Center for Health Research and Rural Advocacy

SPRING 2006

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Construction Management

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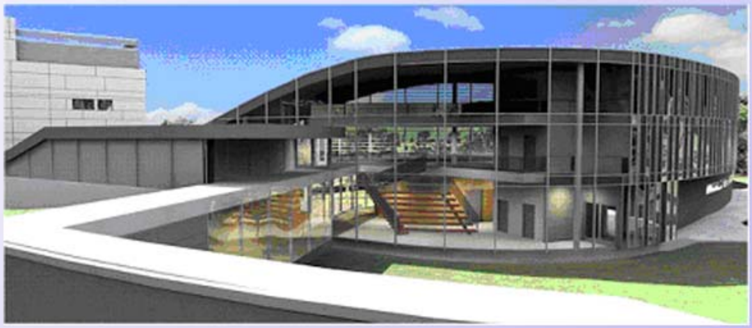
Center for Health Research and Rural Advocacy



Geisinger Medical Campus
Danville, Pennsylvania

EwingCole

Geisinger Health System

Project Overview

Size: 67,000 Square Feet
Cost: $18,400,000
Construction: July 2005 - February 2007
Delivery Method: General Contractor

Architectural

Basic LEED Certification
Aluminum Curtain Wall System
Precast Accent Panels
300 Seat Fully-Functional Auditorium

Project Team

Owner: Geisinger Health System
Architect: Ewing Cole
GC: Geisinger Health System Facilities Administration
Civil Engineers: Borton Lawson
MEP & Structural Engineers: Ewing Cole

Structural System

Four Story Structural Steel Frame
Basement 5" Slab on Grade
7' x 7' Concrete Spread Footings
6" Slab on 20 Gauge Metal Deck

Electrical / Lighting System

Main Switchboard: 2500 Amps
Nine Distribution Panels: 480/277V
3 phase, 4 wire service
Four Dry 300 KVA Transformers
Fixtures: Companct and Tubular Floursecents with Dimming Ballasts

Mechanical System

Four Rooftop Air Handling Units:
Range 4,000 CFM - 27,000 CFM
Three 500 Ton Variable Frequency Chillers
Hydraulically Designed Sprinkler System with Advanced Alert System

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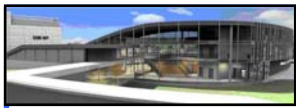
www.arche.psu.edu/thesis/eportfolio/current/portfolios/mwv107/



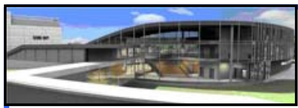
Executive Summary

The Center for Health Research and Rural Advocacy serves as an interesting backdrop for analysis. Aspects of the project include LEED certification, site logistical issues, complex building envelope systems, as well as a connection to an existing facility. This 67,000 square foot facility will house researchers and hospital employees in the large open work floors, auditorium, and multi-use rooms. Geisinger Health System's newest facility will be a crowning architectural achievement on the medical campus.

Since this is the first LEED certified project under Geisinger Facilities supervision, many challenges and issues will be addressed. One of these challenges includes the management of the complex envelope system and its role in sustainable aspects. Using the <u>LEED-NC Version 2.2</u> coupled with the <u>GSA: LEED Cost Study</u> and <u>Green Guide for Health Care Construction</u> it has been determined that 57% of LEED points contain aspects which pertain to the building envelope system. With such a large percentage of points, premium costs for implementing a complex system can range from $150,000 - $250,000. The management team can use many resources to help properly manage the building skin.

When referenced to the project schedule and budget, the aluminum curtain wall is the most expensive and schedule intensive activity. Utilizing a unitized approach with panels prefabricated off-site, the project schedule can be minimized relating to direct general conditions savings. This mindset of only using this type of construction on highly repeatable systems is not applicable, since the complex curtain wall system also had numerous advantages such as logistic alleviation, schedule reduction, and decreased labor rates.

4D CAD has been used to analyze construction sequences now more than ever. Using a 4D model on the Center for Health Research and Rural Advocacy provided valuable insight into hazardous construction activities and congested areas. All of the envelope construction began in close proximity to one another on the North elevation which will more than likely cause numerous headaches and delays. Crane position was also analyzed and determined to be operating in a hazardous manner. These and numerous other advantages clearly display the value a 4D model can be as a tool for construction managers.



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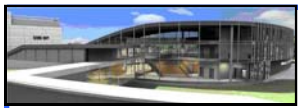
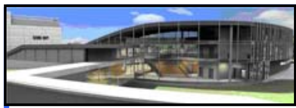


Project Introduction

This thesis focuses on the Center for Health Research and Rural Advocacy project currently under construction on the Geisinger Medical Campus in Danville, Pennsylvania. The 67,200 square foot facility will house numerous conference spaces, research offices, and a three hundred seat auditorium. Funds for the design and construction of the facility are through the Geisinger Health System in the amount of approximately $18,400,000. This amount includes design and general building construction costs as well as utility and infrastructure redevelopment. The eventual client of the facility will be the Health Research and Rural Advocacy division of the Geisinger Health System. The facility will be a center for healthcare research regionally, nationally, and globally in the years to come.

The Center for Health Research and Rural Advocacy will connect directly to the Weis Research Center, a predominately beige brick and CMU constructed facility. The design of the CHRRA counteracts the beige brick of the Weis Center, through the use of a "high tech" appearance of an aluminum curtain wall system. The research center slices through the medical campus with its arching glazed façade and lack of harsh corners. The project features a link between the adjacent research facilities on the ground floor. Upon completion, the CHRRA will be the prized architectural achievement of the Geisinger Hospital Campus. The four level multi-use facility will house numerous clinical, epidemiological and health services researchers, as well as large conference spaces and a 300 person capacity, full functional auditorium. Bordering the auditorium is an open two-story café with an outdoor terrace. The roof of the auditorium will be a roof garden similar to those designed by Le Corbusier, overlooking the café terrace at the ground level. A large, two-story multi-purpose room is located adjacent to the connection point between the Weis Research Center and the new CHRRA. The fit-out of the Weis Research Center includes the demolition of the mechanical room on the lower floor, and replacing it with offices and restrooms.



