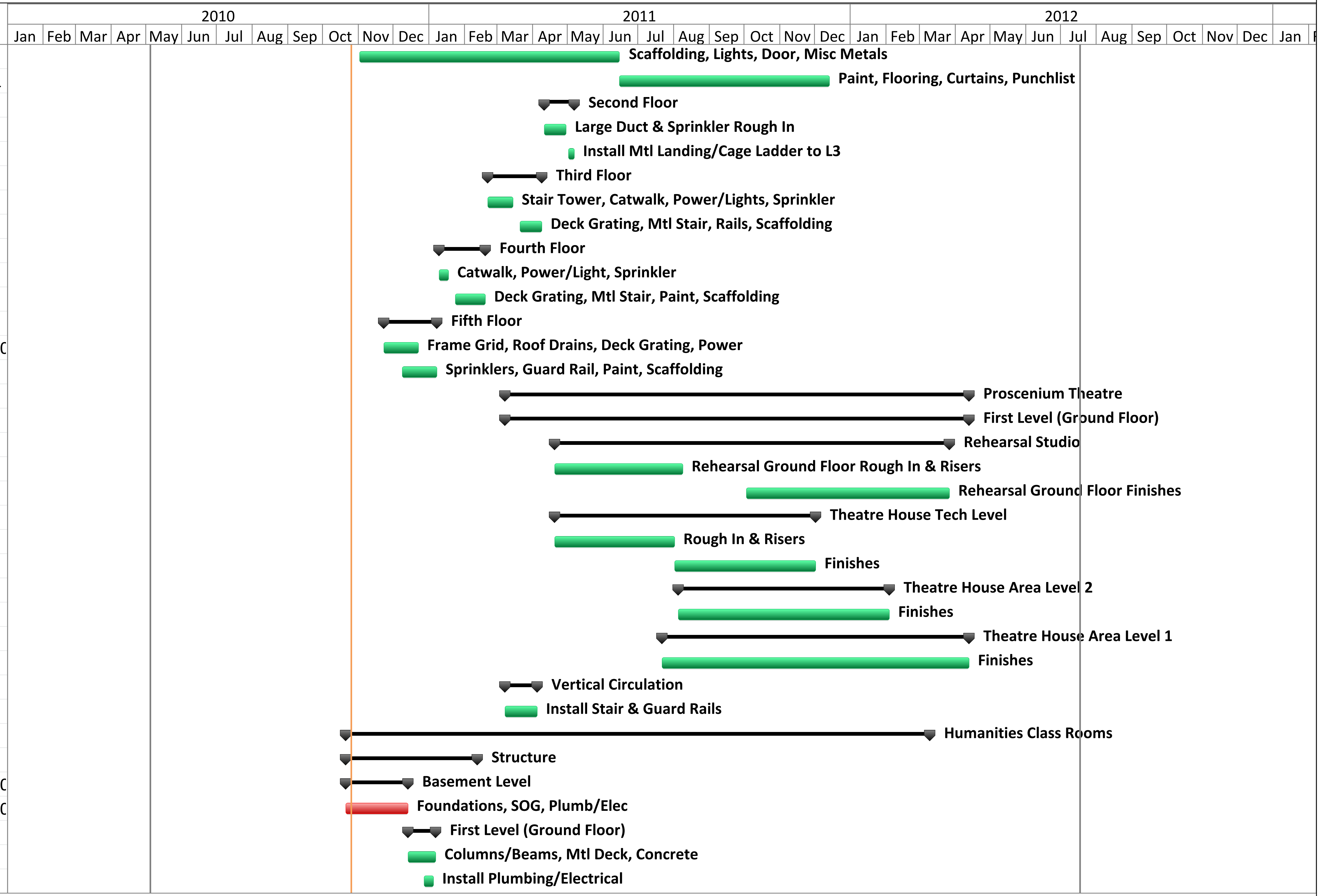
Task Name	Duration	Start	Finish
Install Plumbing/Electrical	5 days	Fri 10/8/10	Thu 10/14/10
First Level (Ground Floor)	98 days	Fri 10/8/10	Tue 2/22/11
Structure	98 days	Fri 10/8/10	Tue 2/22/11
Footings, Walls, SOG, Steel	98 days	Fri 10/8/10	Tue 2/22/11
Install Plumbing/Electrical	18 days	Wed 11/10/10	Fri 12/3/10
Second Floor	57 days	Fri 10/29/10	Mon 1/17/11
Structure	57 days	Fri 10/29/10	Mon 1/17/11
Walls, Pour Concrete, Scaffold, CMU walls	57 days	Fri 10/29/10	Mon 1/17/11
Rough In Seat Lighting Electric	11 days	Mon 12/13/10	Mon 12/27/10
Third Floor	90 days	Fri 11/12/10	Thu 3/17/11
Structure	90 days	Fri 11/12/10	Thu 3/17/11
Walls Lift & Bracing	67 days	Fri 11/12/10	Mon 2/14/11
Pour SOD & Erect Steel	43 days	Tue 1/18/11	Thu 3/17/11
Fourth Floor	60 days	Tue 12/14/10	Mon 3/7/11
Structure	60 days	Tue 12/14/10	Mon 3/7/11
Walls, Steel, & Catwalk	27 days	Tue 12/14/10	Wed 1/19/11
Roof	43 days	Thu 1/6/11	Mon 3/7/11
Building Skin	133 days	Thu 1/20/11	Mon 7/25/11
East Elevation	93 days	Thu 2/17/11	Sat 6/25/11
Struct. Stl. Tube, Metal Studs, Insulation	58 days	Thu 2/17/11	Mon 5/9/11
Plywood Sheathing, Mtl Panels, Windows, Scaf.	38 days	Thu 5/5/11	Sat 6/25/11
North Elevation	25 days	Thu 2/17/11	Wed 3/23/11
Membrane & Insulation	5 days	Thu 2/17/11	Wed 2/23/11
Plywood Sheathing & Metal Panels	20 days	Thu 2/24/11	Wed 3/23/11
South Elevation	96 days	Thu 1/20/11	Thu 6/2/11
Struct. Stl. Tube, Metal Studs, Insulation	65 days	Thu 1/20/11	Wed 4/20/11
Plywood Sheating & Metal Panels	73 days	Tue 2/22/11	Thu 6/2/11
West Elevation	111 days	Thu 2/3/11	Thu 7/7/11
Membrane & Insulation	10 days	Thu 2/3/11	Wed 2/16/11
Plywood Sheathing, Mtl Panels, Scaffolding	101 days	Thu 2/17/11	Thu 7/7/11
Roof Level	112 days	Fri 2/18/11	Mon 7/25/11
Taper Insulation, Hatches, Lightning Protection	112 days	Fri 2/18/11	Mon 7/25/11
Built up Roof Sys. & Flashing/Trim	92 days	Fri 3/4/11	Mon 7/11/11
Flytower at Proscenium	291 days	Tue 11/2/10	Tue 12/13/11
First Level (Ground Floor)	291 days	Tue 11/2/10	Tue 12/13/11



Project: DETAILED PROJECT SCHED
Date: Tue 10/26/10

Early Bar | Milestone | Summary | Progress Bar | Critical Activity

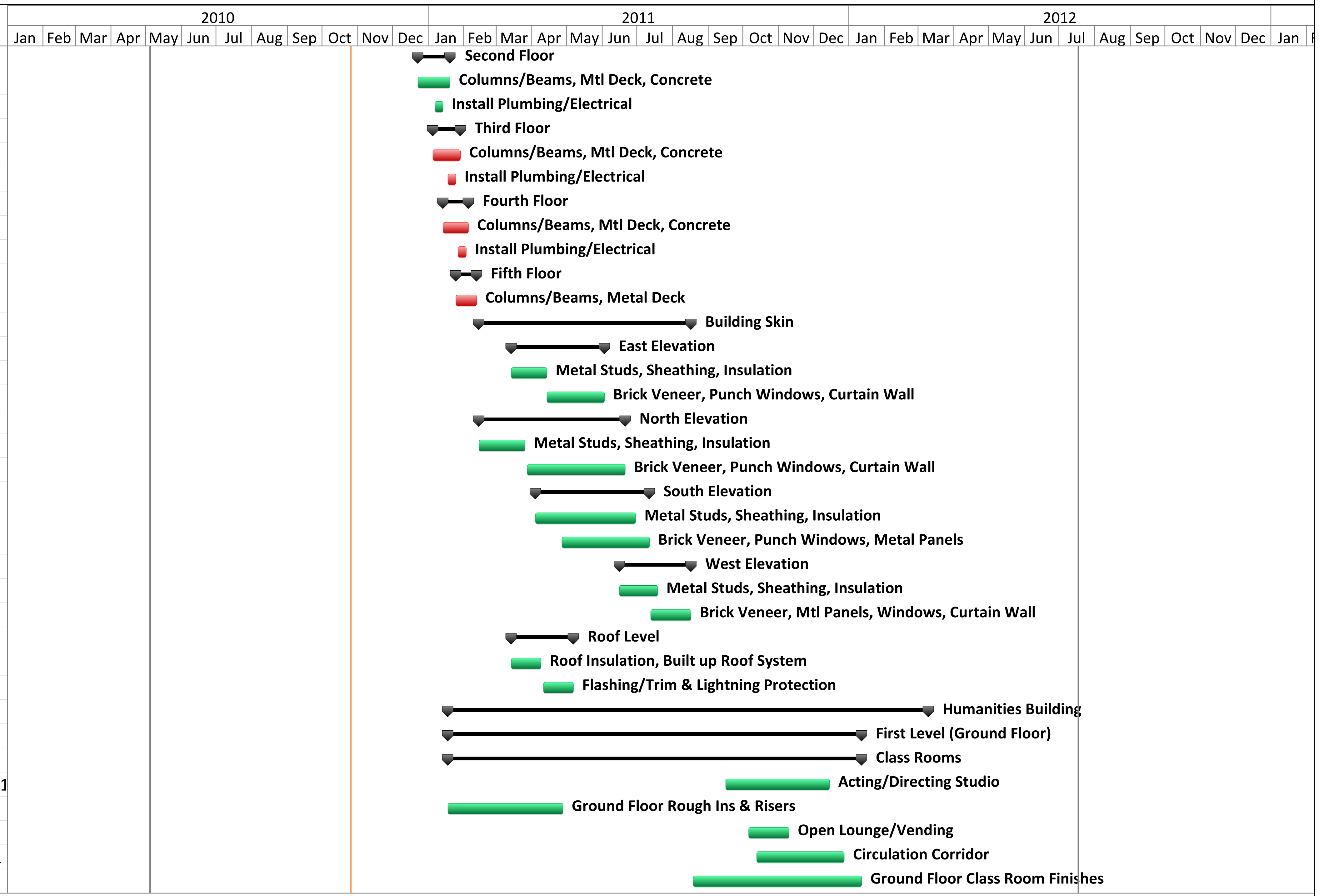
Task Name	Duration	Start	Finish
Scaffolding, Lights, Door, Misc Metals	161 days	Tue 11/2/10	Tue 6/14/11
Paint, Flooring, Curtains, Punchlist	130 days	Wed 6/15/11	Tue 12/13/11
Second Floor	20 days	Mon 4/11/11	Fri 5/6/11
Large Duct & Sprinkler Rough In	15 days	Mon 4/11/11	Fri 4/29/11
Install Mtl Landing/Cage Ladder to L3	5 days	Mon 5/2/11	Fri 5/6/11
Third Floor	35 days	Mon 2/21/11	Fri 4/8/11
Stair Tower, Catwalk, Power/Lights, Sprinkler	16 days	Mon 2/21/11	Mon 3/14/11
Deck Grating, Mtl Stair, Rails, Scaffolding	15 days	Mon 3/21/11	Fri 4/8/11
Fourth Floor	30 days	Mon 1/10/11	Fri 2/18/11
Catwalk, Power/Light, Sprinkler	6 days	Mon 1/10/11	Mon 1/17/11
Deck Grating, Mtl Stair, Paint, Scaffolding	20 days	Mon 1/24/11	Fri 2/18/11
Fifth Floor	34 days	Tue 11/23/10	Fri 1/7/11
Frame Grid, Roof Drains, Deck Grating, Power	22 days	Tue 11/23/10	Wed 12/22/10
Sprinklers, Guard Rail, Paint, Scaffolding	22 days	Thu 12/9/10	Fri 1/7/11
Proscenium Theatre	288 days	Tue 3/8/11	Thu 4/12/12
First Level (Ground Floor)	288 days	Tue 3/8/11	Thu 4/12/12
Rehearsal Studio	244 days	Wed 4/20/11	Mon 3/26/12
Rehearsal Ground Floor Rough In & Risers	79 days	Wed 4/20/11	Mon 8/8/11
Rehearsal Ground Floor Finishes	126 days	Mon 10/3/11	Mon 3/26/12
Theatre House Tech Level	162 days	Wed 4/20/11	Thu 12/1/11
Rough In & Risers	74 days	Wed 4/20/11	Mon 8/1/11
Finishes	88 days	Tue 8/2/11	Thu 12/1/11
Theatre House Area Level 2	131 days	Fri 8/5/11	Fri 2/3/12
Finishes	131 days	Fri 8/5/11	Fri 2/3/12
Theatre House Area Level 1	190 days	Fri 7/22/11	Thu 4/12/12
Finishes	190 days	Fri 7/22/11	Thu 4/12/12
Vertical Circulation	20 days	Tue 3/8/11	Mon 4/4/11
Install Stair & Guard Rails	20 days	Tue 3/8/11	Mon 4/4/11
Humanities Class Rooms	362 days	Thu 10/21/10	Fri 3/9/12
Structure	82 days	Thu 10/21/10	Fri 2/11/11
Basement Level	38 days	Thu 10/21/10	Mon 12/13/10
Foundations, SOG, Plumb/Elec	38 days	Thu 10/21/10	Mon 12/13/10
First Level (Ground Floor)	18 days	Tue 12/14/10	Thu 1/6/11
Columns/Beams, Mtl Deck, Concrete	18 days	Tue 12/14/10	Thu 1/6/11
Install Plumbing/Electrical	6 days	Tue 12/28/10	Tue 1/4/11



Project: DETAILED PROJECT SCHED
Date: Tue 10/26/10

Early Bar | Milestone | Summary | Progress Bar | Critical Activity

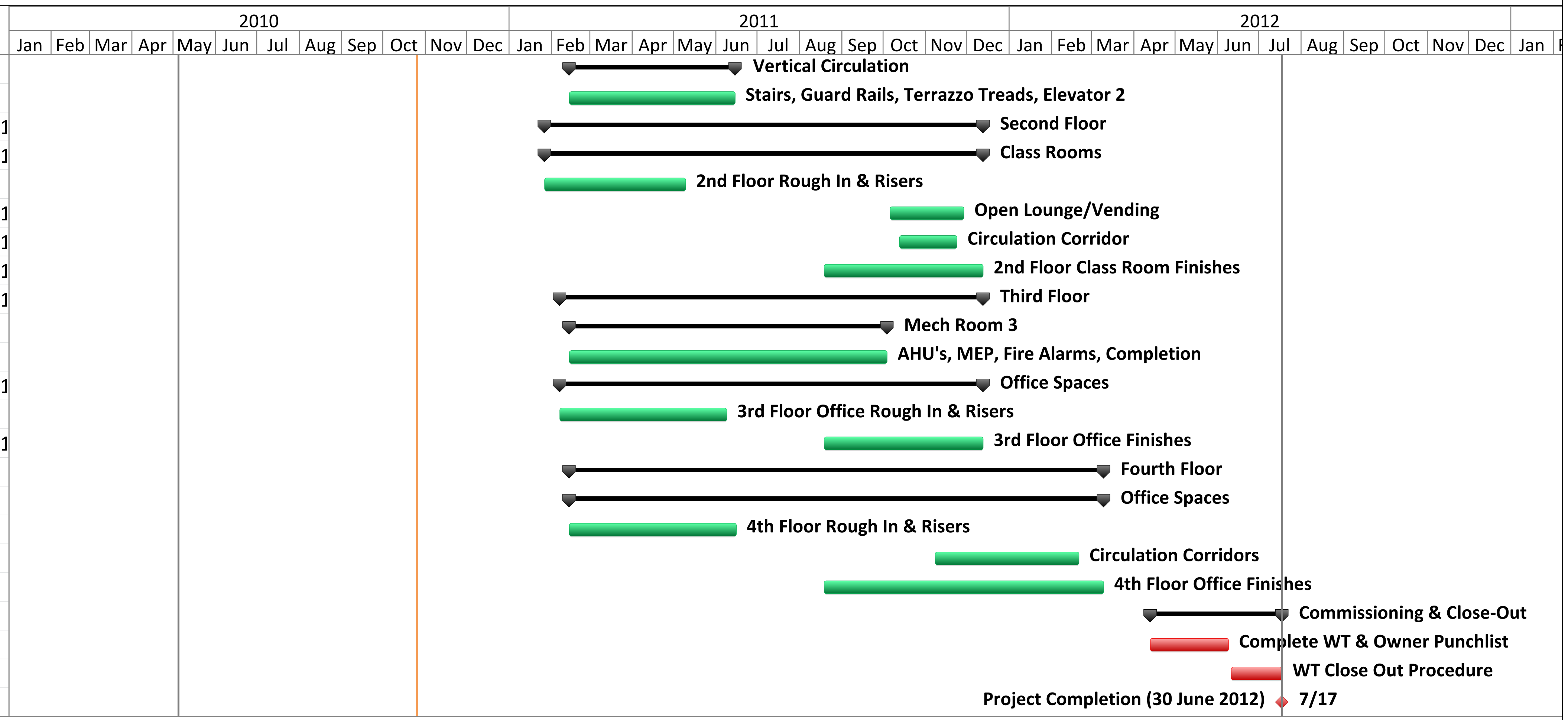
Task Name	Duration	Start	Finish
Second Floor	20 days	Thu 12/23/10	Wed 1/19/11
Columns/Beams, Mtl Deck, Concrete	20 days	Thu 12/23/10	Wed 1/19/11
Install Plumbing/Electrical	5 days	Fri 1/7/11	Thu 1/13/11
Third Floor	18 days	Wed 1/5/11	Fri 1/28/11
Columns/Beams, Mtl Deck, Concrete	18 days	Wed 1/5/11	Fri 1/28/11
Install Plumbing/Electrical	5 days	Tue 1/18/11	Mon 1/24/11
Fourth Floor	16 days	Fri 1/14/11	Fri 2/4/11
Columns/Beams, Mtl Deck, Concrete	16 days	Fri 1/14/11	Fri 2/4/11
Install Plumbing/Electrical	5 days	Thu 1/27/11	Wed 2/2/11
Fifth Floor	14 days	Tue 1/25/11	Fri 2/11/11
Columns/Beams, Metal Deck	14 days	Tue 1/25/11	Fri 2/11/11
Building Skin	132 days	Mon 2/14/11	Tue 8/16/11
East Elevation	59 days	Mon 3/14/11	Thu 6/2/11
Metal Studs, Sheathing, Insulation	23 days	Mon 3/14/11	Wed 4/13/11
Brick Veneer, Punch Windows, Curtain Wall	36 days	Thu 4/14/11	Thu 6/2/11
North Elevation	91 days	Mon 2/14/11	Mon 6/20/11
Metal Studs, Sheathing, Insulation	30 days	Mon 2/14/11	Fri 3/25/11
Brick Veneer, Punch Windows, Curtain Wall	61 days	Mon 3/28/11	Mon 6/20/11
South Elevation	71 days	Mon 4/4/11	Mon 7/11/11
Metal Studs, Sheathing, Insulation	63 days	Mon 4/4/11	Wed 6/29/11
Brick Veneer, Punch Windows, Metal Panels	54 days	Wed 4/27/11	Mon 7/11/11
West Elevation	44 days	Thu 6/16/11	Tue 8/16/11
Metal Studs, Sheathing, Insulation	23 days	Thu 6/16/11	Mon 7/18/11
Brick Veneer, Mtl Panels, Windows, Curtain Wall	25 days	Wed 7/13/11	Tue 8/16/11
Roof Level	40 days	Mon 3/14/11	Fri 5/6/11
Roof Insulation, Built up Roof System	20 days	Mon 3/14/11	Fri 4/8/11
Flashing/Trim & Lightning Protection	20 days	Mon 4/11/11	Fri 5/6/11
Humanities Building	299 days	Tue 1/18/11	Fri 3/9/12
First Level (Ground Floor)	257 days	Tue 1/18/11	Wed 1/11/12
Class Rooms	257 days	Tue 1/18/11	Wed 1/11/12
Acting/Directing Studio	64 days	Fri 9/16/11	Wed 12/14/11
Ground Floor Rough Ins & Risers	72 days	Tue 1/18/11	Wed 4/27/11
Open Lounge/Vending	25 days	Thu 10/6/11	Wed 11/9/11
Circulation Corridor	54 days	Thu 10/13/11	Tue 12/27/11
Ground Floor Class Room Finishes	104 days	Fri 8/19/11	Wed 1/11/12



Project: DETAILED PROJECT SCHED
Date: Tue 10/26/10

Early Bar | Milestone | Summary | Progress Bar | Critical Activity

Task Name	Duration	Start	Finish
Vertical Circulation	87 days	Mon 2/14/11	Tue 6/14/11
Stairs, Guard Rails, Terrazzo Treads, Elevator 2	87 days	Mon 2/14/11	Tue 6/14/11
Second Floor	228 days	Thu 1/27/11	Mon 12/12/11
Class Rooms	228 days	Thu 1/27/11	Mon 12/12/11
2nd Floor Rough In & Risers	73 days	Thu 1/27/11	Mon 5/9/11
Open Lounge/Vending	38 days	Thu 10/6/11	Mon 11/28/11
Circulation Corridor	30 days	Thu 10/13/11	Wed 11/23/11
2nd Floor Class Room Finishes	82 days	Fri 8/19/11	Mon 12/12/11
Third Floor	221 days	Mon 2/7/11	Mon 12/12/11
Mech Room 3	166 days	Mon 2/14/11	Mon 10/3/11
AHU's, MEP, Fire Alarms, Completion	166 days	Mon 2/14/11	Mon 10/3/11
Office Spaces	221 days	Mon 2/7/11	Mon 12/12/11
3rd Floor Office Rough In & Risers	88 days	Mon 2/7/11	Wed 6/8/11
3rd Floor Office Finishes	82 days	Fri 8/19/11	Mon 12/12/11
Fourth Floor	280 days	Mon 2/14/11	Fri 3/9/12
Office Spaces	280 days	Mon 2/14/11	Fri 3/9/12
4th Floor Rough In & Risers	88 days	Mon 2/14/11	Wed 6/15/11
Circulation Corridors	75 days	Tue 11/8/11	Mon 2/20/12
4th Floor Office Finishes	146 days	Fri 8/19/11	Fri 3/9/12
Commissioning & Close-Out	68 days	Fri 4/13/12	Tue 7/17/12
Complete WT & Owner Punchlist	41 days	Fri 4/13/12	Fri 6/8/12
WT Close Out Procedure	27 days	Mon 6/11/12	Tue 7/17/12
Project Completion (30 June 2012)	0 days	Tue 7/17/12	Tue 7/17/12



Project: DETAILED PROJECT SCHED
Date: Tue 10/26/10

Early Bar | Milestone | Summary | Progress Bar | Critical Activity

APPENDIX C – Site Layout Plans

LEGEND:

Existing Utilities

Water
Gas
Storm Drain
Sanitary
Electric

Symbols

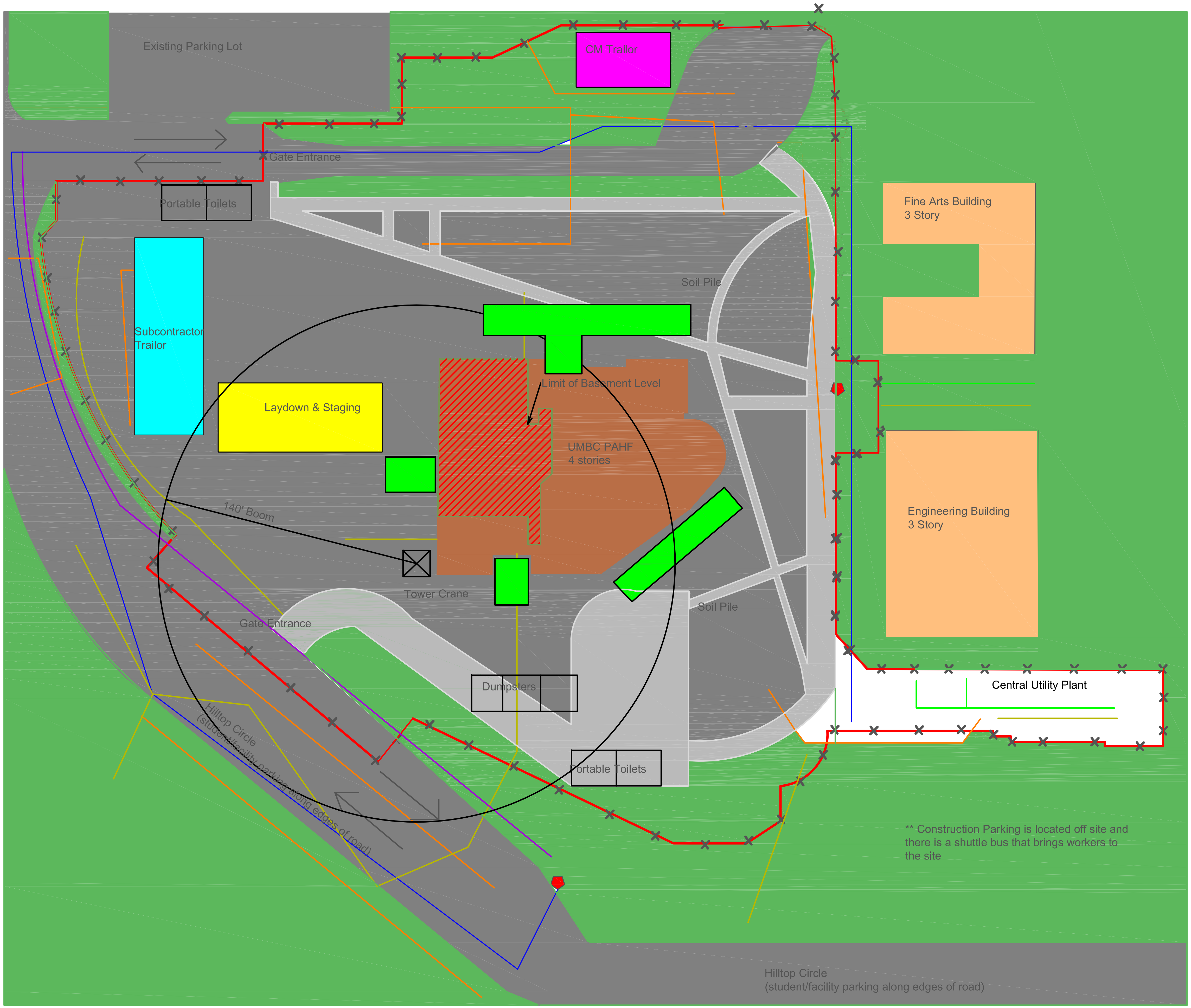
Fire Hydrant
Vehicular Traffic
Construction Fence

UMBC
Performing Arts & Humanities Facility

Site Utilization Plan
Excavation

October 27, 2010

Courtney Glaub - CM



LEGEND:

Existing Utilities

- Water
- Gas
- Storm Drain
- Sanitary
- Electric

Symbols

- Fire Hydrant
- Vehicular Traffic
- Construction Fence

Crane Paths

UMBC
Performing Arts & Humanities Facility

Site Utilization Plan
Structure

October 27, 2010

Courtney Glaub - CM

APPENDIX D – General Conditions Estimate

Staff Reimbursables

Line Item	Quantity	Unit	Unit Cost	Cost
Senior Project Manager	3792	Hrs	$101	$382,992
Project Manager 1	3792	Hrs	$94.00	$356,448
Project Manager 2	3792	Hrs	$80.00	$303,360
Project Engineer 1	3792	Hrs	$58.00	$219,936
Project Engineer 2	3792	Hrs	$55.00	$208,560
Project Engineer 3	1896	Hrs	$52.00	$98,592
Superintendent	3792	Hrs	$98.00	$371,616
Assistant Superintendent	3792	Hrs	$62.00	$235,104
TOTAL				$2,176,608

CM-GMP Contingency

Line Item	Quantity	Unit	Unit Cost	Cost
GMP Contingency	1	LS	$1,000,000	$1,000,000
TOTAL CM-GMP CONTINGENCY				$1,000,000

Non-Personnel Reimbursable Costs

Line Item	Quantity	Unit	Unit Cost	Cost
Bonds	1	LS	$475,000	$475,000
Liability Insurance	1	LS	$285,000	$285,000
Builders Risk	1	LS	$130,000	$130,000
Mobilization	1	EA	$20,000	$20,000
Office Trailers (Triple Wide)	24	MO	$4,000	$96,000
Field Furniture & Setup	10	SET	$1,000	$10,000
Telephones & Service	24	MO	$400	$9,600
Setup Fee	1	LS	$1,500	$1,500
Phone Jacks	10	EA	$150	$1,500
Lease for Telephones	24	MO	$500	$12,000
Line Lease - Verizon DSL	24	EA	$250	$6,000
Cleaning Services, trailers	24	MO	$600	$14,400
Security System, trailers	24	MO	$100	$2,400
Electrical Power Connections	1	LS	$15,000	$15,000
Power Consumption, trailers	24	MO	$1,200	$28,800
Sanitary Facilities, trailer complex	1	LS	$4,500	$4,500
Temporary Construction	24	MO	$5,000	$120,000
Temporary Heat	6	MO	$20,000	$120,000
Misc, Trailer Supplies	24	MO	$200	$4,800
Small Tools for CM Field Staff	24	MO	$1,000	$24,000
Safety Supplies/Ladders/Cables/Vests	1	LS	$50,000	$50,000
Shipping/Receiving System	24	MO	$200	$4,800
Miscellaneous Materials	24	MO	$100	$2,400
Drawing Reproduction in Construction Phase	200	SET	$150	$30,000
Site Surveys	1	LS	$100,000	$100,000
Layout	1	LS	$50,000	$50,000
Permits (not required, state project)	0	LS	$0	$0
Third Party Inspection/Testing	1	Allow	$250,000	$250,000
E-Maryland Marketplace Fee	1	Allow	$15,000	$15,000
Safety Program, First Aid Supplies	24	MO	$1,500	$36,000
Daily Cleanup	24	MO	$1,000	$24,000
Trash Chutes	2	EA	$5,000	$10,000
Barricades & Warning Signs	24	MO	$500	$12,000
Ladders & Stairs	24	MO	$2,500	$60,000
Misc Supplies	24	MO	$1,500	$36,000
Employee Orientation	300	EA	$10	$3,000
Parking	0	MO	$0	$0
Site Fencing	1	LS	$45,000.00	$45,000

Snow Removal	1	LS	$12,000	$12,000
Clean up	0	MO	$0	$0
Laborer	8320	HR	$40	$332,800
Carpenter	4160	HR	$55	$228,800
Coffee, Water	24	MO	$150	$3,600
Final Cleaning	1	LS	$75,000	$75,000
Purchase of Staff Computers	10	EA	$1,800	$18,000
Purchase of UMB PM Computer	1	EA	$1,800	$1,800
Weather & Dust Protection	1	LS	$25,000	$25,000
Project Signage	2	EA	$2,000	$4,000
Progress Photos, Monthly Reports	24	MO	$1,000	$24,000
Progress Photos Professional	1	LS	$7,500	$7,500
Computers & WT IE Support	24	MO	$1,250	$30,000
Copy Machines	24	MO	$500	$12,000
Fax Machines	3	EA	$500	$1,500
Nextel Phones	24	MO	$500	$12,000
Office Phones	24	MO	$500	$12,000
Travel	1	LS	$15,000	$15,000
Postage	24	MO	$400	$9,600
Misc. Office Supplies	24	MO	$200	$4,800
Auto Allowances	24	MO	$3,500	$84,000
Final Site Clean up	1	LS	$60,000	$60,000
As-Built Drawings for A/E's Record Set	1	LS	$10,000	$10,000
Project File & Records for Univ. Archives	1	LS	$10,000	$10,000
UMB Partnering Allowances	1	Allow	$50,000	$50,000
TOTAL NON-PERSONNEL REIMBURSABLE COSTS				$3,152,100

General Conditions Summary

Line Item	Quantity	Unit	Unit Cost	Cost
Staff Reimbursables	$20,928.92	Week	104	$2,176,608
Total Construction Phase Non-Personnel	$30,308.65	Week	104	$3,152,100
CM-GMP Contingency	$9,615.38	Week	104	$1,000,000
TOTAL CM REIMBURSABLE COSTS	$60,852.95	Week	104	$6,328,708

APPENDIX E – Precast Façade Take-Off

ELEVATION	ITEM	ACTION	QUANTITY	WIDTH	HEIGHT	SF	COST/SF	TOTAL COST
South	Precast 1	Add	1	5	12.33	61.65	$50.50	$3,113.33
	Precast 2	Add	1	5	21.83	109.15	$50.50	$5,512.08
	Precast 3	Add	1	5	21	105	$50.50	$5,302.50
	Precast 4	Add	1	5	14.167	70.835	$50.50	$3,577.17
	Precast 5	Add	2	7	2	28	$50.50	$1,414.00
	Precast 6	Add	4	7	7	196	$50.50	$9,898.00
	Precast 7	Add	5	7	3	105	$50.50	$5,302.50
	Precast 8	Add	5	7	4	140	$50.50	$7,070.00
	Precast 9	Add	2	7	4.5	63	$50.50	$3,181.50
	Precast 10	Add	2	7	3.5	49	$50.50	$2,474.50
	Precast 11	Add	1	6.5	12.33	80.145	$50.50	$4,047.32
	Precast 12	Add	1	6.5	21.83	141.895	$50.50	$7,165.70
	Precast 13	Add	1	6.5	21	136.5	$50.50	$6,893.25
	Precast 14	Add	1	6.5	14.167	92.0855	$50.50	$4,650.32
	Precast 15	Add	1	5	19.33	96.65	$50.50	$4,880.83
	Precast 16	Add	1	5	20.5	102.5	$50.50	$5,176.25
	Precast 17	Add	1	5	16.167	80.835	$50.50	$4,082.17
	Precast 18	Add	1	5	18.33	91.65	$50.50	$4,628.33
	Precast 19	Add	1	5	10	50	$50.50	$2,525.00
	Precast 20	Add	1	5	22.33	111.65	$50.50	$5,638.33
	Precast 21	Add	4	6.5	3	78	$50.50	$3,939.00
	Precast 22	Add	1	6.5	2.5	16.25	$50.50	$820.63
	Precast 23	Add	1	6.5	7	45.5	$50.50	$2,297.75
	Precast 24	Add	1	6.5	6	39	$50.50	$1,969.50
	Precast 25	Add	1	6.5	5.5	35.75	$50.50	$1,805.38
	Precast 26	Add	3	6.5	4	78	$50.50	$3,939.00
	Precast 27	Add	2	6.5	5	65	$50.50	$3,282.50
	Precast 28	Add	1	6.5	2	13	$50.50	$656.50
	Precast 29	Add	1	6.5	10	65	$50.50	$3,282.50
	Precast 30	Add	1	6.5	22.33	145.145	$50.50	$7,329.82
	Precast 31	Add	1	7	10	70	$50.50	$3,535.00
	Precast 32	Add	1	11.75	4	47	$50.50	$2,373.50
	Precast 33	Add	1	3	4	12	$50.50	$606.00
	Precast 34	Add	1	11.67	4	46.68	$50.50	$2,357.34

	Precast 35	Add	4	2	21.5	172	$37.00	$6,364.00
	Precast 36	Add	2	12	21.5	516	$37.00	$19,092.00
	Precast 37	Add	2	6.75	24	324	$37.00	$11,988.00
	Precast 38	Add	2	3	21.5	129	$37.00	$4,773.00
	Precast 39	Add	1	6	21.5	129	$37.00	$4,773.00
	Precast 40	Add	1	4	10	40	$37.00	$1,480.00
	Precast 41	Add	1	6	3	18	$37.00	$666.00
	Precast 42	Add	1	6	10	60	$37.00	$2,220.00
	Precast 43	Add	1	6	6.5	39	$37.00	$1,443.00
	Precast 44	Add	1	6	4	24	$37.00	$888.00
	Precast 45	Add	1	2	10	20	$37.00	$740.00
	Precast 46	Add	1	2	7	14	$37.00	$518.00
	Precast 47	Add	1	2	4.5	9	$37.00	$333.00
	Precast 48	Add	1	10	1	10	$37.00	$370.00
	Precast 49	Add	1	10	1.5	15	$37.00	$555.00
	Precast 50	Add	1	7.5	1.5	11.25	$37.00	$416.25
	Precast 51	Add	1	3	10	30	$37.00	$1,110.00
	Precast 52	Add	1	7.5	5	37.5	$37.00	$1,387.50
	Precast 53	Add	2	2.5	32.5	162.5	$37.00	$6,012.50
	Precast 54	Add	1	5.5	32.5	178.75	$37.00	$6,613.75
	Precast 55	Add	1	10	20	200	$37.00	$7,400.00
	Precast 56	Add	1	10	6.5	65	$37.00	$2,405.00
	Precast 57	Add	1	2	34.5	69	$37.00	$2,553.00
	Precast 58	Add	1	5.5	2	11	$37.00	$407.00
	Precast 59	Add	1	5.5	9	49.5	$37.00	$1,831.50
	Precast 60	Add	1	5.5	13	71.5	$37.00	$2,645.50
	Precast 61	Add	1	5.5	1.5	8.25	$37.00	$305.25
	Precast 62	Add	1	7	8	56	$37.00	$2,072.00
	Precast 63	Add	1	6	29	174	$37.00	$6,438.00
	Precast 64	Add	1	6	28	168	$37.00	$6,216.00
	Precast 65	Add	2	7	12	168	$37.00	$6,216.00
	Precast 66	Add	1	1.5	6	9	$37.00	$333.00
	Precast 67	Add	1	2	6	12	$37.00	$444.00
	Precast 68	Add	2	7	11	154	$37.00	$5,698.00
	Precast 69	Add	2	7	28	392	$37.00	$14,504.00
	Precast 70	Add	2	8	29	464	$37.00	$17,168.00
	Precast 71	Add	2	8	28	448	$37.00	$16,576.00
		TOTAL	**103**			**7126.121**		**$299,682.71**
		MASONRY DEDUCT				**7126.121**	**$41.50**	**$295,734.02**
		TOTAL SAVINGS						**($3,948.69)**

ELEVATION	ITEM	ACTION	QUANTITY	WIDTH	HEIGHT	SF	COST/SF	TOTAL COST
North	Precast 1	Add	1	5	11	55	$50.50	$2,777.50
	Precast 2	Add	1	5	11.33	56.65	$50.50	$2,860.83
	Precast 3	Add	1	5	10	50	$50.50	$2,525.00
	Precast 4	Add	1	5	18.33	91.65	$50.50	$4,628.33
	Precast 5	Add	1	5	16.167	80.835	$50.50	$4,082.17
	Precast 6	Add	1	5	20.5	102.5	$50.50	$5,176.25
	Precast 7	Add	1	5	8.167	40.835	$50.50	$2,062.17
	Precast 8	Add	1	5	19.33	96.65	$50.50	$4,880.83
	Precast 9	Add	1	5	21.33	106.65	$50.50	$5,385.83
	Precast 10	Add	1	5	12.83	64.15	$50.50	$3,239.58
	Precast 11	Add	2	6.5	1.5	19.5	$50.50	$984.75
	Precast 12	Add	2	6.5	4	52	$50.50	$2,626.00
	Precast 13	Add	16	6.5	4.5	468	$50.50	$23,634.00
	Precast 14	Add	10	6.5	2.5	162.5	$50.50	$8,206.25
	Precast 15	Add	4	6.5	6	156	$50.50	$7,878.00
	Precast 16	Add	3	6.5	3	58.5	$50.50	$2,954.25
	Precast 17	Add	2	6.5	11	143	$50.50	$7,221.50
	Precast 18	Add	2	6.5	11.33	147.29	$50.50	$7,438.15
	Precast 19	Add	1	6.5	10	65	$50.50	$3,282.50
	Precast 20	Add	1	6.5	18.33	119.145	$50.50	$6,016.82
	Precast 21	Add	1	6.5	16.167	105.0855	$50.50	$5,306.82
	Precast 22	Add	2	6.5	20.5	266.5	$50.50	$13,458.25
	Precast 23	Add	1	6.5	8.167	53.0855	$50.50	$2,680.82
	Precast 24	Add	1	6.5	19.33	125.645	$50.50	$6,345.07
	Precast 25	Add	2	6.5	19	247	$50.50	$12,473.50
	Precast 26	Add	2	6.5	21.33	277.29	$50.50	$14,003.15
	Precast 27	Add	1	6.5	12.83	83.395	$50.50	$4,211.45
	Precast 28	Add	1	6.5	5.5	35.75	$50.50	$1,805.38
	Precast 29	Add	1	7.5	11	82.5	$50.50	$4,166.25
	Precast 30	Add	1	7.5	11.33	84.975	$50.50	$4,291.24
	Precast 31	Add	1	7.5	10	75	$50.50	$3,787.50
	Precast 32	Add	1	7.5	18.33	137.475	$50.50	$6,942.49
	Precast 33	Add	1	7.5	16.167	121.2525	$50.50	$6,123.25
	Precast 34	Add	2	7.5	20.5	307.5	$50.50	$15,528.75
	Precast 35	Add	1	7.5	17	127.5	$50.50	$6,438.75
	Precast 36	Add	1	7.5	11.5	86.25	$50.50	$4,355.63
	Precast 37	Add	1	7.5	17.5	131.25	$50.50	$6,628.13

	Precast 38	Add	1	7.5	19	142.5	$50.50	$7,196.25
	Precast 39	Add	1	7.5	21.33	159.975	$50.50	$8,078.74
	Precast 40	Add	1	7.5	12.83	96.225	$50.50	$4,859.36
	Precast 41	Add	1	8	12	96	$50.50	$4,848.00
	Precast 42	Add	7	8	4.5	252	$50.50	$12,726.00
	Precast 43	Add	3	8	5.5	132	$50.50	$6,666.00
	Precast 44	Add	2	8	6	96	$50.50	$4,848.00
	Precast 45	Add	1	8	4	32	$50.50	$1,616.00
	Precast 46	Add	1	8	3	24	$50.50	$1,212.00
	Precast 47	Add	1	5.5	16	88	$50.50	$4,444.00
	Precast 48	Add	1	2.5	6	15	$50.50	$757.50
	Precast 49	Add	1	2.5	3	7.5	$50.50	$378.75
	Precast 50	Add	1	6.5	12	78	$50.50	$3,939.00
	Precast 51	Add	1	6.5	5	32.5	$50.50	$1,641.25
	Precast 52	Add	1	6.5	11.5	74.75	$50.50	$3,774.88
	Precast 53	Add	1	6.5	17.5	113.75	$50.50	$5,744.38
	Precast 54	Add	1	5	3	15	$50.50	$757.50
	Precast 55	Add	1	5	4	20	$50.50	$1,010.00
	Precast 56	Add	1	8	1.5	12	$50.50	$606.00
	Precast 57	Add	2	3	11	66	$50.50	$3,333.00
	Precast 58	Add	1	3	11.33	33.99	$50.50	$1,716.50
	Precast 59	Add	1	6	6	36	$50.50	$1,818.00
	Precast 60	Add	1	6	6.5	39	$50.50	$1,969.50
	Precast 61	Add	1	6	12	72	$50.50	$3,636.00
	Precast 62	Add	1	5	18	90	$50.50	$4,545.00
		TOTAL	**109**			**6307.499**		**$318,528.67**
		MASONRY DEDUCT				**6307.499**	**$41.50**	**$261,761.21**
		TOTAL SAVINGS						**($56,767.47)**