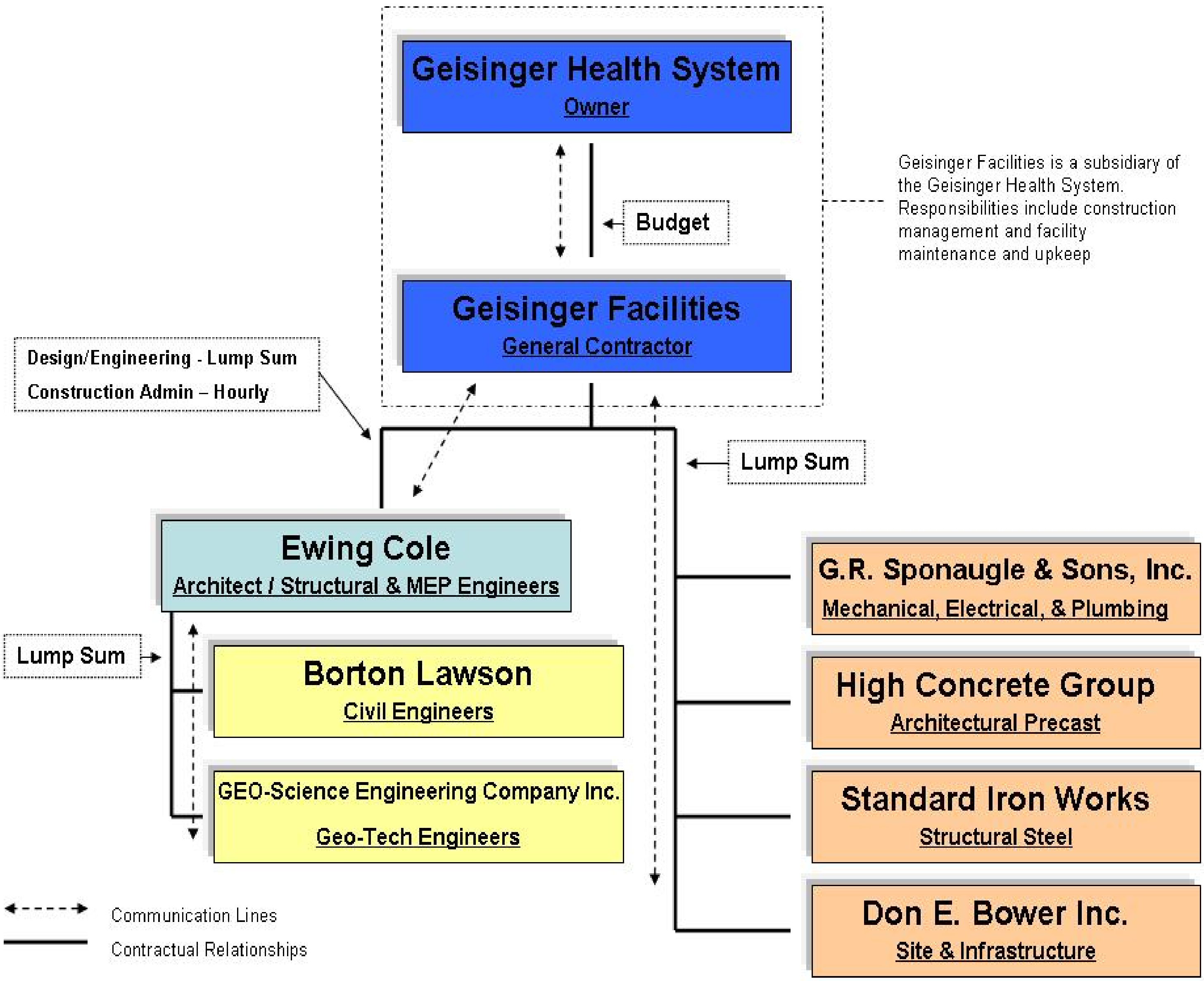
Constructing on a hospital campus has many challenges, and this project is no different. Parking and transit routes for the patients and doctors can not be disturbed, requiring the re-routing of Center Street and relocation of a parking lot. Existing utilities on site are abundant, with the CHRRA building footprint sitting on the water main loop, telecommunication lines, storm water, and sewage lines. All of these may not be shutdown at all during standard hospital operation hours and must be closely coordinated with the hospital facility. It is a phased construction, with the auditorium being constructed before excavation is complete, due to the need to relocate Center Street.

Geisinger Health Systems will budget the project out to their own construction division known as Geisinger Facilities which will act as a general contractor throughout the process. Geisinger Facilities will oversee the design process and manage construction through lump sum contracts with the subcontractors. The project will be delivered through a design-bid-build structure, which will allow for the infrastructure and utility relocations to occur while the remainder of the project is designed. Geisinger Facilities' experience greatly enhances their ability to effectively manage a design-bid-build project on the campus. Here is a brief listing of some of the key project team members as well as an organizational chart on the following page.

Primary Project Team:

Owner: Geisinger Health System
Website: www.geisinger.org
Architect: Ewing Cole
Website: www.ewingcole.com
MEP & Structural Engineers: Ewing Cole
Website: www.ewingcole.com
Geo-Technical Engineers: GEO-Science Engineering Company, Inc.
Civil Engineers: Borton Lawson
Website: *www.borton-lawson.com*
General Contractor: Geisinger Health Systems Facilities Administration
Website: www.geisinger.org

Project Delivery System



Client Information

Heal. Teach. Discover. Serve.