ELEVATION	ITEM	ACTION	QUANTITY	WIDTH	HEIGHT	SF	COST/SF	TOTAL COST
East	Precast 1	Add	1	5	13	65	$50.50	$3,282.50
	Precast 2	Add	1	5	8.33	41.65	$50.50	$2,103.33
	Precast 3	Add	1	5	10.83	54.15	$50.50	$2,734.58
	Precast 4	Add	1	5	11	55	$50.50	$2,777.50
	Precast 5	Add	1	6.5	3	19.5	$50.50	$984.75
	Precast 6	Add	1	6.5	6	39	$50.50	$1,969.50
	Precast 7	Add	3	6.5	4	78	$50.50	$3,939.00
	Precast 8	Add	1	6.5	1	6.5	$50.50	$328.25
	Precast 9	Add	1	4	13	52	$50.50	$2,626.00
	Precast 10	Add	1	4	8.33	33.32	$50.50	$1,682.66
	Precast 11	Add	1	4	12	48	$50.50	$2,424.00
	Precast 12	Add	1	4	1	4	$50.50	$202.00
	Precast 13	Add	2	11.5	1	23	$50.50	$1,161.50
	Precast 14	Add	1	6.5	4.5	29.25	$50.50	$1,477.13
	Precast 15	Add	1	2.5	13.5	33.75	$50.50	$1,704.38
	Precast 16	Add	1	2	13.5	27	$50.50	$1,363.50
	Precast 17	Add	2	5	1	10	$50.50	$505.00
	Precast 18	Add	1	5	13.5	67.5	$50.50	$3,408.75
	Precast 19	Add	2	11	1	22	$50.50	$1,111.00
	Precast 20	Add	1	8	4.5	36	$50.50	$1,818.00
	Precast 21	Add	1	8	14	112	$50.50	$5,656.00
	Precast 22	Add	2	3	23.5	141	$50.50	$7,120.50
	Precast 23	Add	1	3.5	1	3.5	$50.50	$176.75
	Precast 24	Add	1	3.5	23.5	82.25	$50.50	$4,153.63
	Precast 25	Add	1	8	5	40	$50.50	$2,020.00
	Precast 26	Add	1	8	3.5	28	$50.50	$1,414.00
	Precast 27	Add	1	8	2	16	$50.50	$808.00
	Precast 28	Add	1	12	25.5	306	$37.00	$11,322.00
	Precast 29	Add	1	2	14.5	29	$37.00	$1,073.00
	Precast 30	Add	2	8	14.5	232	$37.00	$8,584.00
	Precast 31	Add	1	7	14.5	101.5	$37.00	$3,755.50
	Precast 32	Add	1	5	2	10	$37.00	$370.00
	Precast 33	Add	1	5	6	30	$37.00	$1,110.00
	Precast 34	Add	1	2	11	22	$37.00	$814.00
	Precast 35	Add	1	4	6.5	26	$37.00	$962.00
		TOTAL	**42**			**1923.87**		**$86,942.69**
		MASONRY DEDUCT				**1923.87**	**$41.50**	**$79,840.61**
		TOTAL SAVINGS						**($7,102.08)**

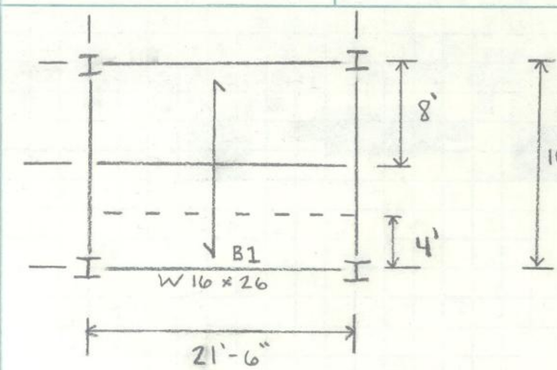
ELEVATION	ITEM	ACTION	QUANTITY	WIDTH	HEIGHT	SF	COST/SF	TOTAL COST
West	Precast 1	Add	1	12	25.5	306	$37.00	$11,322.00
	Precast 2	Add	1	6	14.5	87	$37.00	$3,219.00
	Precast 3	Add	2	10	3	60	$37.00	$2,220.00
	Precast 4	Add	1	10	6	60	$37.00	$2,220.00
	Precast 5	Add	1	2.5	14.5	36.25	$37.00	$1,341.25
	Precast 6	Add	1	5	20	100	$37.00	$3,700.00
	Precast 7	Add	1	5	22.5	112.5	$37.00	$4,162.50
	Precast 8	Add	1	6.5	2	13	$37.00	$481.00
	Precast 9	Add	1	6.5	5	32.5	$37.00	$1,202.50
	Precast 10	Add	1	6.5	3.5	22.75	$37.00	$841.75
	Precast 11	Add	1	6.5	14.5	94.25	$37.00	$3,487.25
	Precast 12	Add	1	6.5	20	130	$37.00	$4,810.00
	Precast 13	Add	1	6.5	22.5	146.25	$37.00	$5,411.25
	Precast 14	Add	1	6.5	11	71.5	$37.00	$2,645.50
	Precast 15	Add	1	6.5	5.5	35.75	$37.00	$1,322.75
	Precast 16	Add	1	6.5	14.5	94.25	$37.00	$3,487.25
	Precast 17	Add	1	3.5	20	70	$37.00	$2,590.00
	Precast 18	Add	1	3.5	22.5	78.75	$37.00	$2,913.75
	Precast 19	Add	1	3	31	93	$37.00	$3,441.00
	Precast 20	Add	1	8	2	16	$37.00	$592.00
	Precast 21	Add	1	8	4.5	36	$37.00	$1,332.00
	Precast 22	Add	1	8	5	40	$37.00	$1,480.00
	Precast 23	Add	1	8	3	24	$37.00	$888.00
	Precast 24	Add	1	11	3	33	$37.00	$1,221.00
	Precast 25	Add	1	6	31	186	$37.00	$6,882.00
	Precast 26	Add	1	6	3	18	$37.00	$666.00
	Precast 27	Add	1	10	31	310	$37.00	$11,470.00
	Precast 28	Add	1	1	8	8	$37.00	$296.00
	Precast 29	Add	2	8	17	272	$37.00	$10,064.00
	Precast 30	Add	2	8	22.5	360	$37.00	$13,320.00
	Precast 31	Add	2	8	16	256	$37.00	$9,472.00
	Precast 32	Add	2	7	28.5	399	$37.00	$14,763.00
	Precast 33	Add	2	7	17	238	$37.00	$8,806.00
	Precast 34	Add	2	7	22.5	315	$37.00	$11,655.00
	Precast 35	Add	2	7	16	224	$37.00	$8,288.00
		TOTAL	**43**			**4378.75**		**$162,013.75**
		MASONRY DEDUCT				**4378.75**	**$41.50**	**$181,718.13**
		TOTAL SAVINGS						**$19,704.38**

ELEVATION	ITEM	ACTION	QUANTITY	WIDTH	HEIGHT	SF	COST/SF	TOTAL COST
Corners	South Bar	Add	1	1.5	3	4.5	$50.50	$227.25
		Add	1	1.5	11.5	17.25	$50.50	$871.13
		Add	2	2.5	14	70	$50.50	$3,535.00
		Add	1	2.5	16	40	$50.50	$2,020.00
		Add	1	2.5	13	32.5	$50.50	$1,641.25
	South	Add	3	1.5	16	72	$37.00	$2,664.00
		Add	1	2	14	28	$37.00	$1,036.00
		Add	1	2	16	32	$37.00	$1,184.00
		Add	1	2	18	36	$37.00	$1,332.00
		Add	1	1.5	14	21	$37.00	$777.00
		Add	1	1.5	13	19.5	$37.00	$721.50
	North	Add	1	2.75	13	35.75	$50.50	$1,805.38
		Add	1	2.75	14	38.5	$50.50	$1,944.25
		Add	1	2.75	16	44	$50.50	$2,222.00
		Add	1	2.75	14.583	40.10325	$50.50	$2,025.21
		Add	1	1.5	13	19.5	$50.50	$984.75
		Add	1	1.5	14	21	$50.50	$1,060.50
		Add	1	1.5	16	24	$50.50	$1,212.00
	East Bar	Add	4	1.5	14	84	$50.50	$4,242.00
		Add	2	1.5	16	48	$50.50	$2,424.00
		Add	2	1.5	13	39	$50.50	$1,969.50
	East	Add	2	1.67	14	46.76	$37.00	$1,730.12
		Add	1	1.67	16	26.72	$37.00	$988.64
		Add	1	1.67	4	6.68	$37.00	$247.16
	West	Add	1	1.67	14	23.38	$37.00	$865.06
		Add	3	1.67	16	80.16	$37.00	$2,965.92
		Add	3	1.5	13	58.5	$37.00	$2,164.50
		Add	2	1.5	14	42	$37.00	$1,554.00
		Add	2	1.5	16	48	$37.00	$1,776.00
		TOTAL	**44**			**1098.803**		**$48,190.11**
		MASONRY DEDUCT				**1098.803**	**$41.50**	**$45,600.32**
		TOTAL SAVINGS						**($2,589.79)**

TOTALS:	
Pieces	341
SF	20835.043
Precast Cost	$915,357.93
Masonry Cost	$864,654.29
Total Savings	($50,703.64)

APPENDIX F – Structural Breadth Beam Calculations (Precast)

STRUCTURAL CALCS: | CHECK: W16×26 | DESIGN AND DEFLECTION | 1/3



STORY HEIGHT = 15'

TRIBUTARY WIDTH = 4'

3 1/4" LW 4000 PSI COMPOSITE SLAB

2" 20 GA GALVANIZED STEEL DECK

3/4" SHEAR STUDS

DESIGN OF B1

LOADS:

DEAD

SUPERIMPOSED = 10 PSF (4') = 40 lb/ft

FROM VULCRAFT DECK CATALOG → SLAB = 42 PSF (4') = 168 lb/ft

PRECAST PANEL = 75 PSF (15') = 1125 lb/ft

TOTAL DEAD LOAD = 1333 lb/ft

LIVE

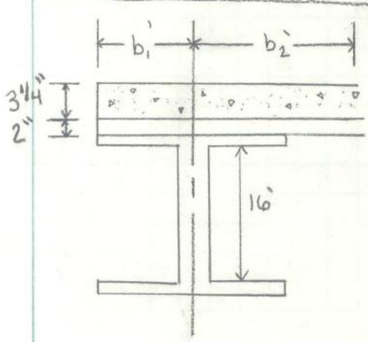
PERFORMING ARTS = (100 PSF)(4') = 400 lb/ft

FACTORED LOAD

$W_u = 1.2(1333) + 1.6(400) = 2239.6 \text{ lb/ft} = 2.24 \frac{\text{kips}}{\text{ft}}$

$M_u = \frac{W_u \ell^2}{8} = \frac{2.24(21.5')^2}{8} = 129.43 \text{ ft·kips}$

DESIGN OF COMPOSITE ACTION BEAM



EFFECTIVE FLANGE

$b_1' = 2.75 \text{ in.}$

$b_2' \le \frac{21.5'}{8} = 2.68'$ ← CONTROLS

or

$\le \frac{8'}{2} = 4'$

$b_{eff} = 2.68' + \frac{2.75"}{12} = 2.9'$

$= 34.8"$

STRUCTURAL CALCS:	CHECK: W16 × 26	DESIGN AND DEFLECTION	2/3

DESIGN OF COMPOSITE ACTION BEAM CONT'D

ASSUME $a = 1"$

$Y_2 = 5\,1/4" - 1/2" = 4.75$ in.

FROM AISC 13TH EDITION, TABLE 3-21:

3/4" SHEAR STUD → $Q_n = 21.2$ Kips

CHECK W16 × 26 : TABLE 3-19:

PNA @7 (LIMITS COMPRESSION IN CONCRETE)

$\phi M_n = 241$ ft·kip > 129.43 ft·kip ∴ OK ✓

$\Sigma Q_n = 96$ kips

CHECK ASSUMPTION $a = 1$ in.

$$a = \frac{96000}{(0.85)(4000)(34.8)} = 0.811 \text{ in} < 1.0 \text{ in} \quad \therefore \text{OK} ✓$$

OF STUDS = 96/21.2 = 4.53 ≈ 5 SHEAR STUDS

CHECK DEFLECTION IN W16 × 26:

CONSTRUCTION LOAD:

$w = w_{D\,CONST} + w_{L\,CONST}$

SLAB: $w_{D\,CONST} = 0.168$ k/ft

20 PSF LL: $w_{L\,CONST} = 0.08$ k/ft

$w = 0.168 + 0.08 = 0.248$ k/ft

TABLE 1-1: $I_x = 301$ in^4

$$\Delta = \frac{5w\ell^4(12)^3}{384\,EI} = \frac{5(0.248)(21.5)^4(1728)}{384(29000)(301)} = 0.137 < \frac{\ell}{240} = \frac{(21.5)(12)}{240}$$

0.137 < 1.075 in

∴ OK ✓

LIVE LOAD:

$w_L = 0.4$ k/ft

LOWER BOUND: $I_{LB} = 535$ in^4 (TABLE 3-20)

$$\Delta_{LL} = \frac{5(0.4)(21.5)^4(1728)}{384(29000)(535)} = 0.124 < \frac{\ell}{360} = \frac{21.5(12)}{360} = 0.717$$

0.124 < 0.717 in ∴ OK ✓

STRUCTURAL CALCS: | CHECK: W16×26 | DESIGN AND DEFLECTION | 3/3

TOTAL LOAD:

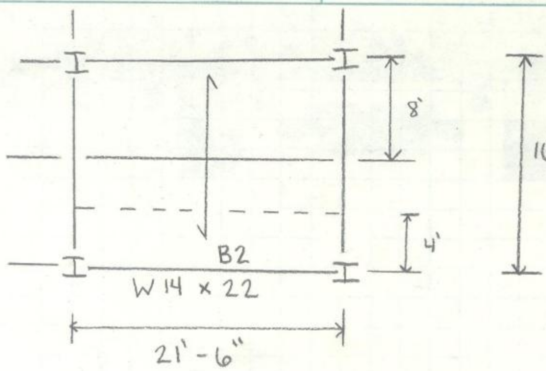
$$W = W_D + W_L = 1.333 + 0.400 = 1.733 \text{ k/ft}$$

$$\Delta_{TOTAL} = \frac{5(1.733)(21.5)^4(1728)}{384(29000)(535)} = 0.537 < \frac{l}{240} = \frac{(21.5)(12)}{240}$$

$$0.537 < 1.075 \text{ in}$$

∴ OK ✓

STRUCTURAL CALCS: | CHECK: W14 x 22 | DESIGN AND DEFLECTION | 1/3



STORY HEIGHT = 15'

TRIBUTARY WIDTH = 4'

3 1/4" LW 4000 PSI COMPOSITE SLAB

2" 20 GA GALVANIZED STEEL DECK

3/4" SHEAR STUDS

DESIGN OF B2

LOADS:

DEAD

SUPERIMPOSED = 10 PSF (4') = 40 lb/ft

FROM VULCRAFT DECK CATALOG → SLAB = 42 psf (4') = 168 lb/ft

PRECAST PANEL = 75 PSF (15') = 1125 lb/ft

TOTAL DEAD LOAD = 1333 lb/ft

LIVE

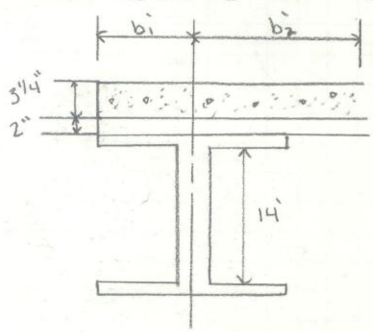
PERFORMING ARTS = (100 psf)(4') = 400 lb/ft

FACTORED LOAD

$W_u = 1.2(1333) + 1.6(400) = 2239.6 \text{ lb/ft} = 2.24 \text{ k/ft}$

$M_u = \frac{W_u \ell^2}{8} = \frac{2.24(21.5')^2}{8} = 129.43 \text{ ft·kips}$

DESIGN OF COMPOSITE ACTION BEAM



EFFECTIVE FLANGE

$b_1 = 2.5 \text{ in.}$

$b_2 \le \frac{21.5'}{8} = 2.68'$ ← CONTROLS

or

$\le \frac{8'}{2} = 4'$

$b_{eff} = 2.68' + \frac{2.5"}{12} = 2.89'$

$= 34.68"$

STRUCTURAL CALCS: | CHECK: W14×22 | DESIGN AND DEFLECTION | 2/3

DESIGN OF COMPOSITE ACTION BEAM CONT'D

ASSUME $a = 1"$

$Y_2 = 5\frac{1}{4}" - \frac{1}{2}" = 4.75$ in.

FROM AISC 13TH EDITION, TABLE 3-21:

3/4" SHEAR STUD → $Q_n = 21.2$ Kips

CHECK W14×22: TABLE 3-19:

PNA @7 (LIMITS COMPRESSION IN CONCRETE)

$\phi M_n = 183$ ft·Kip > 129.43 ft·Kips ∴ OK ✓

$\Sigma Q_n = 81.2$ K

CHECK ASSUMPTION $a = 1$ in.

$$a = \frac{81200}{(0.85)(4000)(34.68)} = 0.689 \text{ in} < 1.0 \text{ in} \quad \therefore \text{OK} \checkmark$$

\# OF STUDS = 81.2 / 21.2 = 3.83 ≈ 4 SHEAR STUDS

CHECK DEFLECTION IN W14×22:

CONSTRUCTION LOAD:

$W = W_{D\,CONS} + W_{L\,CONST}$

SLAB: $W_{D\,CONST} = 0.168$ K/ft

20 PSF LL: $W_{L\,CONST} = 0.08$ K/ft

$W = 0.168 + 0.08 = 0.248$ K/ft

TABLE 1-1: $I_x = 199 \text{ in}^4$

$$\Delta = \frac{5 w l^4 (12)^3}{384 EI} = \frac{5(0.248)(21.5)^4(1728)}{384(29000)(199)} = 0.2066 < \frac{l}{240} = \frac{(21.5)(12)}{240}$$

$0.2066 < 1.075$ in

∴ OK ✓

LIVE LOAD:

$W_L = 0.4$ K/ft

LOWER BOUND: $I_{LB} = 367 \text{ in}^4$ (TABLE 3-20)

$$\Delta_{LL} = \frac{5(0.4)(21.5)^4(1728)}{384(29000)(367)} = 0.181 < \frac{l}{360} = \frac{21.5(12)}{360}$$

$0.181 < 0.717$ in ∴ OK ✓

STRUCTURAL CALCS:	CHECK: W 14 x 22	DESIGN AND DEFLECTION	3/3

TOTAL LOAD:

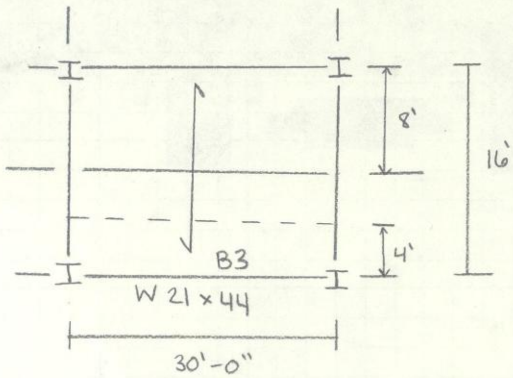
$$W = W_D + W_L = 1.333 + 0.400 = 1.733 \text{ k/ft}$$

$$\Delta_{TOTAL} = \frac{5(1.733)(21.5)^4(1728)}{384(29000)(367)} = 0.783 < \frac{l}{240} = \frac{(21.5)(12)}{240}$$

$$0.783 < 1.075 \text{ in}$$

$\therefore$ OK ✓

STRUCTURAL CALCS:	CHECK: W21 x 44	DESIGN AND DEFLECTION	1/3



STORY HEIGHT = 15'

TRIBUTARY WIDTH = 4'

3¼" LW 4000 PSI COMPOSITE SLAB

2" 20 GA GALVANIZED STEEL DECK

3/4" SHEAR STUDS

DESIGN OF B3

LOADS:

DEAD

SUPERIMPOSED = 10 PSF (4') = 40 lb/ft

FROM VULCRAFT DECK CATALOG → SLAB = 42 PSF (4') = 168 lb/ft

PRECAST PANEL = 75 PSF (15') = 1125 lb/ft

TOTAL DEAD LOAD = 1333 lb/ft

LIVE

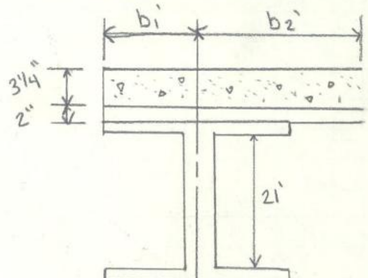
PERFORMING ARTS = 100 PSF (4') = 400 lb/ft

FACTORED LOAD

$W_u = 1.2(1333) + 1.6(400) = 2239.6 \text{ lb/ft} = 2.24 \text{ k/ft}$

$M_u = \frac{W_u \ell^2}{8} = \frac{2.24(30')^2}{8} = 252 \text{ ft. kips}$

DESIGN OF COMPOSITE ACTION BEAM



EFFECTIVE FLANGE

$b_1' = 3.25 \text{ in.}$

$b_2' \leq \frac{30'}{8} = 3.75'$ ← CONTROLS

or

$\leq \frac{8'}{2} = 4'$

$b_{eff} = 3.75' + \frac{3.25"}{12} = 4.02'$
$= 48.24"$

STRUCTURAL CALCS: | CHECK: W21 x 44 | DESIGN AND DEFLECTION | 2/3

DESIGN OF COMPOSITE ACTION BEAM CONT'D

ASSUME $a = 1"$

$Y_2 = 5\frac{1}{4}" - \frac{1}{2}" = 4.75$ in.

FROM AISC 13TH EDITION, TABLE 3-21:

3/4" SHEAR STUD → $Q_n = 21.2$ kips

CHECK W21 x 44: TABLE 3-19:

PNA @ 7 (LIMITS COMPRESSION IN CONCRETE)

$\phi M_n = 510$ ft·kip > 252 ft·kip ∴ OK ✓

$\Sigma Q_n = 162$ kips

CHECK ASSUMPTION $a = 1$ in.

$$a = \frac{162000}{(0.85)(4000)(48.24)} = 0.988 \text{ in} < 1.0 \text{in} \quad \therefore \text{OK} ✓$$

OF STUDS = 162/21.2 = 7.64 ≈ 8 SHEAR STUDS

CHECK DEFLECTION IN W21 x 44:

CONSTRUCTION LOAD:

$W = W_{D\,CONST} + W_{L\,CONST}$

SLAB: $W_{D\,CONST} = 0.168$ k/ft

20 PSF LL: $W_{L\,CONST} = 0.08$ k/ft

$W = 0.168 + 0.08 = 0.248$ k/ft

TABLE 1-1: $I_x = 843$ in⁴

$$\Delta = \frac{5 w \ell^4 (12)^3}{384 EI} = \frac{5(.248)(30)^4(1728)}{384(29000)(843)} = 0.185 < \frac{\ell}{240} = \frac{(30)(12)}{240}$$

$0.185 < 1.5$ in

∴ OK ✓

LIVE LOAD:

$W_L = 0.4$ k/ft

LOWER BOUND: $I_{LB} = 1410$ in⁴ (TABLE 3-20)

$$\Delta_{LL} = \frac{5(0.4)(30)^4(1728)}{384(29000)(1410)} = 0.178 < \frac{\ell}{360} = \frac{30(12)}{360} = 1.0$$

$0.178 < 1.0$ in ∴ OK ✓

STRUCTURAL CALCS: | CHECK: W21x44 | DESIGN AND DEFLECTION | 3/3

TOTAL LOAD:

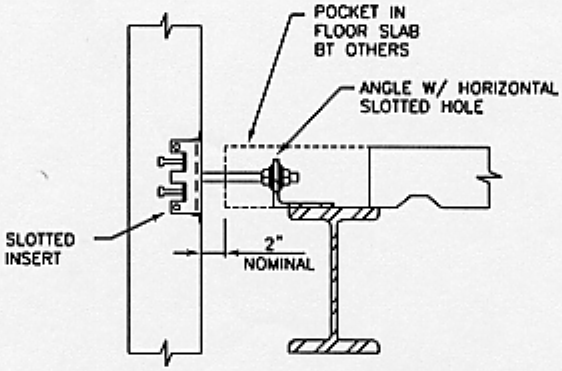
$$W = W_D + W_L = 1.333 + 0.400 = 1.733 \text{ k/ft}$$

$$\Delta_{TOTAL} = \frac{5(1.733)(30)^4(1728)}{384(29000)(1410)} = 0.7724 < \frac{l}{240} = \frac{30(12)}{240}$$

$$0.7724 < 1.5 \text{ in}$$

$\therefore$ OK ✓

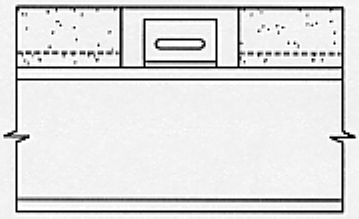
APPENDIX G – Precast Tie-Back Connections



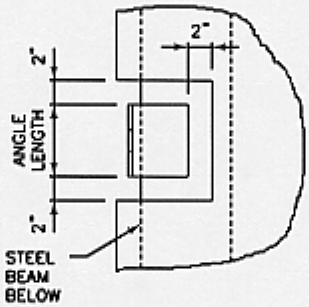
NOTES

1. OVERALL HEIGHT OF ANGLE SHOULD NOT EXCEED FLOOR THICKNESS UNLESS CONNECTION FALLS WITHIN FINISHED FLOOR.

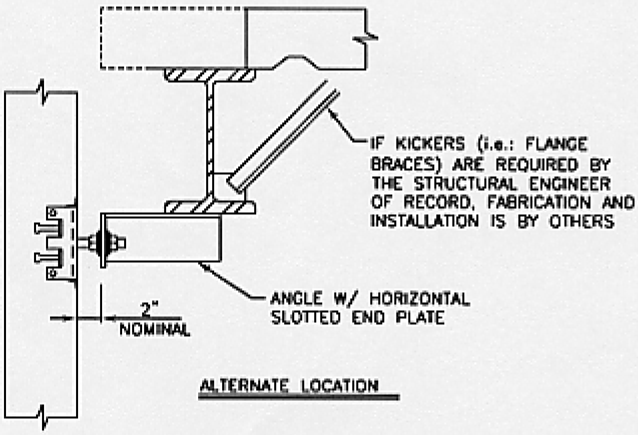
2. FORMING POCKETS, CUTTING DECK, POUR STOP AND PATCHING OF POCKETS NOT BY PRECASTER.



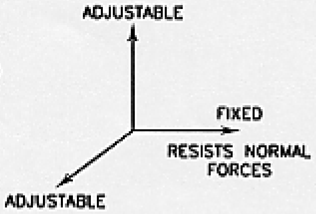
ELEVATION VIEW



PLAN VIEW



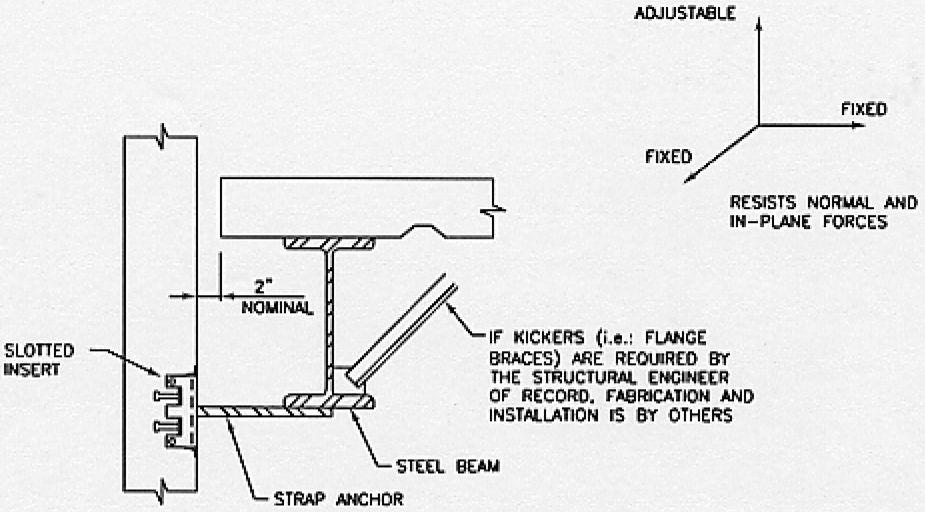
ALTERNATE LOCATION

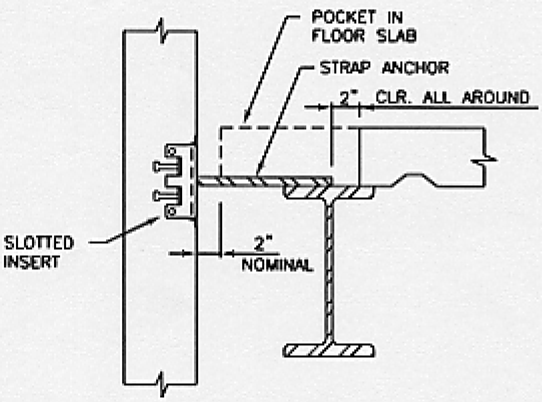


BEARING / ADJUSTABLE TIE-BACK CONNECTION

MID-ATLANTIC PRECAST ASSOCIATION

MID-ATLANTIC PRECAST ASSOCIATION
P.O. BOX 831
HOCKESSIN, DE 19707
WWW.MAPAPRECAST.ORG





ALTERNATE

NOTE

FORMING POCKETS, CUTTING DECK POUR STOP AND PATCHING OF POCKETS NOT BY PRECASTER.

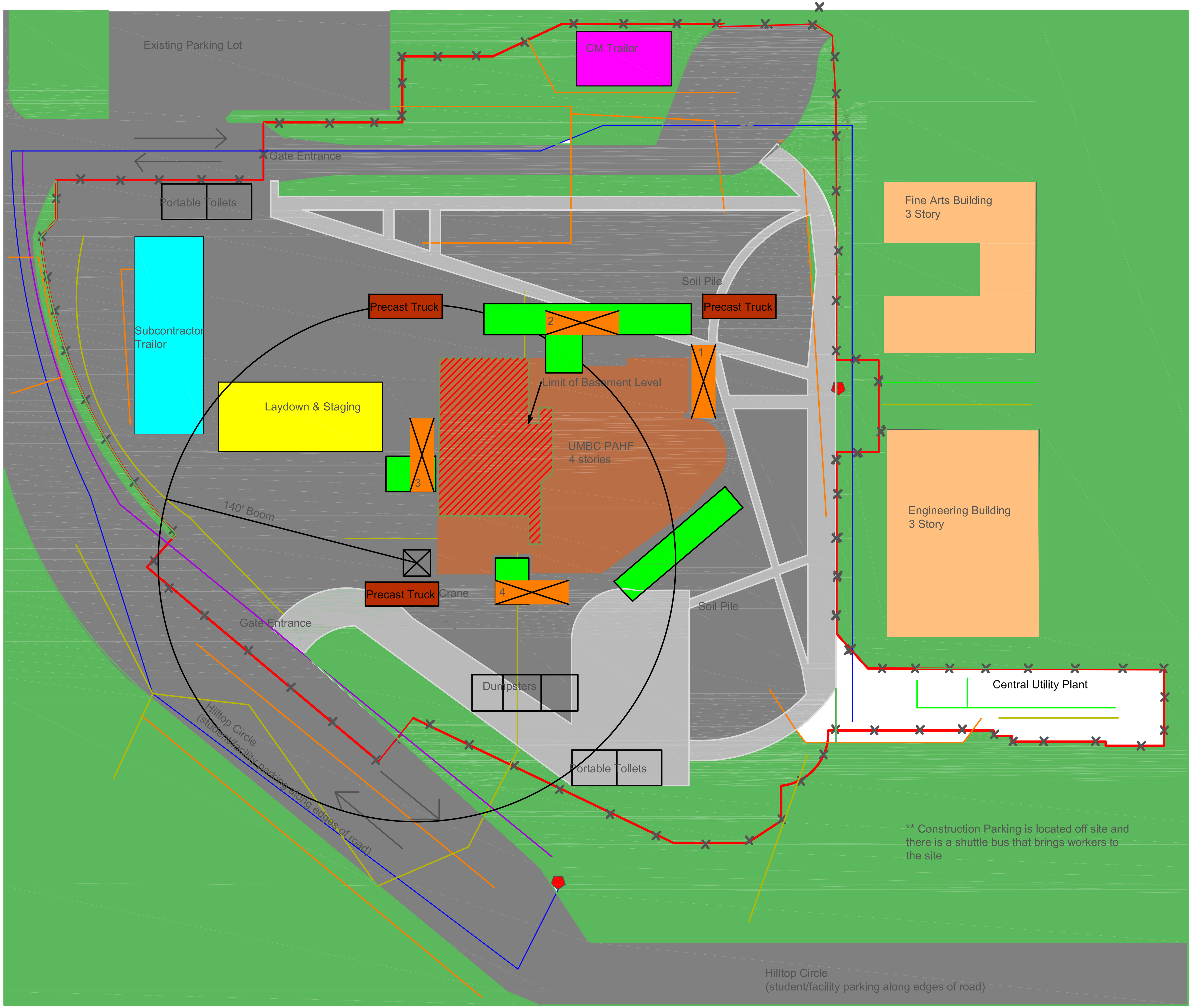
FIXED TIE-BACK CONNECTION

MID-ATLANTIC PRECAST ASSOCIATION

MID-ATLANTIC PRECAST ASSOCIATION
P.O. BOX 831
HOCKESSIN, DE 19707
WWW.MAPAPRECAST.ORG

Drawing Name: F:\karnold\Jose Project\MAPA-NITER.dwg Last Modified: Mar 27, 2002 - 8:04am Plotted on: Mar 27, 2002 - 8:05am by karnold

APPENDIX H – Site Layout Plans for Precast Facade



LEGEND:

Existing Utilities

- Water
- Gas
- Storm Drain
- Sanitary
- Electric

Symbols

- Fire Hydrant
- Vehicular Traffic
- Construction Fence

Crane Paths

Precast Crane Location

UMBC
Performing Arts & Humanities Facility

Precast Facade Phase Plan
(Delivery and Erection)

April 7, 2011

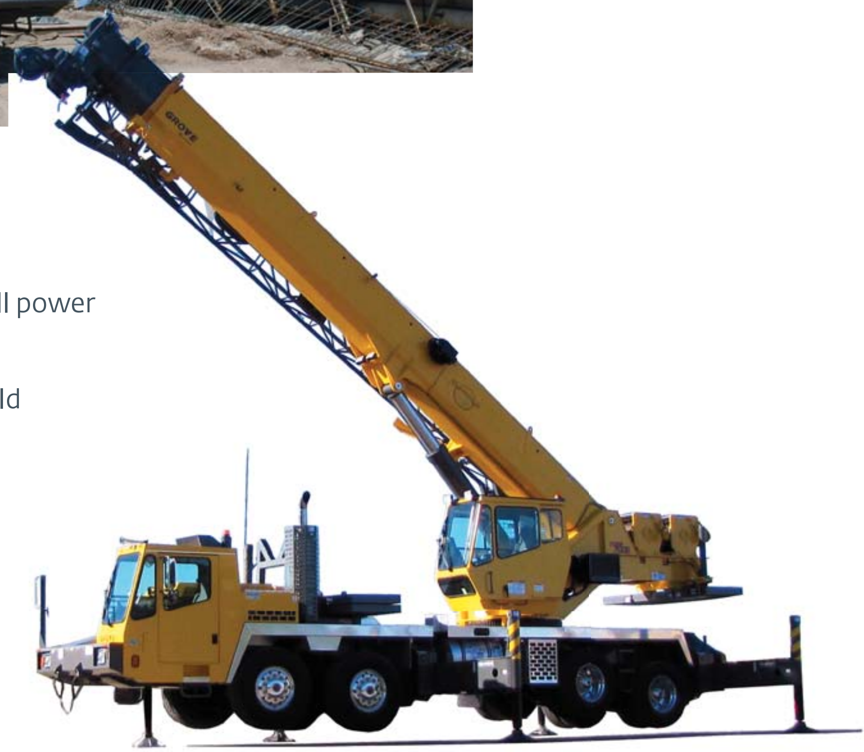
Courtney Glaub - CM

APPENDIX I – Mobile Crane Data Sheets

Manitowoc

Grove TMS700E

Product Guide



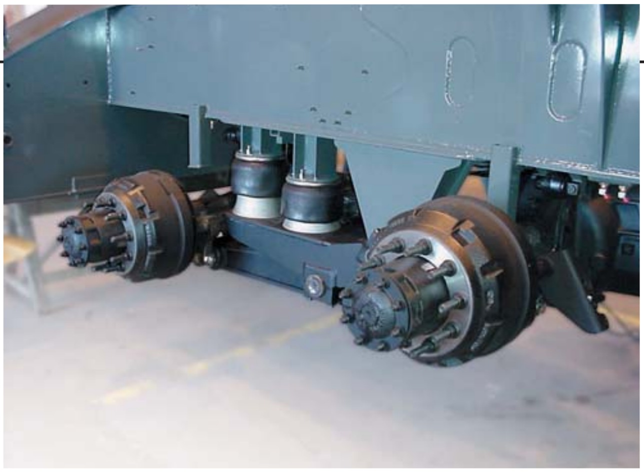
Features

- 50 t or 55 t (50 USt or 60 USt) capacity
- 11 m – 33,5 m (36 ft – 110 ft) four-section, full power sequenced synchronized boom
- 10,1 m – 17 m (33 ft – 56 ft) offsettable bi-fold lattice swingaway extension
- Optional 6,1 m (20 ft) or 12,2 m (40 ft) swingaway extension inserts
- Grove MEGAFORM™ boom
- Up to 7484 kg (16,500 lb) hydraulically installed and removed counterweight

Features

Swingaway extension inserts

Optional 6,1 m (20 ft) or 12,2 m (40 ft) swingaway extension inserts offer excellent capacities with an unprecedented tip height of up to 212 ft.



Suspension system

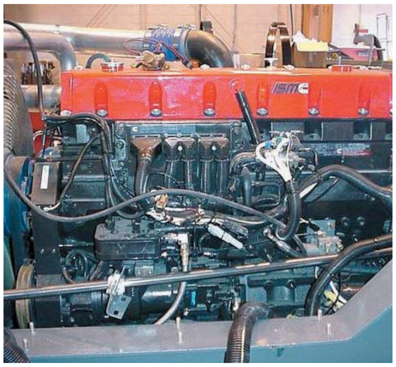
Standard front and rear air ride suspension provides a comfortable ride at maximum speed of 105 km/h (65 mph).

MEGAFORM™ boom

The 11 m – 33,5 m (36 ft – 110 ft) four-section full power sequenced synchronized MEGAFORM™ boom is designed for maximum vertical and lateral strength.

Cummins diesel carrier engine

Cummins ISM 450 diesel carrier engine delivers the horsepower and torque needed to negotiate tough job sites and achieve highway travel speeds.



Specifications

Superstructure

Boom

11 m – 33,5 m (36 ft – 110 ft) four (4) section, full power sequenced synchronized boom.

Maximum tip height: 35,9 m (118 ft).

Folding lattice extension

10,1 m – 17,1 m (33 ft – 56 ft) folding lattice swingaway extension offsettable at 0°, 25° or 45°. Stows alongside base boom section.

Maximum tip height: 52,6 m (172.5 ft).

*Lattice extensions

Two (2) 6,1 m (20 ft) lattice extensions used with the swingaway extension to increase the length to 23,2 m (76 ft) or 29,3 m (96 ft).

Maximum tip height: 64,6 m (212 ft).

Boom nose

Quick reeving type boom nose with 3 nylatron sheaves (TMS750E), (4 for TMS760E [60 ton rating]) mounted on heavy duty tapered roller bearings with removable pin-type rope guards. Removable auxiliary boom nose with removable pin type rope guard.

Boom elevation

One double acting hydraulic cylinder with integral holding valve provides elevation from -3˚ to 78˚.

Load moment and anti-two block system

Standard “Graphics Display” load moment and anti-two block system with audio-visual warning and control lever lockout. These systems provide electronic display of boom angle, boom length, radius, tip height, relative load moment, maximum permissible load, load indication and warning of impending two-block condition. The standard “Work Area Definition System” allows the operator to pre-select and define safe working areas. If the crane approaches the pre-set limits, audio-visual warnings aid the operator in avoiding job-site obstructions.

Cab

High visibility, all steel cab with acoustical lining and tinted safety glass throughout. Deluxe seat with armrest mounted hydraulic single axis controls. Dash panel incorporates gauges for all engine functions. Other standard features include: sliding side and rear windows, hot water heat, electric windshield wash/wipe, circulating air fan, sliding skylight with sunscreen and electric skylight wiper, fire extinguisher, cup holder, air conditioning.

Swing

Planetary swing with foot applied multi-disc wet brake. Spring applied, hydraulically released parking brake. Two position plunger type and 360˚ mechanical house locks operated from cab.

Maximum speed: 2.0 rpm.

Counterweight

4990 kg (11,000 lb) consisting of (2) 2495 kg ([2] 5500 lb) sections. *Optional “Heavy Lift” package consisting of (1) additional 2495 kg (5500 lb) section, for a total of 7484 kg (16,500 lb). Hydraulic installation/removal.

Hydraulic system

Four main gear pumps with a combined capacity of 513 L/m (135.4 gpm). Individual pressure compensated valve banks. Maximum operating pressure: 27,6 Mpa (4000 psi).

Return line type filter with full flow by-pass protection and service indicator. Replaceable cartridge with beta rating of 5/12/16. 643 L (170 gal) reservoir. Remote mounted oil cooler with thermostatically controlled electric motor driven fan.

Denotes optional equipment

Superstructure, continued

Hoist specifications main and auxiliary hoists-model HP30A-19G

Planetary reduction with integral automatic brake, electronic hoist drum rotation indicator, and hoist drum cable follower. Grooved drum.

Single line pull:	1st layer:	8226 kg (18,134 lb)
	3rd layer:	6994 kg (15,420 lb)
	5th layer:	6084 kg (13,413 lb)

Maximum single line speed: 162 m/min (531 fpm)

Maximum permissible line pull: 7620 kg (16,800 lb) with standard 6 x 37 class rope

7620 kg (16,800 lb) with optional 35 x 7 class rope

Rope diameter: 19 mm (.75 in)

Rope length: 152 m (500 ft)

Rope type: 6 x 36 EIPS IWRC special flexible

Optional 35 x 7 rotation resistant

Maximum rope stowage: 256 m (841 ft)

Carrier

Chassis

Triple box section, four-axle carrier, fabricated from high strength, low alloy steel with towing and tie-down lugs.

Outrigger system

Four hydraulic telescoping, single stage, double box beam outriggers with inverted jack and integral holding valves. Quick release type steel outrigger floats 610 mm (24 in) diameter. Three position setting with fully extended, intermediate (50%) extended and fully retracted capacities.

Outrigger controls

Located in the superstructure cab and both sides of chassis. Level indicator at each control station.