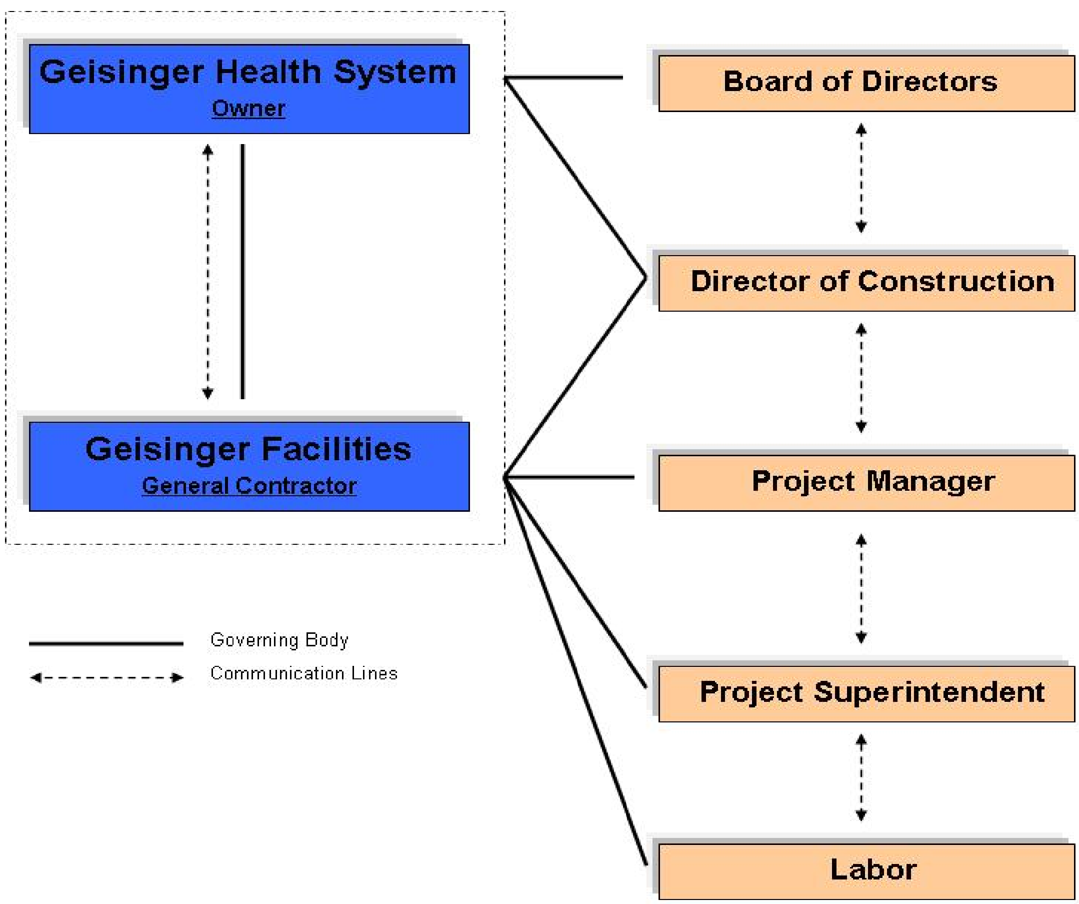
Geisinger Health System is a physician-led health care system, providing health care, education, research, and service to almost two million people across Pennsylvania. The 437-bed Geisinger Medical Center houses doctors, nurses, researchers, and other healthcare specialists dedicated to providing exceptional service through state-of-the-art facilities. The Geisinger Health System contains a division known as Geisinger Facilities which manages all aspects of the buildings and infrastructure on the Geisinger Health Campus located in Danville, Pennsylvania. The Geisinger Facilities division is essentially a General Contractor employed during the design phases their projects. Once the Geisinger Health System Foundation Board of Directors approves the construction of a project, the Geisinger Facilities managers act as the owners and general contractor for that specific project.

The Center for Health Research and Rural Advocacy (CHRRA) needed a new high tech facility to cope with ever changing demands in healthcare research. The relocation of one hundred and twenty staff members from the Weis Research Center to the CHRRA building will allow for improvements in the effectiveness of health services and medical treatments research. The three hundred seat auditorium and numerous other conference rooms will fulfill CHRRA’s need for educational spaces where professionals from across the country may present research findings.

The Geisinger Facilities’ goals for the project include a timely and cost efficient management of the relocation, construction, and infrastructure work required for the Center for Health Research and Rural Advocacy. Safety standards are extremely high, which includes the laborers on-site, as well as protection for the doctors, nurses, and other healthcare specialists who drive and walk by the construction site everyday. Waste management, emissions control, and other health risks are of high concern due to the close proximity to the existing Weis Research Center and the main patient care compound. The Geisinger Health System always employs a high quality of construction for all their healthcare projects which is evident in all the facilities on the Geisinger Medical Campus.

Sequencing issues for the Facilities' project management team are important, but not critical for the CHRRA building. It is more important that the project is completed when scheduled to allow a smooth transition for the researchers rather than monetary concerns as in most other construction projects. Some key sequencing issues the owner cares about include integrating the MEP systems for the two research facilities during normal operating hours, as well as the eventual connection of the two facilities.

At completion of the Center for Health Research and Rural Advocacy project, the Geisinger Facilities' team would like to see a state-of-the-art facility completed as scheduled and at a cost equal to or less than the allotted budget. The CHRRA will be a jewel on the Geisinger Medical Campus and will hopefully be a center for healthcare research regionally, nationally, and globally in the years to come. The following is an illustration of the project team employed for the Center for Health Research and Rural Advocacy project.



Building Systems Summary

Demolition

There are two phases or areas of the Center for Health Research and Rural Advocacy project which involve the demolition and relocation of existing facilities and structure. The CHRRA building will connect directly to the Weis Research Center through a walkway on the lower level. Materials to be removed include concrete structure and core, gypsum wallboards, masonry exterior walls, fireproofing, roof membrane where piping is removed, and partitions.

Additionally, two existing exhaust fans will be relocated from the Weis Research Center's mechanical area on the roof to the new mechanical suites in the CHRRA. One cooling tower and required piping will be completely removed from the Weis Research Center since the two buildings will eventually share a mechanical system.

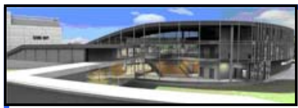
Electrical demolition for the project includes the removal of two automatic switch controls, 6 sixty amp control panels, and 2 thirty amp control panels and wiring. These systems are located in one electrical room in the Weis Research Center where the connection to the CHRRA will occur.

Structural Steel Frame

The structural steel frame for the Center for Health Research and Rural Advocacy employs a braced frame system with diagonal HSS steel. These are of typical sizes 7x7x1/2" or 10x6x5/8" and are connected to the structural columns and beams with ¾" gusset plates. At the ground level, these connections are encased in concrete for additional support.

The basement floor is a 5" concrete slab on grade with the intermediate floor systems being 6" concrete slab reinforced with 6x6-W2.9xW2.9 welded wire fabricate on top of 2" 20 gauge metal decking.

Since the largest and highest pick for the crane will involve a 43' W10x100 column, a 35 ton mobile crane with a 120 foot boom will be used for the structural steel erection. The mobility of the crane will allow it to travel around the arched building footprint to reach areas that would



require an oversized tower crane. Since the lifting heights do not exceed 43’ above grade, a mobile crane can be used extensively.

Cast in Place Concrete

Cast in place concrete is used for the basement walls as well as the for the floor slabs. The horizontal and vertical formwork is to be made of wood of quality related to if the surface is exposed or not. Unexposed concrete surfaces may be formed with No. 2 Common lumber or plywood while exposed concrete surfaces must be formed with New Douglas Fir B-B not less than 5-ply and at least 5/8” thick.