Engine

Cummins ISM 450, 10,8 L diesel (On Highway EPA Certified) six cylinders, after cooled, 336 kW (450 bhp) at 2000 rpm. Maximum torque 2102 Nm (1550 ft-lb) at 1200 rpm.

Fuel requirement — Maximum of 15 ppm sulfur content (ultra low sulfur diesel).

Equipped with engine compression brake, block heater, cold start aid (less canister) and audio-visual engine distress system.

*Engine (required for sale outside North America)

Cummins QSM 402, 10,8 L diesel (Off Highway EPA Certified) six cylinders, after cooled 300 kW (402 bhp) at 1800 rpm. Maximum torque 1898 Nm (1400 ft lb) at 1400 rpm.

Fuel requirement — Maximum of 5000 ppm sulfur content.

Equipped with engine compression brake, block heater, cold start aid (less canister) and audio-visual engine distress system.

Fuel tank capacity

379 L (100 gal).

Transmission

Roadranger 11 speeds forward, 3 reverse.

**Denotes optional equipment*

Specifications

Carrier, continued

Drive

Drive 8 x 4 x 4.

Steering

Front axles, single circuit, mechanical steering with hydraulic assist.

Axles

Front: (2) beam-type steering axles, 2,1 m (83.3 in) track.

Rear: (2) single reduction drive axles, 1,9 m (75.1 in) track. Inter-axle differential lock.

Brakes

S-cam, dual system operating on all wheels. Spring applied air released parking brake acting on rear axles.

Suspension

Front: Walking beam with air bags and shock absorbers.

Rear: Walking beam with air bags and shock absorbers.

Tires

Front: 445/65R 22.5, tubeless, mounted on aluminum disc wheels.

Rear: 315/80R 22.5, tubeless, mounted on aluminum disc wheels, steel inner.

Lights

Full lighting package including turn indicators, head, tail, brake, and hazard warning lights.

Cab

One man design, all steel fabricated with acoustical lining and tinted safety glass throughout. Deluxe fabric covered, fully adjustable air ride seat. Complete driving controls and engine instrumentation including tilt telescope steering wheel, tachometer, speedometer, voltmeter, water temp., oil pressure, fuel level, air pressure gauge with A/V warning and engine high temp./low oil pressure A/V warning. Other standard items include hot water heater/defroster, electric windshield wash/wipe, fire extinguisher, seat belt, air conditioning, air horn and door lock.

Electrical system

Two (2) 12V batteries. 12V lighting/starting. Battery disconnect standard equipment.

Maximum speed

104 km/h (65 mph)

Gradeability (theoretical)

70%

Miscellaneous standard equipment

Aluminum fenders with rear storage compartments; dual rear view mirrors; electronic back-up alarm; pump disconnect; tire inflation kit; air cleaner restriction indicator; headache ball stowage; chrome package which includes aluminum wheels, and LMI event recorder.

*Optional equipment

- **Auxiliary Lighting and Convenience Package** — includes amber strobe for superstructure and carrier cabs, dual boom base mounted floodlights, and LMI light bar (in cab)
- **Trailing Boom Package** — includes trailer air and electrical disconnects, no spin differential and trailing boom kit (less dolly)
- Wind speed indicator
- Hook blocks
- Rear pintle hook
- Cross axle differential locks
- Winter front radiator cover
- Aluminum outrigger pads
- Tow cable
- LMI calibration for on rubber

**Denotes optional equipment*

Technical Data

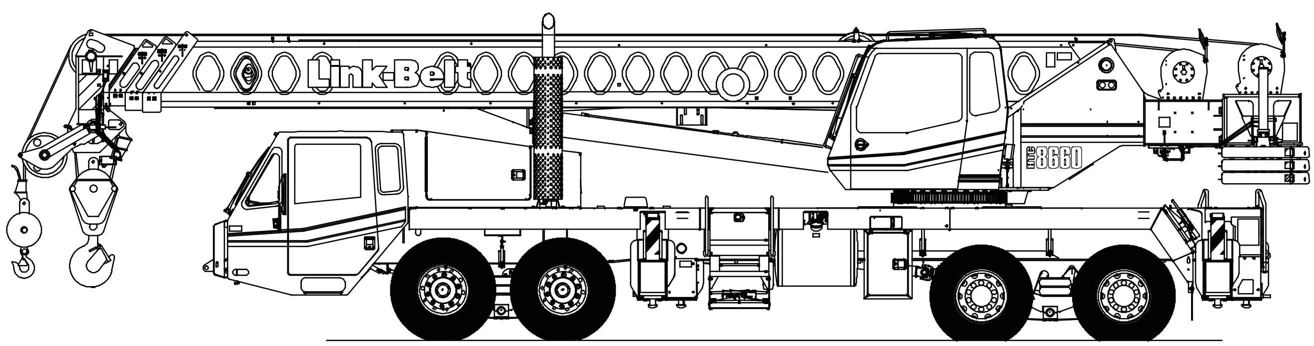
Specifications & Capacities

HTC 8660

Series II

Telescopic Boom Truck Crane

60 ton *(50.0 metric ton)*



CAUTION: This material is supplied for reference use only. Operator must refer to in – cab Crane Rating Manual and Operator's Manual to determine allowable crane lifting capacities and assembly and operating procedures.

Boom, Attachments, and Upper Structure

■ Boom

Design – Four section, box type construction of high tensile steel consisting of one base section and three telescoping sections. The vertical side plates have diamond shaped impression for superior strength to weight ratio. The first telescoping section extends independently by means of one double–acting, single stage hydraulic cylinder with integrated holding valves. The second and third telescoping sections extend proportionally by means of one double–acting, single stage cylinder with integrated holding valves and cables.

Boom

- 35.5–110 ft *(10.8–33.5m)* four–section full power boom
- Two mode boom extension: A–max mode provides superior capacities by extending the first telescope section to 60.3 ft *(18.4m)*. Standard mode synchronizes all the telescoping sections proportionally to 110 ft *(33.5m)*. Controlled from operator's cab.
- Mechanical boom angle indicator
- Maximum tip height for A–max mode is 68.8 ft *(21.0m)* and standard mode is 117.4 ft *(35.8m).*

Boom Head

- Four 16.5 in *(41.9cm)* root diameter nylon sheaves to handle up to eight parts of line
- Easily removable wire rope guards
- Rope dead end lugs on each side of the boom head
- Boom head is designed for quick–reeve of the hook block

Boom Elevation

- One double acting hydraulic cylinder with integral holding valve
- Boom elevation: –3° to 78°

Auxiliary Lifting Sheave – Optional

- Single 16.5 in (*41.9m*) root diameter nylon sheave
- Easily removable wire rope guards
- Does not affect erection of the fly or use of the main head sheaves

Hook Blocks and Balls – Optional

- 25 ton (*22.7mt*) 3 sheave quick–reeve hook block with safety latch
- 40 ton (*36.3mt*) 4 sheave quick–reeve hook block with safety latch
- 50 ton (*45.4mt*) 5 sheave quick–reeve hook block with safety latch
- 8.5 ton (*7.7mt*) swivel and non–swivel hook balls with safety latch

Fly – Optional

- 28.5 ft *(8.7m)* one piece lattice fly, stowable, offsettable to 2°, 20°, and 40°. Maximum tip height is 144.8 ft *(44.1m)*.
- 28.5–51 ft *(8.7–15.5m)* two piece bi–fold lattice fly, stowable, offsettable to 2°, 20° and 40°. Maximum tip height is 166.9 ft *(50.9m).*

■ Upper Operator's Cab and Controls

Environmental Cab – Fully enclosed, one person cab of galvaneal steel structure with acoustical insulation. Equipped with:

- Tinted and tempered glass windows
- Extra–large fixed front window with windshield wiper and washer
- Swing up roof window with windshield wiper
- Sliding left side door with large fixed window
- Sliding rear and right side windows for ventilation
- Six way adjustable, cushioned seat with seat belt and storage compartment
- Diesel fired warm–water heater with air ducts for front windshield defroster and cab floor
- Defroster fan for the front window
- Bubble level
- Circulating fan
- Adjustable sun visor
- Dome light
- Cup holder
- Fire extinguisher
- Left side viewing mirror
- Pull–out cabwalk
- Two position travel swing lock

Air Conditioning – Optional – Integral with cab heating system utilizing the same ventilation outlets

Armrest Controls – Two dual axis hydraulic joystick controllers or optional single axis hydraulic controllers for:

- Swing
- Boom hoist
- Main rear winch
- Auxiliary front winch – optional
- Drum rotation indication
- Drum rotation indicator activation switch
- Swing park brake switch
- Winch high/low speed and disable switch(es)
- Diesel particulate filter switch (EPA 2007 Engine Only)
- Telescope override switch
- Warning horn button

Outrigger Controls – Hand held control box with umbilical cord gives the operator the freedom to view operation while setting the outriggers.

Drive and Steer Controls – Optional – Hand held control box with umbilical cord gives the operator the ability to drive and steer the crane at low speed from the operator's cab.

Foot Controls

- Boom telescope
- Swing brake
- Engine throttle
- Carrier service brake – optional

Right Front Console – Controls and indicators for:

- Engine ignition
- Engine throttle lock
- Pump enable
- Function disable
- Front windshield wiper and washer
- Cab floodlights
- Warning horn
- Heating controls
- Console dimmer switch
- Bubble level
- 12 volt power connection
- Air conditioning – optional
- Boom floodlight – optional
- Rotating beacon or strobe light switch – optional
- Carrier park brake – optional
- Third wrap selector switch – optional

Cab Instrumentation – Ergonomically positioned, analog instrumentation for crane operation including:

- Check and stop engine indicators
- Low air pressure warning indicator
- Swing park brake indicator
- Diesel particulate filter indicator (2007 EPA Engine Only)
- High exhaust temperature indicator (2007 EPA Engine Only)
- Engine coolant temperature with warning indicator
- Hydraulic oil temperature with warning indicator
- Fuel level
- Tachometer

Rated Capacity Limiter – Microguard graphic audio–visual warning system integrated into the dash with anti–two block and function limiter. Operating data available includes:

- Crane configuration
- Boom length and angle
- Boom head height
- Allowed load and % of allowed load
- Boom angle
- Radius of load
- Actual load
- Operator settable alarms (include):
  - Maximum and minimum boom angles
  - Maximum and minimum tip height
  - Maximum boom length
  - Left/right swing positions
  - Operator defined area (imaginary plane)

Internal RCL Light Bar – Optional – Visually informs the operator when crane is approaching maximum load capacity with a series of green, yellow, and red lights.

External RCL Light Bar – Optional – Visually informs the ground crew when crane is approaching maximum load capacity with a series of green, yellow, and red lights.

■ Swing

Motor/Planetary – Bi–directional hydraulic swing motor mounted to a planetary reducer for 360° continuous smooth swing at 2.5 rpm.

Swing Park Brake – 360°, electric over hydraulic, (spring applied/hydraulic released) multi–disc brake mounted on the speed reducer. Operated by a switch from the operator's cab.

Swing Brake – 360°, foot operated, hydraulic applied disc brake mounted to the speed reducer.

Swing Lock – Two–position swing lock (boom over front or rear) operated from the operator's cab.

360° Positive Swing Lock – Optional – Meets New York City requirement.

■ Electrical

Swing Alarm – Audio warning device signals when the upper is swinging.

Lights

- Two working lights on front of the cab
- One rotating amber beacon on top of the cab – optional
- One amber strobe beacon on top of the cab – optional
- Boom floodlight – optional

Manitowoc

Grove TMS800E
Product Guide

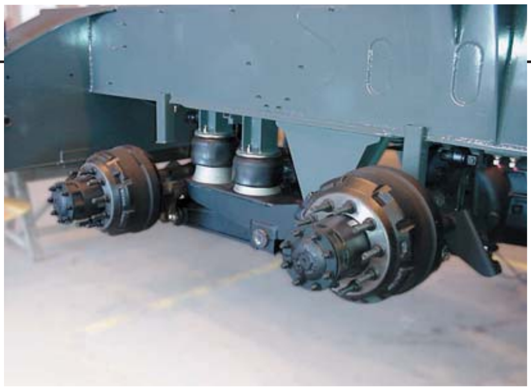
Features

- 12,6 m - 39 m (41 ft - 128 ft) four-section full power MEGAFORM™ boom
- 10 m – 17 m (33 ft – 56 ft) manual offset bifold swingaway
- 2 x 20 ft intermediate lattice inserts
- 10 886 kg (24,000 lb) counterweight with hydraulic removal system
- Cummins ISM 450, six cylinder after cooled 336 kW (450 hp) engine
- Front and rear air ride suspension

Features

MEGAFORM™ boom

The Grove MEGAFORM™ boom shape eliminates weight and increases capacity compared to conventional shapes.

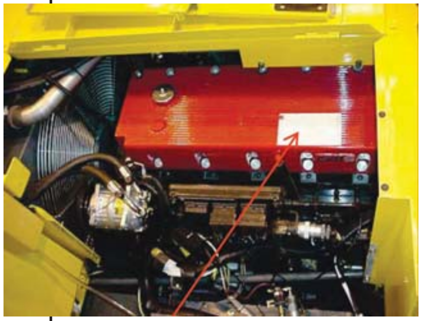


Suspension system

Standard front and rear air ride suspension provides a comfortable ride at maximum speed of 105 km/h (65 mph).

Lattice extension

For improved up and over reach, a bifold lattice extension is available on the TMS800E and manually offsets from 0° to 40°.



Cummins diesel carrier engine

The electronically controlled Cummins ISM diesel engine provides plenty of power, on highway and at the jobsite.

Specifications

Superstructure

Boom

12,5 m - 39 m (41 ft - 128 ft) four section, full power MEGAFORM™ boom.
Maximum tip height: 41,1 m (135 ft).

Boom nose

Four nylatron sheaves, mounted on heavy duty tapered roller bearings with removable pin type rope guards. Quick reeve boom nose. Removable auxiliary boom nose with removable pin type rope guard.

Boom elevation

Single lift cylinder with safety valve provides boom angle from -3° to +78°.

Offsettable lattice extension

10 m - 17 m (33 ft - 56 ft) bifold lattice swingaway extension, manual offsettable at 0°, 20° and 40°.
Maximum tip height: 58,2 m (191 ft)

* Optional lattice extension

Two 6,1 m (20 ft) inserts for use with lattice swingaway extension to increase length up to 23,2 m (76 ft) or 29,3 m (96 ft).
Maximum tip height: 70,1 m (230 ft)

Load moment and anti-two block system

Standard "Graphics Display" load moment and anti-two block system with audio-visual warning and control lever lockout. These systems provide electronic display of boom angle, boom length, radius, tip height, relative load moment, maximum permissible load, load indication and warning of impending two-block condition. The standard **"Work Area Definition System"** allows the operator to pre-select and define safe working areas. If the crane approaches the pre-set limits, audio-visual warnings aid the operator in avoiding job-site obstructions.

Cab

All aluminum constructed cab with acoustical lining, **hydraulically tiltable** (0° to +20°). Includes tinted safety glass, adjustable operator's seat, sliding windows in side and rear, hinged skylight with wiper, skylight sunscreen. Other features include hot water heater/defroster, armrest integrated dual axis crane controls, and ergonomically arranged instrumentation.

Swing

Axial piston fixed displacement motor and planetary gear box. Infinitely variable to 1.7 rpm. Holding brake and service brake.

Counterweight

3629 kg (8000 lb) consisting of various sections with hydraulic installation/removal system.

*Optional "Heavy Lift" package consisting of (1) 1814 kg (4000 lb) and (1) 2722 kg (6000 lb) section, for a total of 8165 kg (18,000 lb).

*Optional "XL" counterweight package consisting of (1) 2721 kg (6000 lb) slab, (1) 1814 kg (4000 lb) slab and (2) 1361 kg (3000 lb) wing weights in addition to standard; for a total of 10 886 kg (24,000 lb) of counterweight.

Hydraulic system

1 piston and 3 gear type pumps with a total capacity of 678 l/m (179 gpm). Maximum operating pressure, 27,6 MPa (4000 psi).
Thermostatically controlled oil cooler keeps oil at optimum operating temperature.
Tank capacity: 693 L (183 gal)

Hoist

Main and auxiliary hoist are powered by axial piston motor with planetary gear and brake. "Thumb-thumper" hoist drum rotation indicator alerts operator of hoist movement.

Single line pull:	1st layer:	9185 kg (20,250 lb)
	3rd layer:	7716 kg (17,010 lb)
	5th layer:	6650 kg (14,660 lb)

Denotes optional equipment

Superstructure continued

Maximum line speed: 157 m/min (514 fpm)

Maximum permissible line pull:
7620 kg (16 800 lb) 6x36 rope
7620 kg (16 800 lb) 35x7 rope

Rope diameter: 19 mm (3/4 in)

Rope length: 183 m (600 ft) main hoist
185 m (607 ft) auxiliary hoist

Rope type: 6 x 36 EIPS IWRC, Special Flexible
35 x 7 Flex-x, Rotation Resistant

Maximum rope stowage: 256 m (841 ft)

Carrier

Chassis

Triple box section, four-axle carrier, fabricated from high strength, low alloy steel with towing and tie-down lugs.

Outrigger system

Four hydraulic telescoping, two-stage, double box beam outriggers with inverted jack and integral holding valves. Quick release type outrigger floats 610 mm (24 in) diameter. Three position setting with fully extended, intermediate (50%) extended and fully retracted capacities. Maximum outrigger pad load: 101,800 lb

Outrigger controls

Located in the superstructure cab and on either side of the carrier. Crane level indicator (sight bubble).

Engine

Cummins ISM 450 10.8 L diesel (On Highway EPA Certified) six cylinders, after cooled, 336 kW (450 bhp) (gross) @ 2000 rpm. Maximum torque 2102 Nm (1550 ft lb) @ 1200 rpm.

Equipped with engine compression brake, block heater, cold start aid (less canister) and audio-visual engine distress system.

Fuel Requirement - Maximum of 15 ppm sulfur content (Ultra Low Sulfur Diesel).

Engine (required for sale outside North America

Cummins QSM 402 10,8 L diesel (Off Highway EPA Certified) six cylinders, after cooled, 300 kW (402 bhp) (gross) @ 1800 RPM. Maximum torque 1898 Nm (1400 ft lb) @ 1400 RPM.

Equipped with engine compression brake, block heater, cold start aid (less canister) and audio-visual engine distress system.

Fuel Requirement - Maximum of 5000 ppm sulfur content.

Fuel tank capacity

379 L (100 gal).

Transmission

Roadranger Ultra Shift 10 speeds forward, two speeds reverse. Two speed auxiliary transmission. Used with ISM450 “On Highway” engine.

Roadranger manual transmission with 11 speeds forward, three speeds reverse. Used with QSM 402 “Off Highway” engine.

Drive

8 x 4 x 4.

Steering

Front axles, single circuit, mechanical steering with hydraulic power assist. Turning radius: 45.1 ft.

Axles

Front: (2) beam-type steering axles, 2,12 m (83.4 in) track.
Rear: (2) single reduction drive axles, 1,89 m (74.5 in) track. Inter-axle differential locks.

Brakes

S-cam, dual air split system operating on all wheels. Spring-applied, air released parking brake acting on rear axles. Air dryer.

Suspension

Front: Walking beam with air bags and shock absorbers.
Rear: Walking beam with air bags and shock absorbers.

**Denotes optional equipment*

Specifications

Carrier continued

Tires

Front: 445/65R 22.5 tubeless, mounted on aluminum disc wheels.
Rear: 315/80R 22.5 tubeless, mounted on aluminum disc wheels, inner steel.

Lights

Full lighting package including turn indicators, head, tail, brake, and hazard warning lights.

Cab

One man design, aluminum fabricated with acoustical lining and tinted safety glass throughout. Deluxe fabric covered seat with air adjustment. Complete driving controls and engine instrumentation including tilt telescope steering wheel, tachometer, speedometer, voltmeter, water temp., oil pressure, fuel level, air pressure gauge with A/V warning and engine high temp./low oil pressure A/V warning. Other standard items include hot water heater/defroster, electric windshield wash/wipe, fire extinguisher, seat belt, door lock, air horn, and air conditioning.

Electrical system

Two 12V – maintenance free batteries provides 12 V electrical system. Standard battery disconnect.

Maximum speed

104 km/h (65 mph)

Gradeability (theoretical)

70%

Miscellaneous standard equipment

Aluminum fenders with rear storage compartments; dual rear view mirrors; electronic back-up alarm; sling/tool box; tire inflation kit; air cleaner restriction indicator; headache ball stowage; aluminum wheels, event recorder.