The cast in place work is in accordance with ACI 301, ACI 318, and ACI 347 and is to be completed in phases. The slab on grade is to be made in two pours, one being the large mechanical room space. The other composite floor systems are to be poured in two sections as well, one being the open office spaces, while the other includes the multi-use areas and supporting facilities.

Pre-cast Concrete

The casting of the architectural pre-cast concrete will occur at High Concrete Structures, Inc. facilities in Denver, Pennsylvania and transported to site. The architectural panels range in rectangular shapes from 18’ x 4’ to 12’ x 2’ and are all 6” thick. The panels will match the existing Weis Research Center in terms of color, texture, and finish.

Panels will be connected through the use of shear bars, 1’x4’x6” embedded to the structural steel below the finished floor elevations. Pre-cast panels will be lifted with a mobile crane similar to the structural steel. The mobile crane will be able to move around the site and position the pre-cast panels as needed.

Mechanical System

The mechanical support system of the CHRRA will also serve the Weis Center. The new mechanical system will use 4 variable fan speed Air Handling Units, each with ½” coiling coils and 5/8” heating coils ranging in size from 27,000 CFM to 4,000 CFM. Three, 500 ton capacity, variable frequency drive water chillers will service the two buildings. A complex refrigerant recovery system will have the ability to monitor, test, and purge all refrigerant. There are four designated mechanical spaces servicing the two buildings, three rooms in the CHRRA and the Weis roof. Extensive re-piping work is to be done in the Weis Center for hot and cold water, high pressure steam, and condensate return. The distribution piping is made of copper type L, hard temper and of typical sizes 1" to 4", riser piping made of black steel for sizes larger than 10".

A hydraulically designed sprinkler system is used for fire protection at the CHRRA. Sprinklers service no more than 225 square feet in the office and open areas, and no more than 130 square feet in mechanical spaces. Concealed quick response heads are used in finished ceiling areas and are designed for use in 155^{oF} temperatures. Sprinkler piping is made of black steel typically 2" in distribution areas and 6" in riser piping.

Notification system includes addressable heat and smoke detectors, standard manual pull stations, and electro-magnetic door holders. There are also two LCD annunciators located at the main entrance and nurse's station.

Electrical System

Power supply comes into the new research facility at 480/277V standard from the Plant Engineering Building. A 1500/1750KVA transformer, located in the electrical substation room, is used to feed the substation 2500A, 480/277V supply power. The substation serves nine distribution panels utilizing the three phase service. An additional four dry 300KVA transformers are to be used to step down the voltage to 208/120V for the main distribution panels. All circuit breakers and switches for the project are three-pole.

Emergency power for the facility is provided by a 1250 KW, three phase, 60 Hz emergency generator located in the emergency generator room on the lower level. The generator includes electronic metering of supply needs as well as an adjacent emergency standby motor control center.

Curtain Wall

The finished aluminum curtain wall system with glazing at the main lobby entrance, and west stairwell will consist of structurally reinforced .125” thick extruded aluminum framing with glass infill panels of typical size 4’ x 9’-6”. The color will be an Architectural Class 1 clear anodic coating. The remaining aluminum wall system, which is the majority of the project, is made up of a two glass system. The insulating glass is spliced by 1” thick strengthened float glass with reflective coating. These reflective glass panels are also used above the windows on the west façade.

The remaining façade consists of a 2” metal panel system fastened to 16 gauge metal framing. These metal panels will be 2” thick and typically 1’ x 13’ fabricated from 22 gauge G90 galvanized steel. There are seven metal wall louvers at the mechanical room which are also finished to match the aluminum anodic coating of the curtain wall system.

The design and construction responsibilities rest directly on the selected subcontractor, who must submit shop drawings and product data with a letter of certification of a registered Professional Structural Engineer in the commonwealth of Pennsylvania that the shop drawings were completed under their direction. Field testing must also be conducted to verify performance criteria of the curtain wall system. The design basis was created by Ewing Cole.

The construction of the system occurs in two phases. First, the aluminum framing will be installed, followed by the installation of the glazing and required sealing.

Support of Excavation

Since most of the site was made up of stiff silty clay, the excavation for the auditorium could be sloped and comply with OSHA regulations. Dewatering was necessary for ground water during auditorium excavation. Once excavation begins on the remainder of the site, a soldier beam and lagging system will be used to retain the newly positioned Centre Street. The remainder of the site will utilize a slope since there is plenty of available area to the west and south.

Local Conditions

The preferred method of construction for Geisinger Medical Campus projects includes a structural steel frame, with composite floor slabs, and typical tan brick and masonry facades. The Center for Health Research and Rural Advocacy is drastically different than the other projects in terms of the exterior envelope. The other Geisinger facilities do not employ large aluminum curtain wall systems or large pre-cast concrete panels. Since infrastructure work is not an aspect that Geisinger Facilities has a lot of experience in, an MEP contractor was brought on early in the construction process to raise issues and concerns with the movement of utilities and roadways.

Construction parking is a complex issue at the Center for Health Research and Rural Advocacy site, since a large doctor parking lot sits adjacent to the property. Contractors must park in the large patient parking lots located on the opposite side of the medical campus, and then ride the Geisinger bus system to the site. Geisinger Facilities denoted an area for the contractors to park as to not take parking away from normal hospital patients.

Since the Center for Health Research and Rural Advocacy will be a LEED certified building, recycling is huge issue. Danville, Pennsylvania offers free recycling for all residents; however, the commercial building industry is not as lucky. The lack of a local recycling plant makes tipping fees upward of $20 per ton.

Ground water locations for the project site were encountered at 25 feet below finished grade, however; only three of the eleven bore samples found any water when drilled to 30 feet. The vast majority of the boring logs found reddish brown silty clay which was moist and stiff. This clay material was found throughout the entire range of the boring logs, with the exception of some sporadic brown clay with rock fragments.

Existing Project Conditions

General Conditions Estimate

The Center for Health Research and Rural Advocacy is constructed under the supervision of the Geisinger Facilities Division. The project team develops a general conditions cost estimate for the main reason of tracking expenses throughout the course of the project. Once an accurate estimate has been established by the team, it is submitted to the Geisinger Health System Board of Directors for approval. If approved, the general conditions costs are added to the job cost system and are monitored closely during construction. Often times the initial general conditions are a bit inflated, as to guarantee money is given back to the Health System at the completion of the job. It is difficult to garner more general conditions funding once the project has commenced.

Another interesting aspect of the general conditions for the CHRRA is that Geisinger Facilities does not charge a fee on top of the base costs. This clearly shows the contractual connection between Geisinger Facilities and the Geisinger Health System. The Facilities management team operates as a salary driven entity, and does not make additional profits on a successful project or incur losses.

Project management travel and facilities are already provided to the Facilities team by the Health system. The operation headquarters is located within walking distance of the project site which minimizes actual on-site facilities. A small office trailer housing drawings, small tools, safety equipment, etc. is all that is located on site. The three portable toilets are spread across the site for easy access for all.

The general conditions estimate will be used to assess savings from schedule reduction in the later analyses. A month reduction in schedule would equate to almost $40,000 in savings. Please refer to following table for the general conditions breakout for the Center for Health Research and Rural Advocacy project.

General Conditions Estimate

Code	Description	Quantity	Labor	Material	LS	Total
Project Management						
PM001	Director of Construction (1)	4 months	$8,200	$0	$0	$32,800
PM002	Project Manager (1)	21 months	$6,400	$0	$0	$134,400
PM003	Superintendent (1)	21 months	$4,960	$0	$0	$104,160
PM004	Project Engineer (1)	Hourly (500)	$36 / hr	$0	$0	$18,000
PM005	CPM Schedule	LS	$0	$0	$4,852	$4,852
Temporary Utilities						
T001	Job Telephone	21 months	$0	$75 / mo	$0	$1,575
T002	Trailer Electric	21 months	$0	$210 / mo	$0	$4,410
T003	Temporary Heat	4 months	$0	$1,045 / mo	$0	$4,180
T004	Fire Protection	12 months	$0	$280 / mo	$0	$3,360
T005	Air Compressor (2)	21 months	$0	$325 / mo	$0	$13,650
T006	Temp Generators (2)	21 months	$0	$1,216 / mo	$0	$51,072
Equipment						
E001	Mobile Crane	11 months	$0	$12,200 / mo	$0	$134,200
E002	Jobsite Forklift (2)	21 months	$0	$700 / mo	$0	$29,400
E003	Jobsite Trailer	21 months	$0	$380 / mo	$0	$7,980
E004	Equipment Hoist	4 months	$0	$2600 / mo	$0	$10,400
E005	Scissor Lifts (3)	12 months	$0	$900 / mo	$0	$32,400
Site Safety & Prep						
SS001	Temporary Fence	LF (900 FT)	$2 / LF	$12 / LF	$0	$12,600
SS002	Temporary Road	SQYD (60)	$1.20 / SQYD	$4 / SQYD	$0	$312
SS003	Job Signs	EA (6)	$275 / EA	$115 / EA	$0	$2,310
SS004	Clean Up	SF (67,200)	$0.5 / SF	$0	$0	$33,600
SS005	Trash Removal	CY (200)	$32 / CY	$4 / CY	$0	$7,200
SS006	Trash Chutes	Floors (3)	$0	$0	$642	$642

Miscellaneous Materials & Supplies						
MM001	Management Phones (2)	21 months	$0	$65 / mo	$0	$2,730
MM002	Trailer Supplies	21 months	$0	$220 / mo	$0	$4,620
MM003	Portable Toilet (3)	21 months	$0	$80 / mo	$0	$5,040
MM004	First Aid Supplies (2)	LS	$0	$0	$460	$460
MM005	Safety Supplies	LS	$0	$0	$820	$820
MM006	Drawing Reproduction	LS	$0	$0	$4,500	$4,500

Permits, Bonds, Insurance, & Testing						
PT001	Occupancy Permits	LS	$0	$0	$950	$950
PT002	Land Permits	LS	$0	$0	$1,350	$1,350
PT003	Bonds	N/A	$0	$0	$0	$0
PT004	Insurance	N/A	$0	$0	$0	$0
PT005	System Testing & Certification	LS	$0	$0	$122,600	$122,600

Labor Subtotal	**$332,861**
Material Subtotal	**$317,538**
Miscellaneous Subtotal	**$136,174**
Fee (0%)	**$0**

General Conditions Grand Total **$786,573**

Monthly Billing (21 months) $37,456

Schedule Summary

Some interesting aspects of the project schedule include the phasing of the structural cast-in-place concrete. The reason for this is due to that Geisinger Facilities is self performing half the work and subcontracting the rest. The first pour will be used by the Geisinger Facilities to manage the quality control and schedule of the subcontracted group. Once Geisinger Facilities feels the output is acceptable, two separate teams will begin pouring on separate portions and working towards the auditorium.

Structural erection will occur during two phases, with the second phase incorporating two different crane locations. The east wing of the center will be constructed first with the crane stationed outside the sheeting and shoring system. Once complete, the crane will move inside Centre Street and erect half the west wing and then move one more time to finish the structural steel.

Building envelope construction will be completed in two sections. The curtain wall subcontractor will erect the framing system of the aluminum mullions and beams. Once complete, the glazing and sealants will be installed to finish the building enclosure. This sequence will be explored in the second technical analysis and expanded upon.

The rest of the schedule is fairly standard. The interior spaces will start on the ground floor since there is a minimal amount of finish work on that floor. Once this is completed, finishes will start on the second floor and work down towards the lower level dumpsters and loading dock. This will keep crews and trash moving away from already finished areas and will minimize punch-list items and damage to finished work. The recreational room is designated as the last room because it does not require extensive finishes and may be used as an interior equipment staging area.

Appendix D contains the summary schedule discussed in this section. Please reference for additional insight into the sequencing of the Center for Health Research and Rural Advocacy.

Site Logistics

Site planning for this project is extremely important due to the fully operational Centre Street and the proximity of the Weis Research Center. The expansive footprint of the Center for Health Research and Rural Advocacy requires three separate lift points for the crane. Careful consideration must be made by the geo-technical engineers to ensure that the sheeting and shoring system can maintain the added load of a close proximity pick point. The restriction of the site also requires two separate staging areas for the structural steel which will increase costs and management headaches to manage traffic patterns.

The three crane locations are necessary due to the site restrictions. Close proximity to the Weis Research Center and Geisinger Hospital make crane placement and lift operation extremely difficult. Productivity of lifts will be tested with narrow passageways between buildings for the first pick location. Even though the project is schedule for structural steel erection in two phases, the relocation of the crane from position two to three will not be difficult, since both locations can use the same staging area.