* Optional equipment

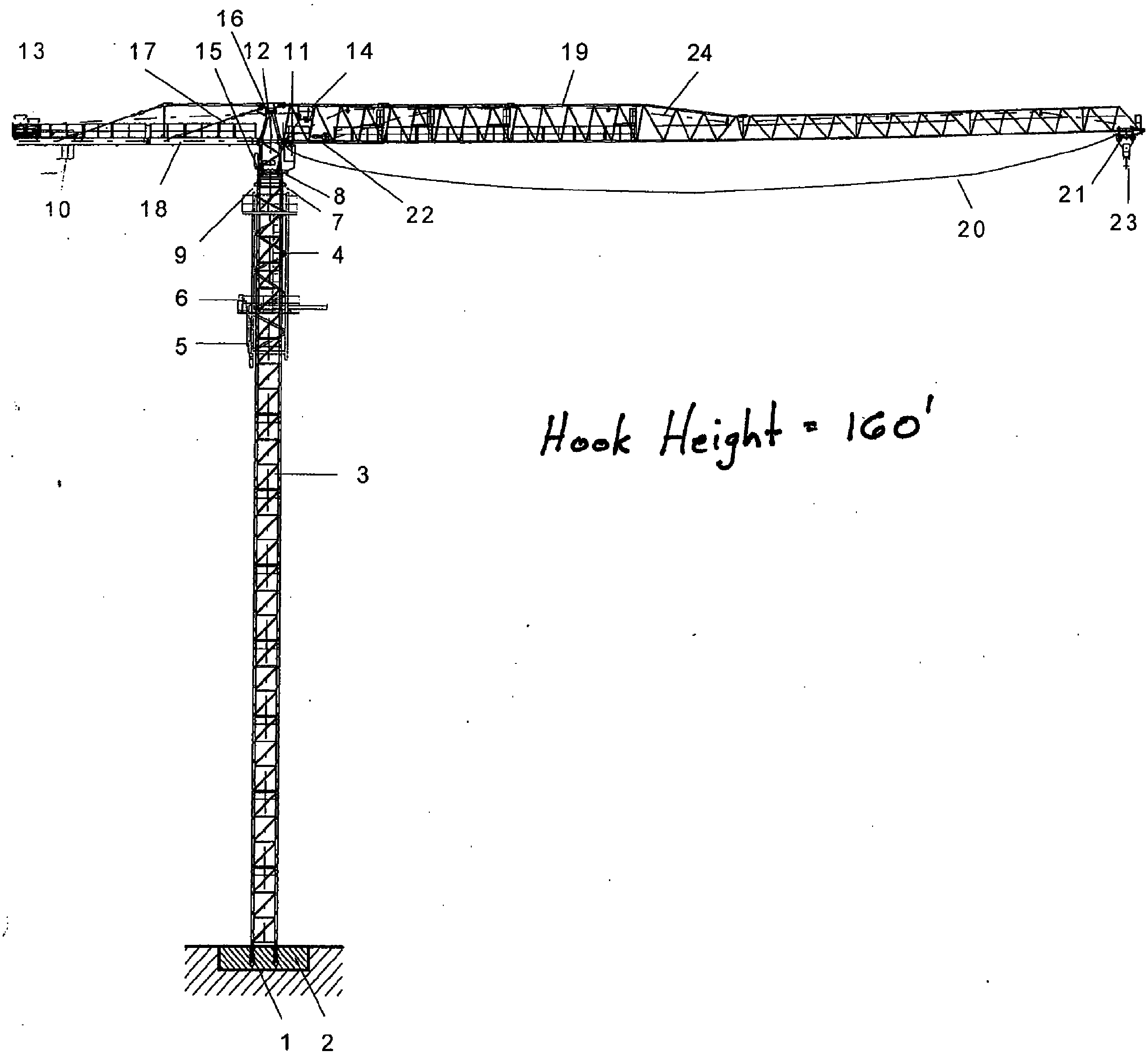
- Auxiliary Lighting and Convenience Package: Includes amber strobe for superstructure and carrier cabs, dual boom base mounted floodlights and LMI light bar.
- Hookblocks
- Pintle hook (rear)
- Cross axle differential locks
- Trailing Boom Package
- Aluminum outrigger pads
- Heavy Counterweight Package
- Tow cable
- Wind speed indicator
- Winterfront radiator cover

Denotes optional equipment

APPENDIX J– Tower Crane Data Sheet

BK 412

Components of tower crane



1	Fixing angles	FF
2	Foundation	
3	Tower section	TG
4	Climbing device	KE
5	Climbing traverse	
6	Climbing hydraulic	
7	Fixed pivot	KDA
8	Slewing ring	
9	Turntable	
10	Counterweight	BG
11	Cabin	
12	Slewing unit	

13	Hoist unit
14	Max. load limiter
15	Switch board
16	Load moment limiter
17	Counterjib suspension
18	Counterjib
19	Jib
20	Hoist rope
21	Trolley
22	Trolley unit
23	Hook block
24	Trolley rope

BK 412-10 FEM 1.001 A 3

BKT

Hoist unit 79 kW SL/WB

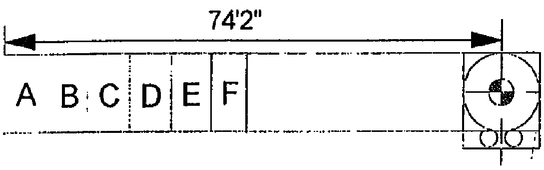
Radius and capacity

Jib	Max. capacity		Radius (ft) and capacity (lbs)											
	lbs	ft	91'10"	98'5"	104'12"	114'10"	131'3"	147'8"	164'1"	180'5"	196'10"	213'3"	229'8"	246'1"
L 7 246 ft	22.000	9'6" - 92'6"	22.000	20.507	19.184	17.199	14.774	12.789	11.246	10.143	9.041	8.159	7.497	6.836
L 6 230 ft	22.000	9'6" - 105'4"	22.000	22.000	22.000	20.066	17.199	14.994	13.230	11.907	10.584	9.702	8.820	
L 5 213 ft	22.000	9'6" - 115'2"	22.000	22.000	22.000	22.000	18.963	16.538	14.774	13.230	11.907	10.805		
L 4 196 ft	22.000	9'6" -125'12"	22.000	22.000	22.000	22.000	20.948	18.522	16.317	14.553	13.230			
L 3 181 ft	22.000	9'6" - 133'6"	22.000	22.000	22.000	22.000	22.000	19.625	17.420	15.656				
L 2 164 ft	22.000	9'6" - 137'6"	22.000	22.000	22.000	22.000	22.000	20.286	18.081					
L 1 131 ft	22.000	9'6" - 131'3"	22.000	22.000	22.000	22.000	22.000							

Speeds

	v = 0 - 279 ft/min				9,0 kW-WB
	n = 0 - 1,0 rpm			L = 131 ft - 181 ft L = 196 ft - 246 ft	2x6,6 kW-WB 3x6,6 kW-WB
	v = 0 - 98 ft/min				2x9,0 kW-FK
79S5,0N310		1.Gear	125 ft/min	22.000 lbs	79 kW-WB
			13 ft/min		
		2.Gear	200 ft/min	14.333 lbs	
			20 ft/min		
		3.Gear	315 ft/min	8.600 lbs	
			32 ft/min		
		4.Gear	500 ft/min	4.851 lbs	
			50 ft/min		
		HH max = 509 ft			
480 V - 60 Hz	power required - upper part of crane				135 kVA

Ballast- counterjib

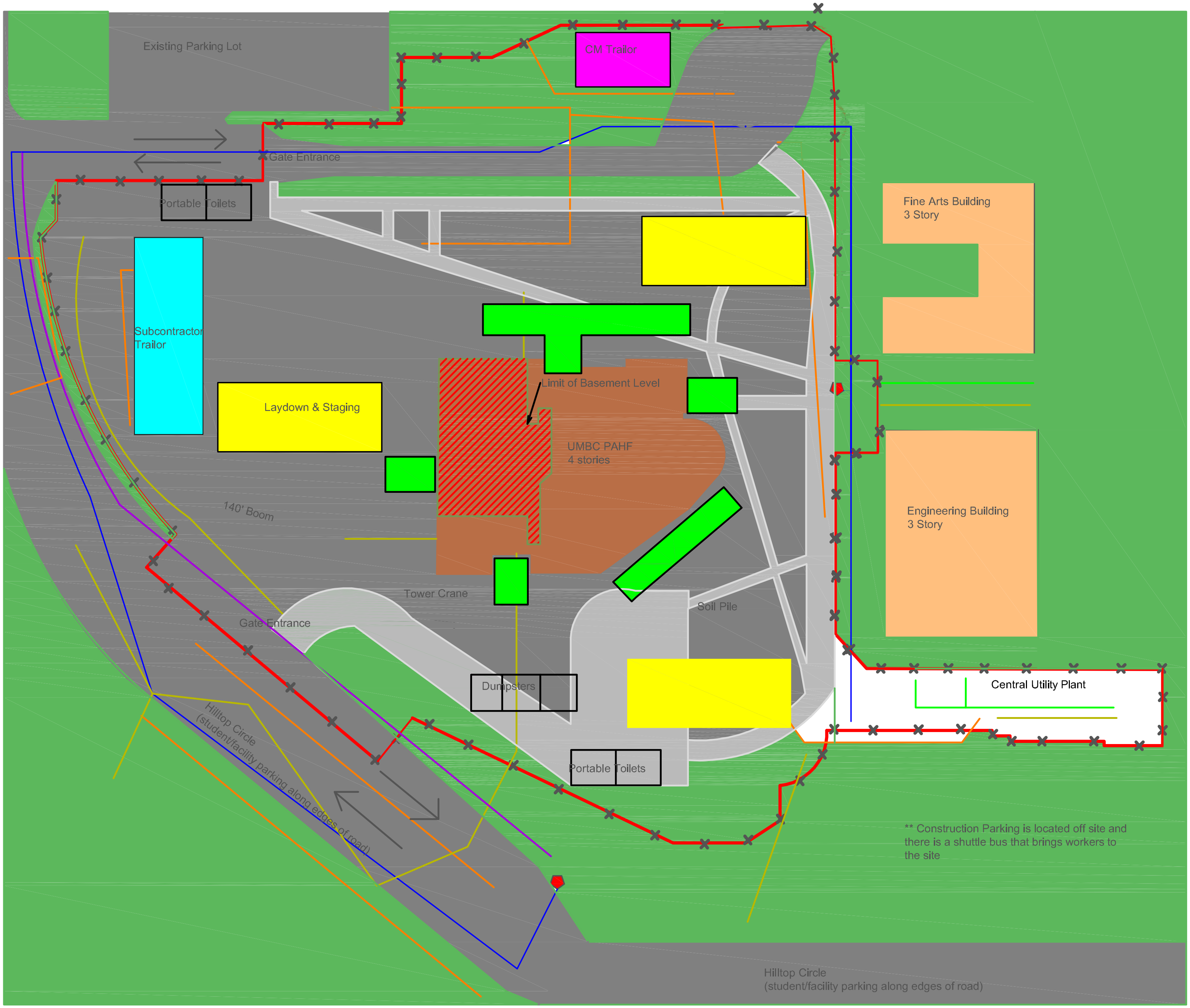


* Put the ballast block before install the jib

Jib (ft)	131	164	181	196	213	230	246
A (lbs)			13.240*	13.230*		8.820*	
B (lbs)	13.240*		13.240	13.240	8.820*	8.820	8.820*
C (lbs)	13.240	13.240*	13.240	13.240	8.820	13.240	13.240
D (lbs)	8.820	13.240	4,00	13.240	13.240	13.240	13.240
E (lbs)		13.240			13240	13.240	13.240
F (lbs)		8.820			13.240		13.240
Total (lbs)	35.280	48.510	48.510	52.920	57.330	57.330	61.740

Part-No.: 2 710 4123

APPENDIX K– Site Logistics Plan without Tower Crane



LEGEND:

Existing Utilities

- Water
- Gas
- Storm Drain
- Sanitary
- Electric

Symbols

- Fire Hydrant
- Vehicular Traffic
- Construction Fence

Crane Paths

UMBC
Performing Arts & Humanities Facility

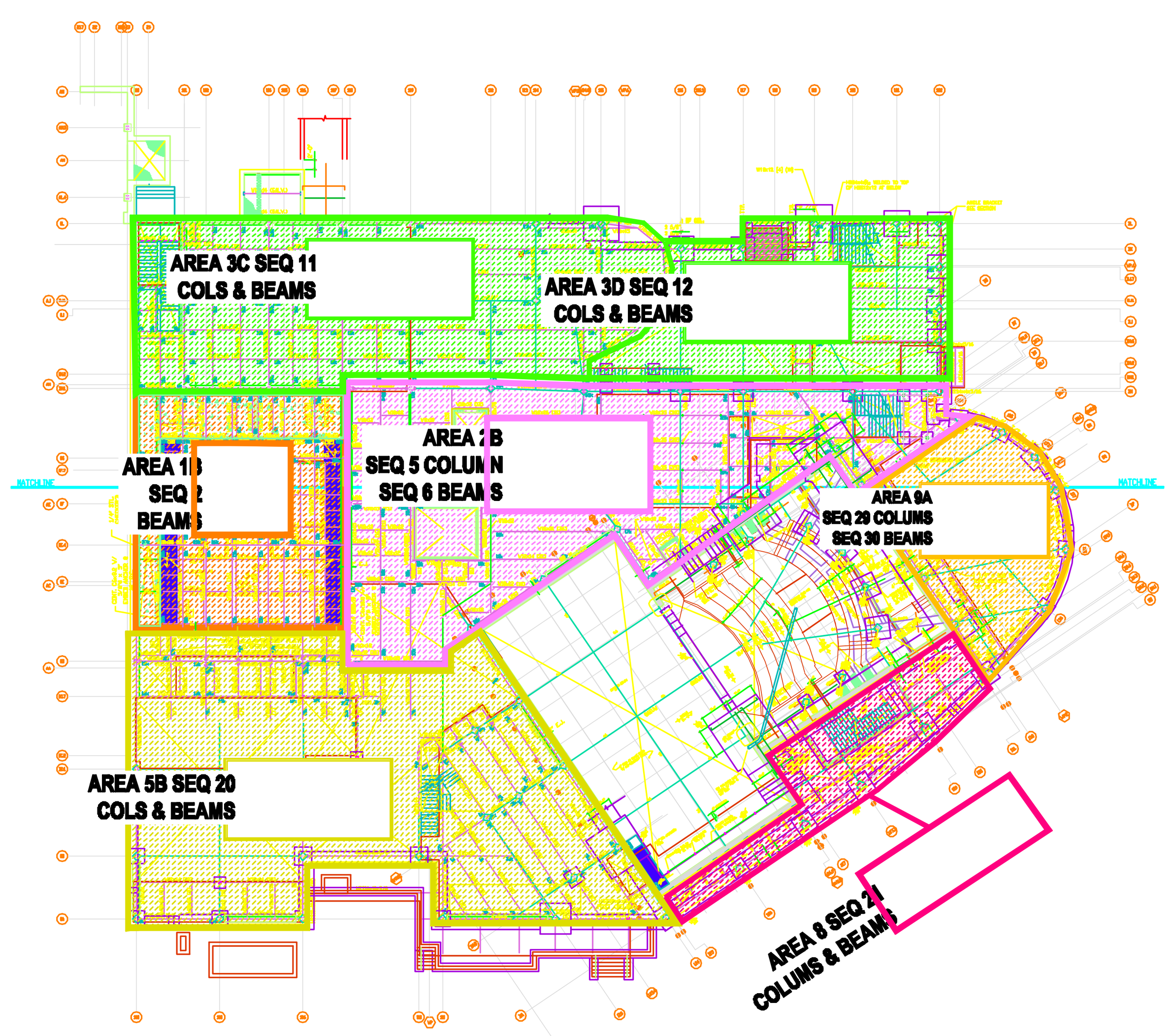
Site Plan w/o the Tower Crane

April 7, 2011

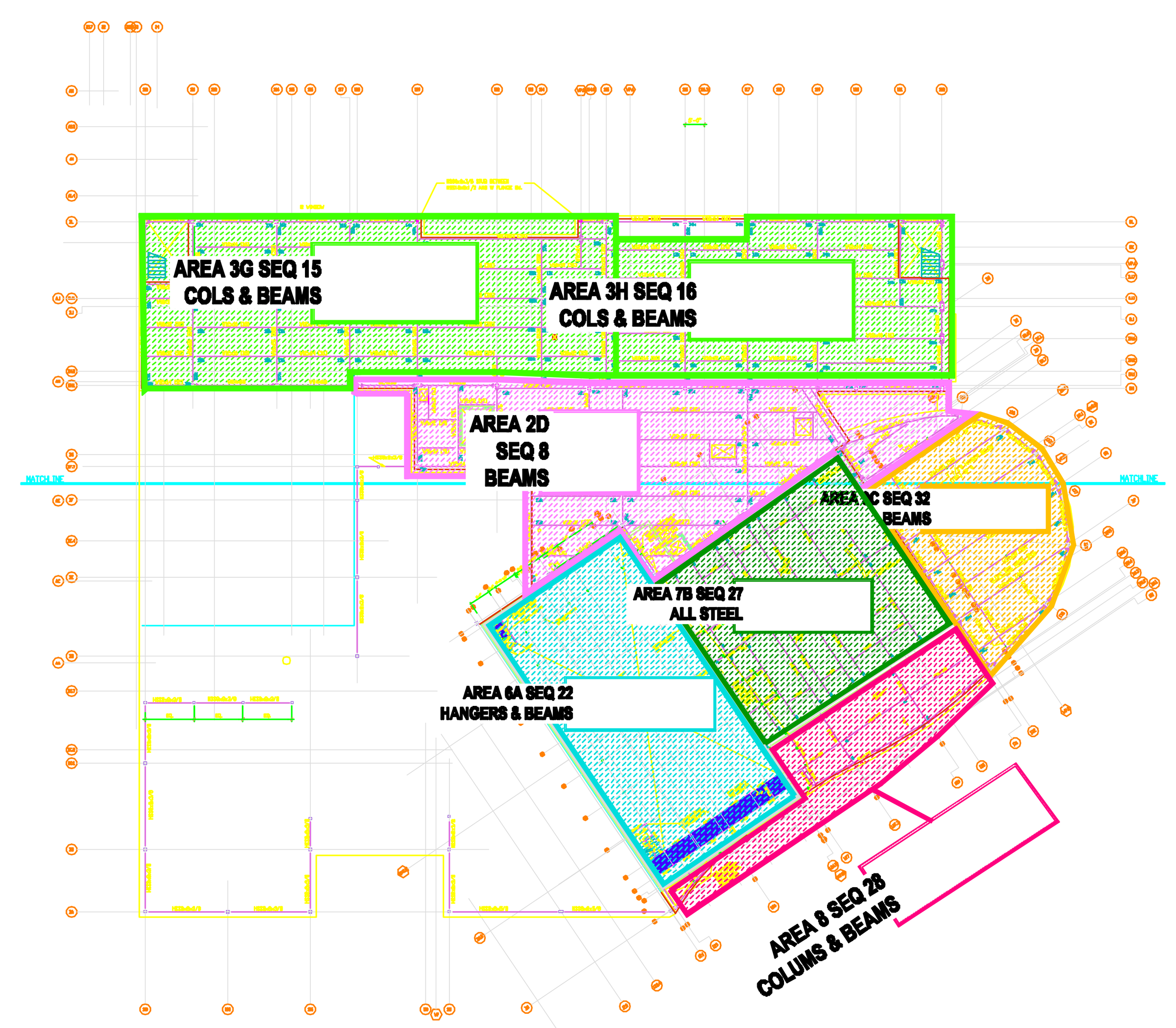
Courtney Glaub - CM

APPENDIX L – UMBC Superstructure Sequence

1006 UMBC SEQUENCE



LEVEL 2



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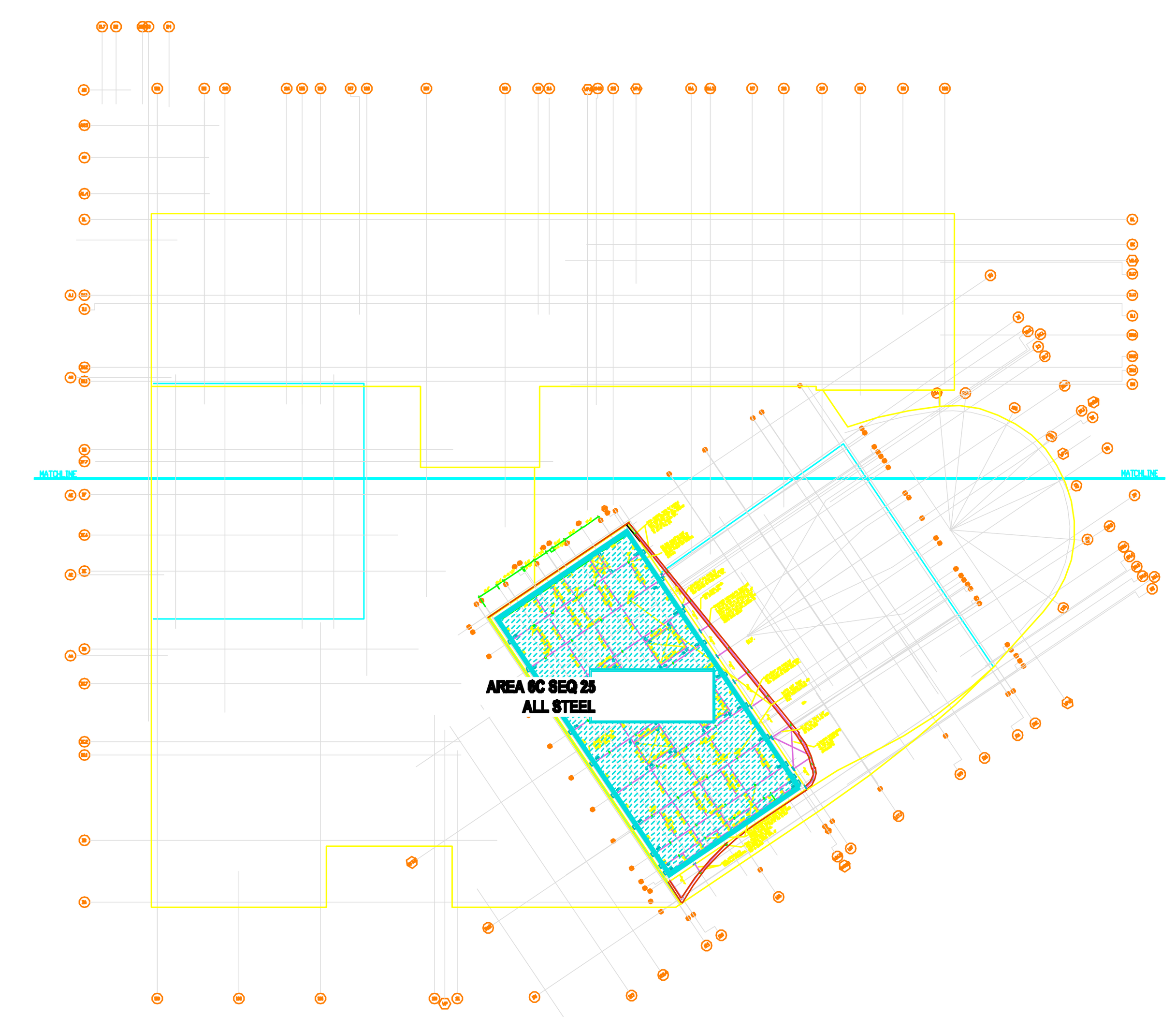
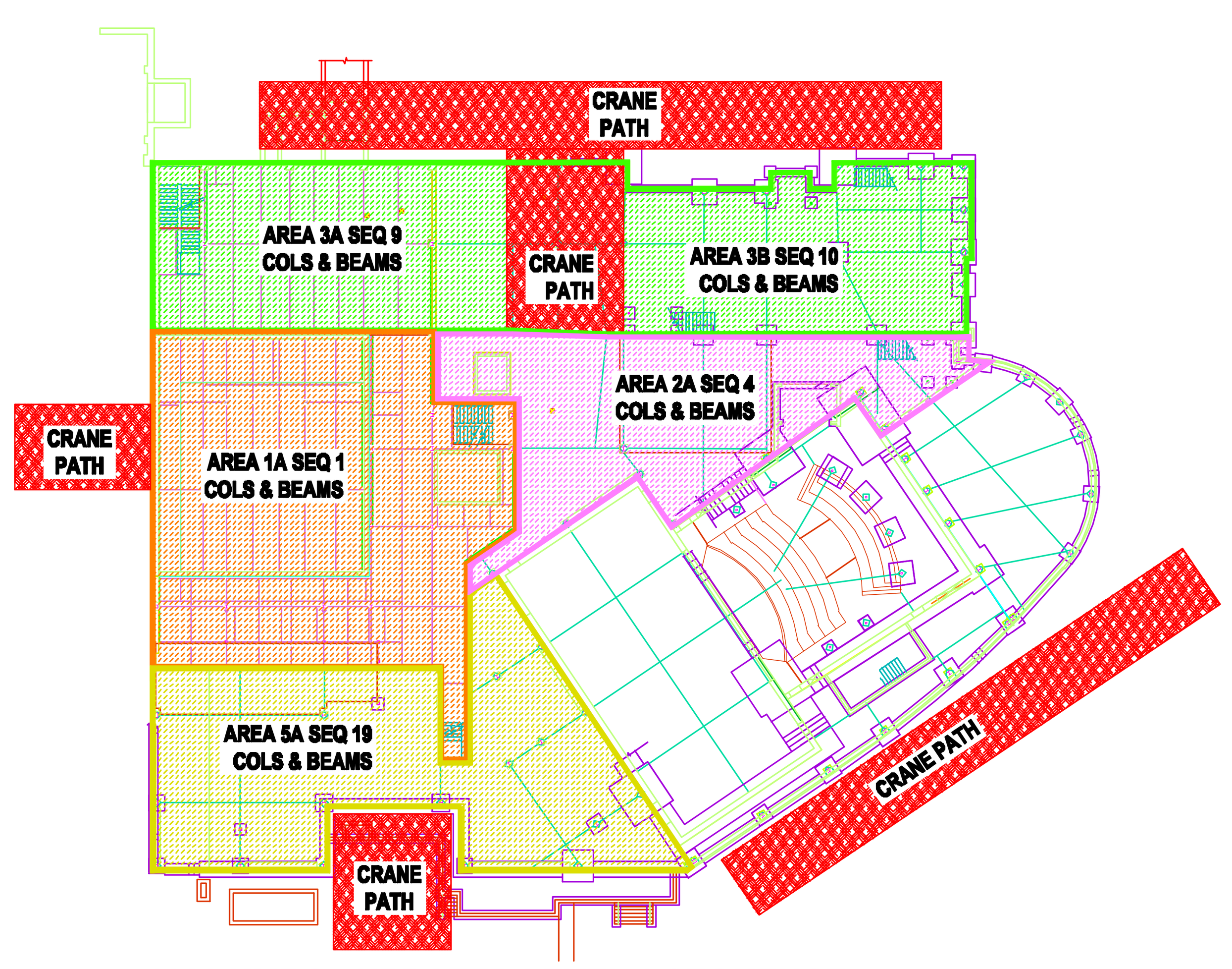
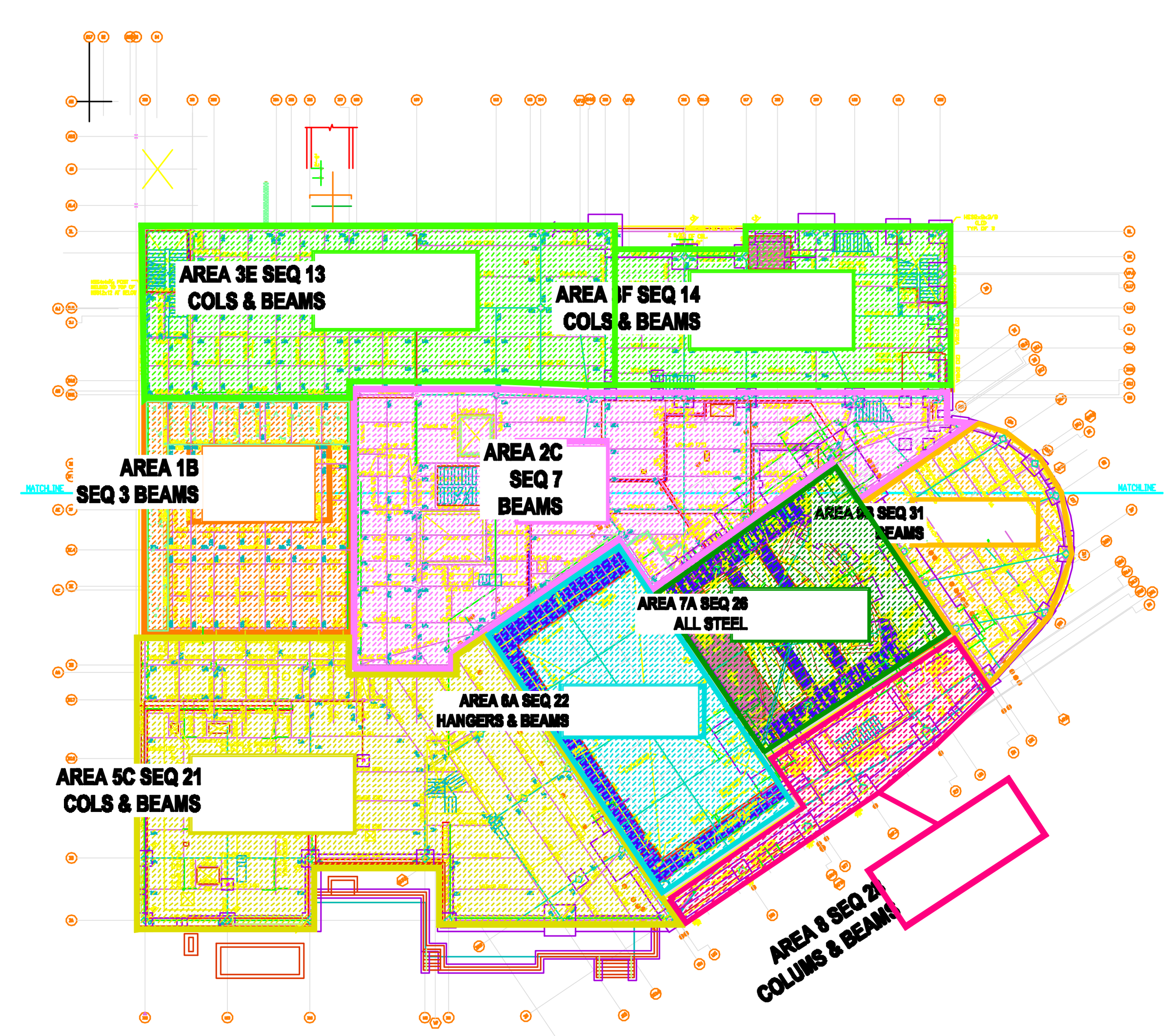


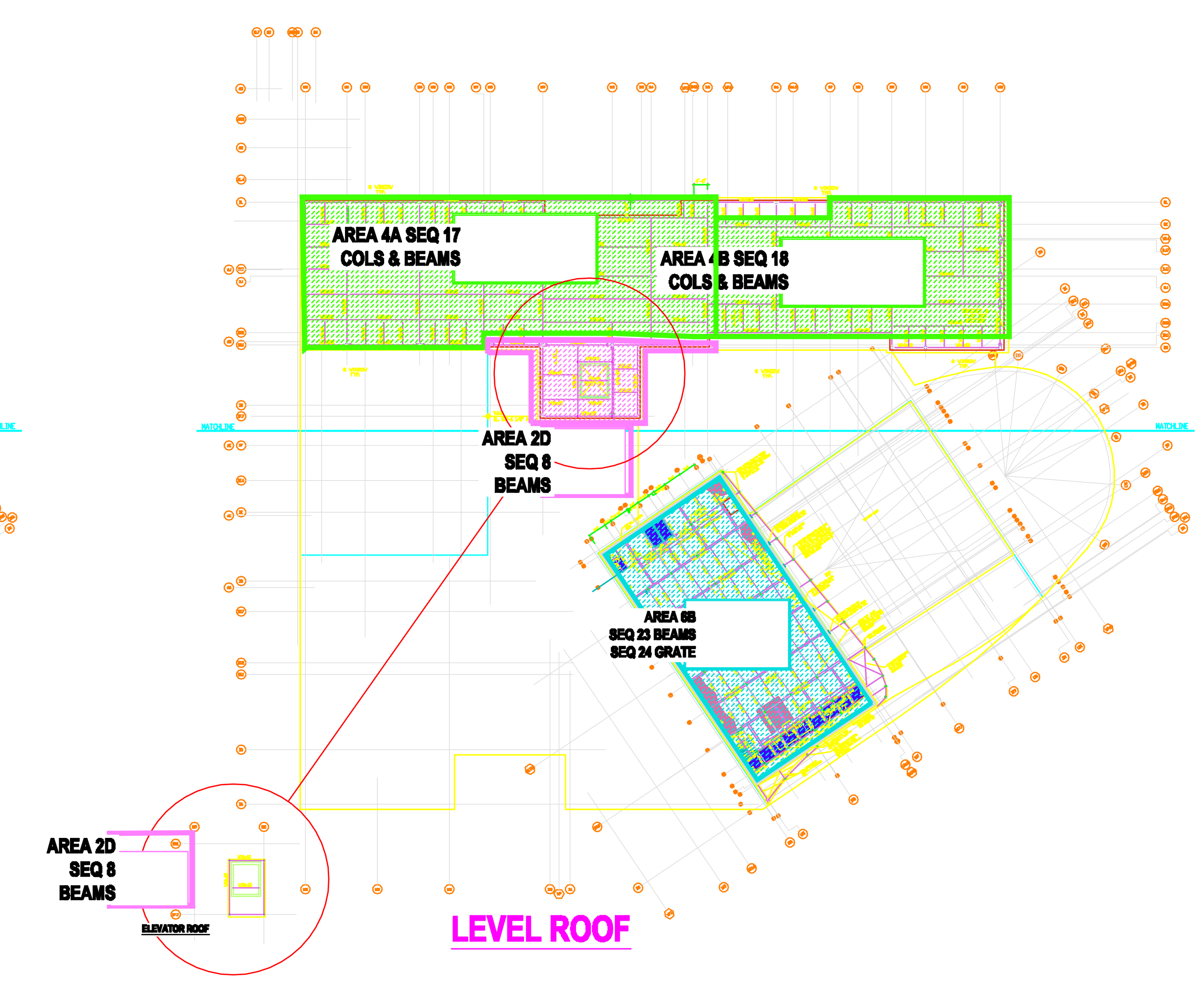
LEVEL HIGH ROOF



1006 UMBC - UPDATED LEVEL 1 SEQUENCE



LEVEL 3



LEVEL ROOF

SEQ 1: 13 DAYS
1 DAY- UNLOAD STEEL AND SHAKE OUT
3 DAYS- SET STEEL
2 DAYS- WELD BEAMS
2 DAYS- BOLT UP
2 DAYS- DETAIL
3 DAYS- DECK AND STUDS

SEQ 2: 1 DAY
1 DAY- UNLOAD STEEL AND SHAKE OUT
LOAD STEEL ON FLOOR IN TOWER

SEQ 3: 18 DAYS
2 DAYS- SET TRUST
4 DAYS- SET MEZZ.
5 DAYS- WELD UP
4 DAYS- BOLT UP
3 DAYS- DECK AND STUDS

SEQ 4: 8 DAYS
1 DAY- UNLOAD STEEL AND SHAKE OUT
2 DAYS- SET STEEL
1 DAY- BOLT UP
3 DAYS- DECK AND DETAIL
1 DAY- STUDS

SEQ 5 AND 6: 11 DAYS
1 DAY- UNLOAD STEEL AND SHAKE OUT
3 DAYS- SET STEEL
2 DAYS- BOLT UP
3 DAYS- DECK
2 DAYS- DETAIL AND STUDS

SEQ 7: 11 DAYS
1 DAY- UNLOAD STEEL AND SHAKE OUT
3 DAYS- SET STEEL
2 DAYS- BOLT UP
3 DAYS- DECK
2 DAYS- DETAIL AND STUDS

SEQ 8: 8 DAYS
1 DAY- UNLOAD STEEL AND SHAKE OUT
2 DAYS- SET STEEL
1 DAY- BOLT UP
2 DAYS- DECK
2 DAYS- DETAIL AND STUDS

SEQ 9 AND 10: 8 DAYS
1 DAY- UNLOAD STEEL AND SHAKE OUT
2 DAYS- SET STEEL
2 DAYS- BOLT UP
1 DAY- DECK
2 DAYS- DETAIL AND STUDS

SEQ 11: 11 DAYS
1 DAY- UNLOAD STEEL AND SHAKE OUT
3 DAYS- SET STEEL
2 DAYS- BOLT UP
2 DAYS- DECK
3 DAYS- DETAIL AND STUDS

SEQ 12: 8 DAYS
1 DAY- UNLOAD STEEL AND SHAKE OUT
1 DAY- SET STEEL
1 DAY- BOLT UP
2 DAYS- DECK AND STUDS
3 DAYS- HANG SPANDELS

SEQ 13: 17 DAYS
1 DAY- UNLOAD STEEL AND SHAKE OUT
3 DAYS- SET STEEL
2 DAYS- BOLT UP
3 DAYS- DECK
3 DAYS- DETAIL AND STUDS
5 DAYS- SET SPANDELS

SEQ 14: 17 DAYS
1 DAY- UNLOAD STEEL AND SHAKE OUT
3 DAYS- SET STEEL
2 DAYS- BOLT UP
3 DAYS- DECK
3 DAYS- DETAIL AND STUDS
5 DAYS- SET SPANDELS

SEQ 20: 10 DAYS
1 DAY- UNLOAD STEEL AND SHAKE OUT
3 DAYS- SET STEEL
2 DAYS- BOLT UP
4 DAYS- DETAIL AND DECK

SEQ 21: 10 DAYS
1 DAY- UNLOAD STEEL AND SHAKE OUT
3 DAYS- SET STEEL
2 DAYS- BOLT UP
4 DAYS- DETAIL AND DECK

SEQ 22: 10 DAYS
1 DAY- UNLOAD STEEL AND SHAKE OUT
5 DAYS- HANG PLATFORM
4 DAYS- DETAIL

SEQ 23: 8 DAYS
1 DAY- UNLOAD STEEL AND SHAKE OUT
7 DAYS- SET STEEL

SEQ 24: 5 DAYS
1 DAY- UNLOAD GRATE AND SET ON BUILDING
4 DAYS- SET GRATING

SEQ 25: 18 DAYS
1 DAY- UNLOAD STEEL AND SHAKE OUT
6 DAYS- SET STEEL
4 DAYS- BOLT UP AND WELD
4 DAYS- DECK
3 DAYS- DETAIL AND STUDS

SEQ 26: 10 DAYS
1 DAY- UNLOAD STEEL AND LOAD IN BUILDING
9 DAYS- HANG CATWALK AFTER ROOF IS ON

SEQ 27: 9 DAYS
1 DAY- UNLOAD STEEL AND SHAKE OUT
2 DAYS- SET STEEL
2 DAYS- BOLT UP
4 DAYS- DECK AND STUDS

SEQ 28: 16 DAYS
1 DAY- UNLOAD STEEL AND SHAKE OUT
4 DAYS- SET STEEL
3 DAYS- BOLT UP
6 DAYS- DECK AND DETAIL
2 DAYS- STUDS

SEQ 29 AND 30: 5 DAYS
1 DAY- UNLOAD STEEL AND SHAKE OUT
1 DAY- SET STEEL
1 DAY- BOLT UP AND DETAIL
2 DAYS- WELD MOMENTS

SEQ 31: 12 DAYS
1 DAY- UNLOAD STEEL AND SHAKE OUT
4 DAYS- SET STEEL
5 DAYS- BACK WELD
2 DAYS- WELD MOMENTS

SEQ 32: 11 DAYS
1 DAY- UNLOAD STEEL AND SHAKE OUT
3 DAYS- SET STEEL
1 DAY- BOLT UP
2 DAYS- WELD MOMENTS
2 DAYS- DECK
2 DAYS- DETAIL AND STUDS

SEQ 15: 17 DAYS
1 DAY- UNLOAD STEEL AND SHAKE OUT
3 DAYS- SET STEEL
2 DAYS- BOLT UP
3 DAYS- DECK
3 DAYS- DETAIL AND STUDS
5 DAYS- SET SPANDELS

SEQ 16: 17 DAYS
1 DAY- UNLOAD STEEL AND SHAKE OUT
3 DAYS- SET STEEL
2 DAYS- BOLT UP
3 DAYS- DECK
3 DAYS- DETAIL AND STUDS
5 DAYS- SET SPANDELS

SEQ 17: 11 DAYS
1 DAY- UNLOAD STEEL AND SHAKE OUT
2 DAYS- SET STEEL
1 DAY- BOLT UP
2 DAYS- DECK
5 DAYS- SET SPANDELS

SEQ 18: 11 DAYS
1 DAY- UNLOAD STEEL AND SHAKE OUT
2 DAYS- SET STEEL
1 DAY- BOLT UP
2 DAYS- DECK
5 DAYS- SET SPANDELS

SEQ 19: 7 DAYS
1 DAY- UNLOAD STEEL AND SHAKE OUT
2 DAYS- SET STEEL
1 DAY- BOLT UP
3 DAYS- DECK AND DETAIL

APPENDIX M – Photovoltaic Array Product Data

SHARP

solar electricity

235 WATT

MULTI-PURPOSE MODULE

NEC 2008 Compliant

NU-U235F1

MULTI-PURPOSE 235 WATT MODULE FROM THE WORLD'S TRUSTED SOURCE FOR SOLAR.

Using breakthrough technology, made possible by nearly 50 years of proprietary research and development, Sharp's NU-235F1 solar module incorporates an advanced surface texturing process to increase light absorption and improve efficiency. Common applications include commercial and residential grid-tied roof systems as well as ground mounted arrays. Designed to withstand rigorous operating conditions, this module offers high power output per square foot of solar array.

Sharp's most powerful commercial module manufactured today.

ENGINEERING EXCELLENCE

High module efficiency for an outstanding balance of size and weight to power and performance.

DURABLE

Tempered glass, EVA lamination and weatherproof backskin provide long-life and enhanced cell performance.

RELIABLE

25-year limited warranty on power output.

HIGH PERFORMANCE

This module uses an advanced surface texturing process to increase light absorption and improve efficiency.

INNOVATIVE

156 mm monocrystalline solar cells provide high power output. Ideal for large commercial rooftops where space is a premium.

The NU-U235F1 offers industry-leading performance for a variety of applications.

Improved Frame Technology

SHARP: THE NAME TO TRUST

When you choose Sharp, you get more than well-engineered products. You also get Sharp's proven reliability, outstanding customer service and the assurance of our 25-year limited warranty on power output. A global leader in solar electricity, Sharp powers more homes and businesses than any other solar manufacturer worldwide.

BECOME POWERFUL

235 WATT

NU-U235F1

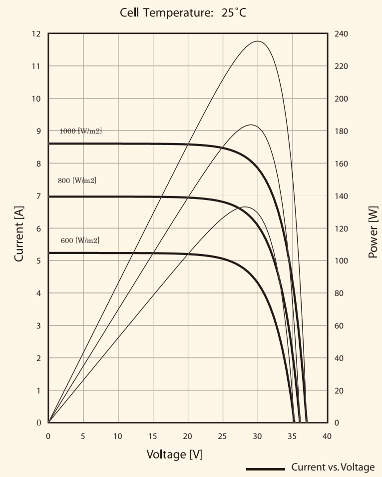
NEC 2008 Compliant
Module output cables 12 AWG with locking connectors

ELECTRICAL CHARACTERISTICS

Maximum Power (Pmax)*	235 W
Tolerance of Pmax	+10%/-5%
Type of Cell	Monocrystalline silicon
Cell Configuration	60 in series
Open Circuit Voltage (Voc)	37.0 V
Maximum Power Voltage (Vpm)	30.0 V
Short Circuit Current (Isc)	8.60 A
Maximum Power Current (Ipm)	7.84 A
Module Efficiency (%)	14.4%
Maximum System (DC) Voltage	600 V
Series Fuse Rating	15 A
NOCT	47.5°C
Temperature Coefficient (Pmax)	-0.485%/°C
Temperature Coefficient (Voc)	-0.351%/°C
Temperature Coefficient (Isc)	0.053%/°C

*Measured at (STC) Standard Test Conditions: 25°C, 1 kW/m² insolation, AM 1.5

IV CURVES



Current, Power vs. Voltage Characteristics

MECHANICAL CHARACTERISTICS

Dimensions (A x B x C below)	39.1" x 64.6" x 1.8"/994 x 1640 x 46 mm
Cable Length (I)	43.3"/1100 mm
Output Interconnect Cable**	12 AWG with MC4 Locking Connector
Weight	44.1 lbs / 20.0 kg
Max Load	50 psf (2400 Pascals)
Operating Temperature (cell)	-40 to 194°F / -40 to 90°C

**A safety lock clip (Multi Contact part number PV-SSH4) may be required in readily accessible locations per NEC 2008 690.33 (C)

QUALIFICATIONS

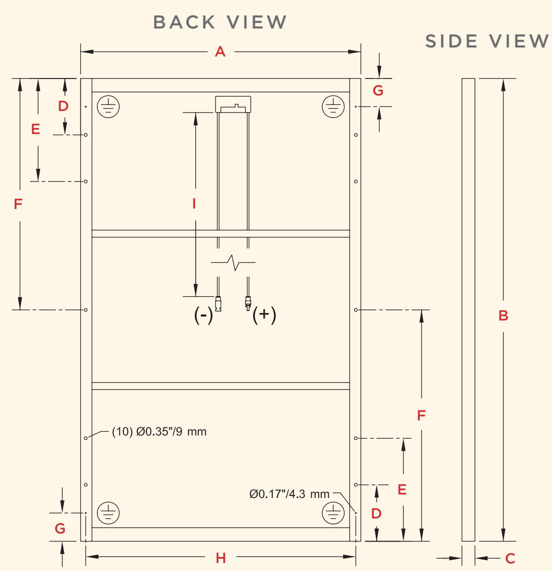
UL Listed	UL 1703
Fire Rating	Class C

WARRANTY

25-year limited warranty on power output
Contact Sharp for complete warranty information

Design and specifications are subject to change without notice. Sharp is a registered trademark of Sharp Corporation. All other trademarks are property of their respective owners. Contact Sharp to obtain the latest product manuals before using any Sharp device. Cover photo: Solar Installation by SPG Solar.