The material hoists, loading dock, and dumpsters are all located on the lower level at the open recreational room. The dumpsters may be extensive depending on the LEED certification desired for the project. Not only do costs increase with trying to achieve the recycling points, but site logistics needs to be reworked to include all the necessary dumpsters and recycling bins. Additional traffic considerations for recycling bins will be coordinated closely to ensure normal construction activities are not interrupted.

The concrete trucks park adjacent to the material auditorium and will have piping to the east portion of the building as well as the west. Trucks will follow this scheme throughout the elevated slab pours and a temporary roadway will be put in place to maintain the constant traffic flow. Please reference the site plan for the superstructure on the following page for more insight into the truck routes, crane placements, and dumpster locations.

Site plans of superstructure erection are also located in Appendix D for easy reference.

Research Analysis: Building Envelope & LEED Credits

SPRING 2006

Michael W. Vergari
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Research Analysis: Building Envelope and LEED Credits

Introduction

Green buildings are no longer a new idea and are quickly becoming the trend in the slowly changing industry of building construction. Even though the essence of LEED (Leadership in Energy and Environmental Design) rating systems are understood more universally throughout construction disciplines than a decade ago, the integration of design, engineering, and construction of systems to be "greener" has a ways to go.

LEED rated buildings have numerous advantages over their more traditional counterparts, whether the facility is simply certified or one of the handful of platinum LEED certified projects. The advantages stem from locally used resources, recycled content, and other environmentally friendly applications. Energy consumption utilized for heating and cooling, as well water usage, can be greatly reduced by building with LEED. This can be a large monetary incentive with annual savings ranging from $20,000 - $120,000 for a typical 100,000 square foot commercial building. Air quality and daylight aspects of sustainable designs have been shown to increase productivity in the work force as well as promote learning in classroom environments.

So what is keeping more owners from building with sustainable aspects in mind? The answer is the price tag for the premium designs for the building systems. Redesigning mechanical, structural, lighting, and envelope systems can be tedious and costly. These systems need to be designed congruently to take full advantage of LEED aspects. This allows for systems to be more economical and cost effective to the building owner and possible tenants. The Center for Health Research and Rural Advocacy is also a health care facility which is governed by more stringent regulations than typical commercial construction. Health care operations utilize different ventilation requirements, occupant needs, waste and recycled content removal, and energy usage compared to that of their commercial counterpart. Health care facilities often operate close to full capacity 24 hours the entire year. The energy savings for these facilities can be significant. System efficiency is critical for these facilities not only for cost and maintenance, but for public safety and well-being.

Goal

The research to be employed in this analysis will take an in-depth look at how the selection and design of the building envelope affects the sustainable aspects of the project. Many resources and guides will be utilized to help understand impacts of LEED credits. A review of the LEED-NC for Commercial Construction Version 2.2 and GSA-LEED Cost Study will be compared to determine which credits are affected by the envelope selection and the relative cost of those credits. The Green Guide for Health Care is a new resource being used to help with the design and construction of these LEED rated facilities. This guide will be used to compare findings with the LEED-NC and GSA Cost study data. The goal of this research is to display the monetary and sustainable effects the exterior skin has on projects and to help designers and owners make educated decisions during the skin selection process.

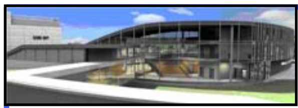
Resource Review and Description

LEED-NC

The first resource used for this research analysis was the LEED-NC for Commercial Buildings Version 2.2. This source outlines the credits and pre-requisites required for attaining LEED certified facilities. The goal for many institutions, including Penn State University, is to construct buildings which are simply LEED certified. By achieving 26 - 32 of the possible 69 points a building will be considered LEED certified. Garnering 33 - 38 points will get a LEED Silver rating and 39 – 51 points equates to a LEED Gold certification. If the building in design and construction earns more than 52 points it achieves the highest rating which is LEED Platinum certification.

GSA LEED® Cost Study

U.S. General Services Administration (GSA) recently published a report outlining cost implications of each of the LEED credits in the LEED-NC guide. This GSA: LEED Cost Study includes credit reviews, calculates individual credit estimates, as well as determines soft costs for LEED credits based on a courthouse and commercial building examples. The credits are broken down according to their related premium costs. Premium cost ratings may range from none ($0)



to high (>$150,000). Once the premium costs are determined, general conditions and soft costs are calculated and added to the credits total expense.

Since the GSA: LEED Cost Study uses courthouses and commercial buildings as examples, an additional resource is needed to compare to health care facilities. The Green Guide for Health Care Construction is a guide being developed by numerous sponsors and organizations. The goal of this pilot document is to provide “A Best Practices Guide for Healthy and Sustainable Building Design, Construction, and Operations”. Additional comments and concerns will be raised by this guide in reference to the LEED credits which are seen as affecting the building envelope design.

Analysis Results

Before the resources can be used for comparison and data collection, the LEED credits must be separated into different categories. The following categories will be used to separate the credits into manageable components based on the degree to which they affect the building envelope design and construction.

Directly Affects Building Envelope

Credit point pertains to one or more of the following:

- The building envelope in reference to its design, construction, and use.
- A system which is contacting the building envelope in regards to structural and mechanical forces. (i.e. mechanical pipes running underneath building skin or supported by structural member)
- Entails day-lighting aspects, UV protection, and other types of solar energy harnessing systems.

In-directly Affects Building Envelope

Credit point does *NOT* directly affect the building envelope and pertains to one or more of the following:

- Pertains to material standards set for the entire project as in terms of locality, made from recycled content, packaging, etc.
- Waste management system for entire project and not just the building envelope.
- Deals with workers, equipment, and materials which will be utilized temporarily for the construction of the building envelope.

Does Not Affect Building Envelope

Credit points which do not directly or in-directly affect the building envelope design, construction, or use.

Since the factors and extents to which the building envelope is affected have been determined, these will be combined with the LEED-NC Version 2.2 for analysis. The following table outlines the LEED credits with a brief description and the category to which it pertains.