DIMENSIONS



A	B	C	D	E
39.1"/994 mm	64.6"/1640 mm	1.8"/46 mm	7.9"/200 mm	14.4"/365 mm

F	G	H	I
32.3"/820 mm	3.9"/100 mm	37.7"/958 mm	43.3"/1100 mm

Contact Sharp for tolerance specifications

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09F-040 • PC-06-09

UL Certified

- UL certified (UL 1741/IEEE-1547)

Reliable

- 10 year standard warranty
- Sealed electronics enclosure and rugged stainless steel outdoor-rated structure
- Opticool™ temperature management system

Simple

- Prewired at factory for three-phase utility interconnection
- Integrated load-break rated lockable AC/DC disconnect switch

Flexible

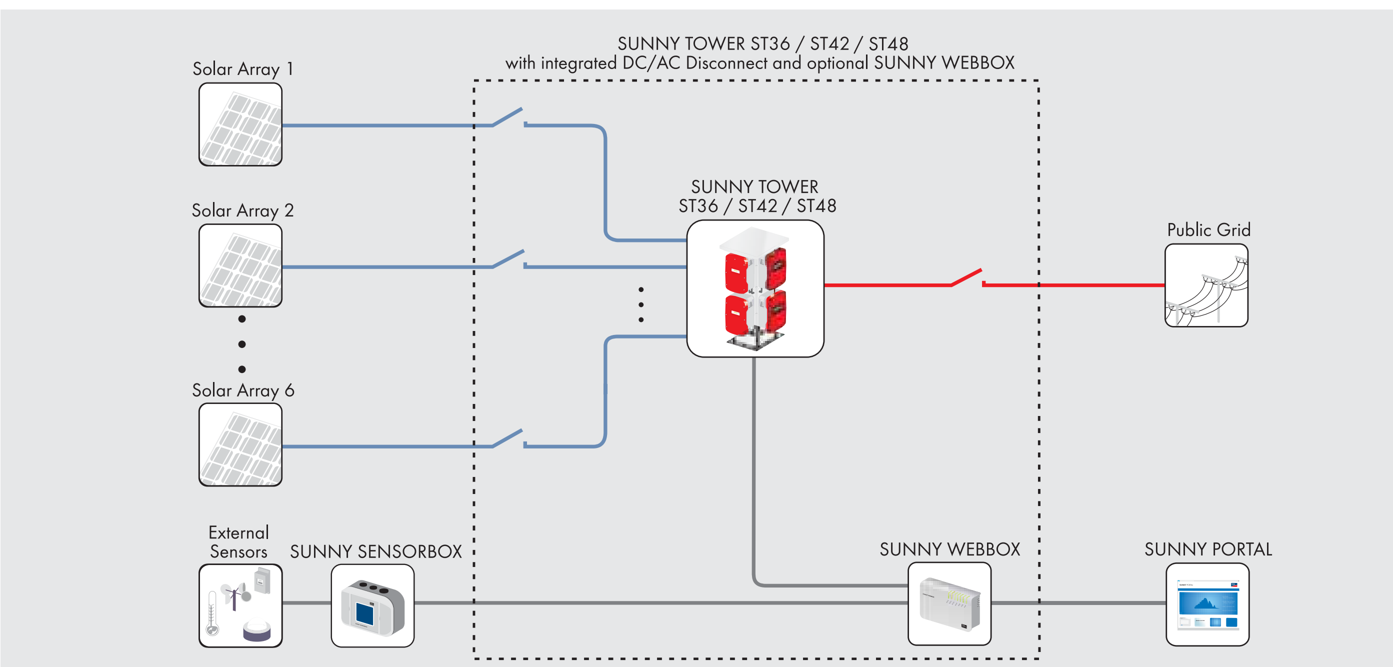
- Internet-ready with Sunny WebBox
- Integrated fused series string combiner
- Ideal for commercial applications

SUNNY TOWER-US

The UL certified, flexible solution for commercial PV systems

Designed with the installer in mind, SMA has combined ease of installation, a low cost per watt and high efficiency in the Sunny Tower-US. The UL-certified inverter system is pre-configured for a per-tower capacity of 36, 42 or 48 kW and its modular design eliminates the need for cost-prohibitive heavy machinery, as is required for large central inverters. It allows installers to apply their existing experience and tools in the residential market to attract commercial-grade projects, all while benefiting from the Sunny Boy's world-class efficiency and SMA's industry-best reliability.

Technical Data	Sunny Tower with 6 Sunny Boy 6000-US	Sunny Tower with 6 Sunny Boy 7000-US	Sunny Tower with 6 Sunny Boy 8000-US
Input (DC)			
Recommended maximum PV power (module STC)	45.0 kW	52.5 kW	60 kW
DC maximum voltage	600 V	600 V	600 V
Peak power tracking voltage	250 – 480 V	250 – 480 V	250 – 480 V
DC maximum input current	150 A	180 A	180 A
DC voltage ripple	< 5%	< 5%	< 5%
Number of fused string inputs	24 x 15 A (AC / DC disconnect)	24 x 15 A (AC / DC disconnect)	24 x 15 A (AC / DC disconnect)
PV start voltage (adjustable)	300 V	300 V	300 V
Output (AC)			
AC nominal power / maximum power	36.0 kW / 36.0 kW	42.0 kW / 42.0 kW	48.0 kW / 48.0 kW
AC maximum output current (per phase @ 208, 240, 277 V)	100 A, 87 A, 44 A	117 A, 101 A, 51 A	N/A, 116 A, 58 A
AC nominal voltage range (3-phase)	183 – 229 V @ 208 V Delta or WYE 244 - 305 V @ 277 V WYE	183 – 229 V @ 208 V Delta or WYE 244 - 305 V @ 277 V WYE	N/A 244 - 305 V @ 277 V WYE
AC Frequency: nominal / range	60 Hz / 59.3 – 60.5 Hz	60 Hz / 59.3 – 60.5 Hz	60 Hz / 59.3 – 60.5 Hz
Power factor (nominal)	0.99	0.99	0.99
Efficiency			
Peak inverter efficiency	97.0%	97.1%	96.3% @ 240 V 96.5% @ 277 V
CEC weighted efficiency	95.5% @ 208 V, 240 V 96.0% @ 277 V	95.5% @ 208 V 96.0% @ 240 V, 277 V	96.0%
General data			
Dimensions (W / H / D) in mm (in)	1100 / 1810 / 990 (43 / 71 / 39)	1100 / 1810 / 990 (43 / 71 / 39)	1100 / 1810 / 990 (43 / 71 / 39)
Weight	384 kg (846 lb)	384 kg (846 lb)	384 kg (846 lb)
Ambient temperature range	−13 to 113 °F	−13 to 113 °F	−13 to 113 °F
Internal consumption: standby / nighttime	< 42 W / 0.6 W	< 42 W / 0.6 W	< 42 W / 0.6 W
Topology	Low frequency transformer, true sinewave	Low frequency transformer, true sinewave	Low frequency transformer, true sinewave
Cooling concept	OptiCool, forced active cooling	OptiCool, forced active cooling	OptiCool, forced active cooling
Mounting location: indoor / outdoor (NEMA 3R)	●/●	●/●	●/●
LCD display	●	●	●
Lid color: aluminum / red / blue / yellow	●/○/○/○	●/○/○/○	●/○/○/○
Features			
Communication: RS485 / wireless	○/○	○/○	○/○
Warranty: 10 years	●	●	●
Compliance: IEEE-929, IEEE-1547, UL 1741, UL 1998, FCC Part 15 A & B	●	●	●
Data at nominal conditions			
● Standard features ○ Optional features			
Type designation	ST36	ST42	ST48



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SMA America, LLC

POWER-FAB™
Quality Hardware for the PV Industry

Ballasted Roof Mounts

NON-PENETRATING MOUNTING SYSTEM

chosen by professionals...

QUALITY HARDWARE FOR THE PV INDUSTRY

...favored by experienced installers since 1993.

MANUFACTURED BY DIRECT POWER & WATER CORPORATION

POWER-FAB Ballasted Roof Mounts Are a Unique Solar Solution:

- No roof penetrations necessary
- Structure held in place by the weight of concrete blocks that sit in ballast trays
- EPDM rubber on bottom of rack surfaces to increase friction and protect roofing
- All aluminum construction
- Stainless steel hardware
- Tilt angles up to 45-degrees
- Top-clamping racking components
- Simple design saves labor
- Designed for areas with 90mph maximum wind speeds and Exposure C category
- Consult distributor for areas with heavy snow loads

BALLAST BLOCKS

The ballast blocks are standard concrete blocks called "cap blocks" and are supplied by the installer.

Nominal dimensions of "cap blocks" are 2.25"x8"x16." They weigh 14.5 pounds each.

BALLASTED ROOF MOUNTS				
	PRICE / (NUMBER OF BLOCKS REQUIRED)			
MODULES	**PART NUMBER: DP-BRM3-**	**PART NUMBER: DP-BRM4-**	**PART NUMBER: DP-BRM5-**	**PART NUMBER: DP-BRM6-**
BP160/170	$1200 (36)	$1385 (48)	$1840 (54)	$1935 (64)
BP195	$1275 (36)	$1400 (48)	$1905 (64)	$2340 (72)
EG170/180/190	$1395 (36)	$1470 (48)	$1980 (64)	$2340 (72)
EG200/205/210	$1395 (36)	$1470 (54)	$1980 (72)	$2340 (80)
GE173/200	$1275 (36)	$1400 (48)	$1905 (64)	$2340 (72)
KC175	$1240 (36)	$1400 (48)	$1905 (54)	$2320 (64)
KD180	$1240 (36)	$1400 (48)	$1905 (54)	$2320 (64)
KC200	$1395 (36)	$1470 (48)	$1980 (64)	$2340 (72)
KD205	$1395 (36)	$1470 (48)	$1980 (64)	$2340 (72)
MT120/125/130	$1105 (28)	$1385 (36)	$1570 (48)	$1805 (54)
MT180	$1210 (36)	$1435 (48)	$1840 (64)	$1935 (72)
SY190/195/200	$1195 (28)	$1400 (36)	$1915 (48)	$2320 (64)
SHP167	$1240 (36)	$1400 (48)	$1905 (54)	$2320 (64)
SHP170/185	$1210 (36)	$1385 (48)	$1840 (54)	$1935 (64)
SHP208/216/224	$1395 (36)	$1470 (54)	$1980 (72)	$2340 (80)
SWD175	$1210 (36)	$1435 (48)	$1840 (54)	$2320 (72)
SPR200/220	$1210 (36)	$1435 (48)	$1840 (54)	$2320 (64)
STP175	$1135 (36)	$1325 (48)	$1510 (54)	$1935 (64)
SWZ155/165	$1265 (36)	$1385 (54)	$1905 (64)	$2320 (72)

OTHER POWER-FAB PRODUCTS INCLUDE:

BATTERY/EQUIPMENT ENCLOSURES™

POWER TUBE CRS™

TOP-OF-POLE MOUNTS™

POWER RAIL™

Since 1993, installers and end-users have appreciated DP&W's reputation for rugged, high quality PV mounting structures.

ROOF-GROUND MOUNTS™

SIDE-OF-POLE MOUNTS™

BATTERY CABINETS™

LARGE GROUND MOUNTS™

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Quality Hardware for the PV Industry

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APPENDIX N – Wire Sizing for DC Wires

SIZING DC WIRE FOR 1 PANEL

PV PANEL
$V_{pm} = 30\,v$
$I_{pm} = 7.84\,A$

L = 200' of DC wire

V = 30.0 v

I = 7.84 A

ASSUME 3/4" PVC CONDUIT

TRY WIRE #4

L = 200'

R = 0.31 (NEC TABLE 9 p. 70-682)

I = 7.84 A

$$VD = \frac{2LRI}{1000ft.} = \frac{2(200)(0.31)(7.84\,A)}{1000ft.} = 0.97\,v$$

$$\%\,VD = \frac{0.97\,v}{30\,v} \times 100$$

$$\%\,VD = 3.2\,\% < 5\,\% \quad \therefore \text{OK} \checkmark$$

APPENDIX O– Structural Beam Calculations (PV Array)

LOADS:

ROOF LIVE LOAD = 30 PSF
SUPERIMPOSED DEAD LOAD = 10 PSF
(ASSUMED)
PV PANEL & MOUNTING SYSTEM = 6 PSF

W12 x14

BEAM LOADING CALCS:

FACTORED LOAD = 1.2(10 psf + 6 psf) + 1.6(30 psf)
= 67.2 PSF

LOAD = (67.2 PSF)(7.5' TRIB. AREA) = 504 PLF = 0.504 KLF

LOAD PER SUPPORT = (0.504 KLF)(22'/2) = 5.544 K

BENDING MOMENT = $\frac{w\ell^2}{8} = \frac{0.504(22)^2}{8} = 30.49$ K·ft

TABLE 3-2 AISC → W12 x14 = 65.2 K·ft > 30.49 K·ft ∴ ✓

DEFLECTION CALCULATIONS:

LOAD = 16 PSF + 30 psf = 46 PSF x 7.5'
= 345 PLF

DEFLECTION MAX = $\frac{\ell}{240} = \frac{22' \times 12''/1'}{240} = 1.1''$

DEFLECTION = $\frac{5w\ell^4}{384EI} = \frac{5(.345\text{ KLF})(22')^4(1728)}{384(29000\text{ KSI})(88.6\text{ in}^4)}$

= 0.707" < 1.1" ∴ ✓

W 10 x 12

BEAM LOADING CALCS:

FACTORED LOAD = 1.2(10 PSF + 6 PSF) + 1.6(30 PSF)
= 67.2 PSF

LOAD = (67.2 PSF)(7.5' TRIB AREA) = 504 PLF = 0.504 KLF

LOAD PER SUPPORT = (0.504 KLF)(19'/2) = 4.788 K

BENDING MOMENT = $\frac{w\ell^2}{8} = \frac{0.504(19)^2}{8} = 22.74$ kft

TABLE 3-2 AISC → W10x12 = 46.9 k.ft > 22.74 k.ft

∴ ✓

DEFLECTION CALCULATIONS:

LOAD = 16 PSF + 30 PSF = 46 PSF x 7.5' = 345 PLF

DEFLECTION MAX = $\frac{\ell}{240} = \frac{19' \times 12''/1'}{240} = 0.95''$

DEFLECTION = $\frac{5w\ell^4}{384EI} = \frac{5(.345\ \text{KLF})(19')^4(1728)}{384(29000\ \text{KSI})(53.8\ \text{in}^4)}$

$= 0.648'' < 0.95''$ ∴ ✓

W 16 x 26

BEAM LOADING CALCS:

$$P = 5.544\text{K} + 4.788\text{K} = 10.332\text{ K}$$

TABLE 3-23 (AISC) $\Rightarrow$ $M_{max} = P_a$

$$M_{max} = P_a$$
$$= 10.332(7.5')$$
$$= 77.49\text{ K.ft}$$

TABLE 3-2 AISC $\rightarrow$ W16 x26 = 166 K.ft > 77.49 K.ft $\therefore$ ✓

DEFLECTION CALCULATIONS:

$$\Delta = \frac{P\ell^3}{28EI} = \frac{(10.332\text{ K})(22.5')^3(1728)}{28\ (29000\text{ ksi})(301\text{ in}^4)}$$

$$= 0.83'' < \frac{\ell}{240} = \frac{22.5' \times 12''/1'}{240}$$

$$= 0.83'' < 1.125''$$ $\therefore$ ✓

APPENDIX P – PV System Feasibility Analysis

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a responsible energy company

10616 Beaver Dam Road
Cockeysville, MD 21030
410.785.1760 phone
410.785.1763 fax

April 3, 2011

Ms. Courtney Glaub

Solar Energy System Details for your 32.9 kW System
Penn State Thesis Project

System Description

Mounting Type
Flat Roof

Azimuth (degrees)	Tilt	Site Efficiency Rating	Site Efficiency Rating*	Predicted Yearly AC Electrical Generation (kWh)
180°	**30°**	**99%**	**Excellent**	**43720 kWh**

Total System Size:	Panel Description	Panel Quantity	Panel STC Wattage	Inverter Description	Inverter Quantity
32.9kW / 32900 Watts	**Sharp NU-U235F1**	**140**	**235**	**SMA SB6000 US**	**6**

*** <70% - Poor, 70%-80% - Fair, 80%-90% - Good, 90%-100% Excellent**

Proposed System Cost and Incentives	
Pre-Incentive System Cost	$197,291
Federal Grant	($59,187)
Maryland Grant	($16,450)
Net Cost After One-Time Incentives	**$121,654**
Average electrical savings/yr over payback period	$7,482
Average per year SREC payment over payback period	$12,491
Total average yearly benefit over payback period	$19,973
Payback Period	6.09
Average Yearly ROI	14%

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Investment Analysis Prepared For: Ms. Courtney Glaub

MARYLAND System Analysis	Your Solar System
Solar Panels	
Description	Sharp NU-U235I
Panel STC Wattage	235
Quantity	140
Inverters	
Description	SMA
Quantity	6
Total DC System Wattage/kW	**32.9kW**
	32900 Watts
Production Information	
Azimuth(Degrees)	180°
Panel Tilt Angle (degrees)	30°
Yearly Average Sun Hours per Day	4.47
Derate for Orientation and Shading	Excellent
Yearly kilowatt hours (Est.)	**43,720**
System Financial Analysis	
Total System Price	$197,291
Federal Grant	($59,187)
Maryland Grant	($16,450)
County Property Tax Rebate	
Net Cost	**$121,654**
Current Electric cost per Kilowatt Hour	$0.156
Electricity Rate inflation rate	3%
SREC Rate (% of ACP)	80.00%

Year	SREC Payment per Kilowatt Hour	Yearly Solar Renewable Energy Credit Income	Rate per Kilowatt Hour	Annual Electric Savings	Yearly Savings/ Income	Cumulitive Benefit	Annual ROI
2011	First Year System Net Cost Before Yearly Benefits					-$121,654	
2011	$0.3200	$13,990	$0.156	$6,820	$20,811	-$100,843	17%
2012	$0.3200	$13,990	$0.161	$7,025	$21,015	-$79,828	17%
2013	$0.3200	$13,990	$0.166	$7,236	$21,226	-$58,601	17%
2014	$0.3200	$13,990	$0.170	$7,453	$21,443	-$37,158	18%
2015	$0.2800	$12,242	$0.176	$7,676	$19,918	-$17,240	16%
2016	$0.2800	$12,242	$0.181	$7,907	$20,148	$2,908	17%
2017	$0.2400	$10,493	$0.186	$8,144	$18,637	$21,544	15%
2018	$0.2400	$10,493	$0.192	$8,388	$18,881	$40,425	16%
2019	$0.2000	$8,744	$0.198	$8,640	$17,384	$57,809	14%
2020	$0.2000	$8,744	$0.204	$8,899	$17,643	$75,452	15%
2021	$0.1600	$6,995	$0.210	$9,166	$16,161	$91,613	13%
2022	$0.1600	$6,995	$0.216	$9,441	$16,436	$108,049	14%
2023	$0.1200	$5,246	$0.222	$9,724	$14,971	$123,020	12%
2024	$0.1200	$5,246	$0.229	$10,016	$15,262	$138,282	13%
2025	$0.0800	$3,498	$0.236	$10,316	$13,814	$152,096	11%
2026	$0.0800	$3,498	$0.243	$10,626	$14,123	$166,220	12%
2027	$0.0400	$1,749	$0.250	$10,945	$12,693	$178,913	10%
2028	$0.0400	$1,749	$0.258	$11,273	$13,022	$191,935	11%
2029	$0.0400	$1,749	$0.266	$11,611	$13,360	$205,295	11%
2030	$0.0400	$1,749	$0.274	$11,959	$13,708	$219,003	11%
2031	$0.0400	$1,749	$0.282	$12,318	$14,067	$233,070	12%
2032	$0.0400	$1,749	$0.290	$12,688	$14,437	$247,507	12%
2033	$0.0400	$1,749	$0.299	$13,068	$14,817	$262,324	12%
2034	$0.0400	$1,749	$0.308	$13,460	$15,209	$277,533	13%
2035	$0.0400	$1,749	$0.317	$13,864	$15,613	$293,146	13%
	TOTALS:	**$166,136**		**$248,664**	**$414,800**	**$293,146**