LEED Credits

SS: Site Selection		Direct	In-Direct	No-Effect
SS 1	Site Selection: Ecologically sensitive land or prime farmland			x
SS 2	Development Density or Community Connectivity			x
SS 3	Brownfield Redevelopment: Selection of contaminated site			x
SS 4.1	Public Transportation Access			x
SS 4.2	Alternative Transportation: Bicycle rack coverage		x	
SS 4.3	Low Emitting and Fuel Efficient Vehicles			x
SS 4.4	Parking Capacity: Carpool preferred parking			x
SS 5.1	Protect or Restore Habitat			x
SS 5.2	Maximize Open Space			x
SS 6.1	Storm water Design: Quantity Control			x
SS 6.2	Storm water Design: Quality Control		x	
SS 7.1	Heat Island Effect: Non-roof			x
SS 7.2	Heat Island Effect: Roof	x		
SS 8	Light Pollution Reduction		x	

WE: Water Efficiency		Direct	In-Direct	No-Effect
WE 1.1	Water Efficient Landscaping (50%)			x
WE 1.2	Water Efficient Landscaping (No potable water)			x
WE 2	Innovative Wastewater Technologies			x
WE 3.1	Water Use Reduction (20%)			x
WE 3.2	Water Use Reduction (30%)			x

EA: Energy and Atmosphere		Direct	In-Direct	No-Effect
EA 1	Optimize Energy Performance (1-10 pts.)	x		
EA 2	On-Site Renewable Energy (1-3 pts.)	x		
EA 3	Enhanced Commissioning			x
EA 4	Enhanced Refrigerant Management			x
EA 5	Measurement and Verification			x
EA 6	Green Power			x

MR: Materials and Resources

		Direct	In-Direct	No-Effect
MR 1.1	Building Re-Use (Maintain 75% of existing walls, floors, roofs)		x	
MR 1.2	Building Re-Use (Maintain 95% of existing walls, floors, roofs)		x	
MR 1.3	Building Re-Use (Maintain 50% of non-structural interior elements)			x
MR 2.1	Construction Waste Management (50% Diverted)		x	
MR 2.2	Construction Waste Management (75% Diverted)		x	
MR 3.1	Materials Re-Use (5%)	x		
MR 3.2	Materials Re-Use (10%)	x		
MR 4.1	Recycled Content (10%)	x		
MR 4.2	Recycled Content (20%)	x		
MR 5.1	Regional Materials (10% Processed, Manufactured Regionally)		x	
MR 5.2	Regional Materials (20% Processed, Manufactured Regionally)		x	
MR 6	Rapidly Renewable Materials			x
MR 7	Certified Wood			x

EQ: Indoor Environmental Quality

		Direct	In-Direct	No-Effect
EQ 1	Outdoor Air Delivery Monitoring			x
EQ 2	Increased Ventilation			x
EQ 3.1	Construction IAQ Management Plan: During Construction		x	
EQ 3.2	Construction IAQ Management Plan: Before Occupancy			x
EQ 4.1	Low-Emitting Materials: Adhesives & Sealants	x		
EQ 4.2	Low-Emitting Materials: Paints & Coatings	x		
EQ 4.3	Low-Emitting Materials: Carpet Systems			x
EQ 4.4	Low-Emitting Materials: Composite Wood & Agrifiber Products			
EQ 5	Indoor Chemical & Pollutant Source Control	x		
EQ 6.1	Controllability of Systems: Lighting			x
EQ 6.2	Controllability of Systems: Thermal Comfort	x		
EQ 7.1	Thermal Comfort: Design	x		
EQ 7.2	Thermal Comfort: Verification			x
EQ 8.1	Daylight & Views: Daylight 75% of Spaces	x		
EQ 8.2	Daylight & Views: Daylight 90% of Spaces	x		

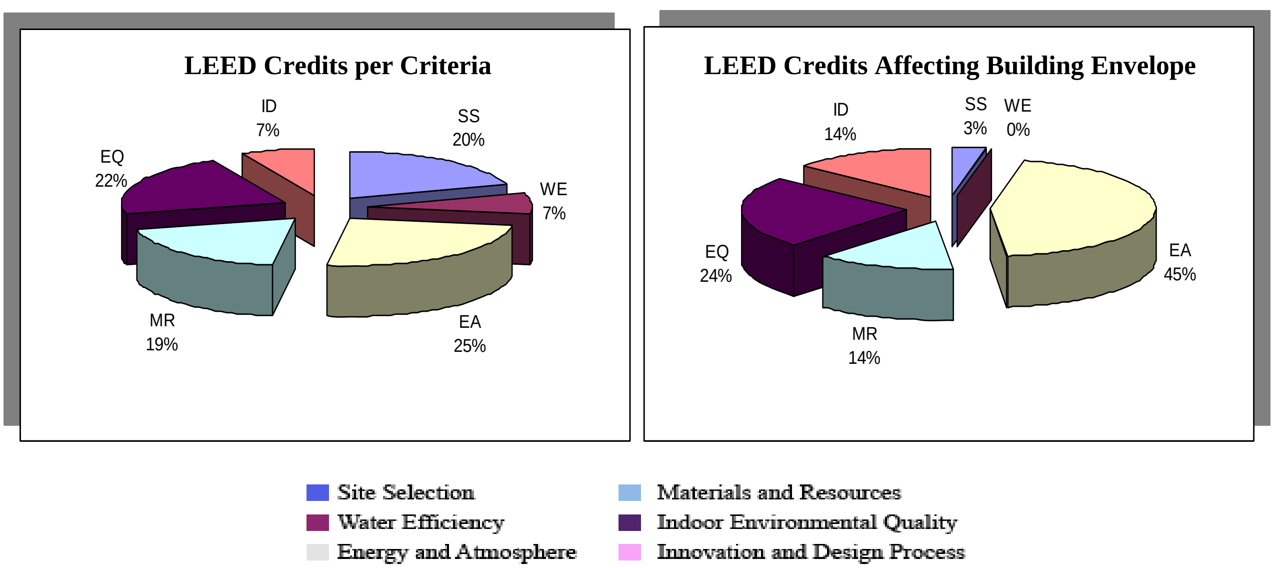
ID: Innovation & Design Process

		Direct	In-Direct	No-Effect
ID 1.1-1.4	Innovation in Design (1-4 pts.)	x		
ID 2	LEED Accredited Professional			x

Summary Table

	# of Credits	SS	WE	EA	MR	EQ	ID
Directly Affect Building Envelope	29	1	0	13	4	7	4
In-Directly Affect Building Envelope	10	3	0	0	6	1	0
No-Effect on Building Envelope	30	10	5	4	3	7	1
Total Credits	**69**	14	5	17	13	15	5

This simple analysis of the LEED credits brings out some interesting insight into the importance the building envelope may play in the design and construction process. 57% of the LEED credits are affected either directly or in-directly by the skin selection and 75% of those credits directly affect the building envelope. The summary table also illustrates the spread of the credits across the various sections of the LEED criterion. The Energy and Atmosphere (EA) section of the LEED-NC is the most critical for exterior systems with 13 of the 17 points being directly affected. The Energy and Atmosphere criterion is one of the most important sustainable aspects of green buildings to most owners and developers. Utility savings in such things as water and electricity can be significant to the everyday operation of certain facilities. Energy efficiency is even more applicable for health care operations which are open 24 hours a day. Building envelope design should be carefully determined for these facilities to maximize owner savings, patient health, and worker productivity. For this and many other reasons the Energy and Atmosphere section of the LEED-NC contains the most possible credit points.



The next most applicable group is the Indoor Environmental Quality (EQ) criterion which determines health aspects for the building occupants. As seen in the Energy and Atmosphere section, the Indoor Environmental Quality is greatly affected by the building envelope design and construction. Of the 15 credit points, 8 are affected by the skin selection. This is attributed to utilizing natural light in facility design as well as thermal comfort controls and design. Exterior systems greatly influence the lighting of spaces as well as the comfort of the occupants. Thermal issues include simple things such as glare protection and cold temperatures near exterior

windows. These issues are amplified in hospitals and health care facilities where patient physical and psychological health is extremely important.

Using the credits which are affected by the building envelope design, a table has been formulated to address cost concerns of pursuing these credit points. Research has shown the positive attributes these additional design considerations have made on other facilities, but owners need to be able to justify the positives outweigh the additional costs accrued. The following table was gathered utilizing the GSA: Cost Study for insight into the premium costs owners could expect if the credit points were pertaining to the building envelope design and construction. Credit points are listed if they are considered directly affecting the envelope system.

Premium Costs

Must Meet by GSA Standards or Mandate	
No Cost Premiums	
Low Cost Premiums (<$50K)	
Moderate Cost Premiums ($50K - $150K)	
Large Cost Premiums (>$150K)	

SS: Site Selection

		$ Impact
SS 7.2	Heat Island Effect: Roof	*($0)*

EA: Energy and Atmosphere

		$ Impact
EA 1	Optimize Energy Performance (1-10 pts.)	*(>$150K)*
EA 2	On-Site Renewable Energy (1-3 pts.)	*(>$150K)*

MR: Materials and Resources

		$ Impact
MR 1.1	Building Re-Use (Maintain 75% of existing walls, floors, roofs)	*($0)*
MR 1.2	Building Re-Use (Maintain 95% of existing walls, floors, roofs)	*($0)*
MR 2.1	Construction Waste Management (50% Diverted)	*(<$50K)*
MR 2.2	Construction Waste Management (75% Diverted)	*($0)*
MR 3.1	Materials Re-Use (5%)	*(<$50K)*
MR 3.2	Materials Re-Use (10%)	*(<$50K)*
MR 4.1	Recycled Content (10%)	*($0)*
MR 4.2	Recycled Content (20%)	*($50K - $150K)*
MR 5.1	Regional Materials (10% Processed, Manufactured Regionally)	*($50K - $150K)*
MR 5.2	Regional Materials (20% Processed, Manufactured Regionally)	*($0)*

EQ: Indoor Environmental Quality

		$ Impact
EQ 3.1	Construction IAQ Management Plan: During Construction	(<$50K)
EQ 4.1	Low-Emitting Materials: Adhesives & Sealants	($0)
EQ 4.2	Low-Emitting Materials: Paints & Coatings	($0)
EQ 5	Indoor Chemical & Pollutant Source Control	(<$50K)
EQ 6.2	Controllability of Systems: Thermal Comfort	Mandate
EQ 7.1	Thermal Comfort: Design	Mandate
EQ 8.1	Daylight & Views: Daylight 75% of Spaces	($0)
EQ 8.2	Daylight & Views: Daylight 90% of Spaces	($0)

ID: Innovation & Design Process

		$ Impact
ID 1.1-1.4	Innovation in Design (1-4 pts.)	(<$50K)

As was the case with the number of credits in each section pertaining to the exterior skin of a project, the Energy and Atmosphere section requires the most premium dollars to achieve. With the first costs escalating above $150,000 it will be more difficult for owners to justify pursuing these credits. Optimizing energy performance credits can be difficult to achieve depending on whether the efficiency needs to be increased by 10% or 50%. According to the individual credit simulations in the Appendix C of the GSA: Cost Study, achieving 5 credit points (25% cost saving) can be achieved at a premium cost of approximately 0.8% of the overall project cost. However, this value escalates to 3.07% if the goal is to achieve 10 credit points (50% cost savings). The large portion of the costs associated with the additional costs is the HVAC and electrical systems which consist of two-thirds of the overall cost. Façade re-design accounts for only 10% of the premium costs while the additional funds are used for design contingencies, phasing premiums, general conditions, and contractor profit.

The remainder of the sustainable credits relating to exterior skin are relatively inexpensive (less than $50,000) or do not require premium costs at all. This can be attributed to the increasing knowledge of green building construction and increased awareness of recycling and waste management, safer materials, and even government mandates.

Indoor environmental quality is extremely important for health care facilities to keep patients comfortable. These health aspects are fueling major concerns in the health care construction industry which is leading to the development of guides to help designers and construction managers in this challenging field. Facility managers can clearly see that they can achieve these healthy aspects at minimal costs which will add value to the proposed project. GSA has even deemed some of the indoor environmental quality credits as mandatory to all new government facilities to be constructed.

Many of the indoor environmental quality concerns can be addressed with simple space planning techniques and architectural features which may be determined during conceptual designs. Day-lighting concerns can be alleviated by minimizing the number of enclosed spaces at the perimeter of the building and allow for large open work areas. Even furniture decisions can make an impact by selecting low-height furniture to allow light to travel throughout the various spaces. However, these easy techniques may not be applicable on large hospitals or other health-care facilities where patients need privacy and often isolation.

The Green Guide for Health-Care Construction expands on the day-lighting credits of the LEED-NC Version 2.2. Day-lighting aspects are now worth 5 points in lieu of the 2 credit points in the LEED version. This demonstrates how important natural light is for health care facilities to promote positive psychological and physical health environments. The essence of this new system employs certain percentages of the overall floor plan being located within 15' of the building perimeter. Architects and planners can use these percentages to provide insight into how to achieve properly day-light areas without extensive rework with lighting designers and changes to the original floor plans. This can alleviate cost premiums due to complex designs of the curtain wall and exterior systems which often occur to try to allow natural light into spaces.

Criteria percent of total floor area within 15' of perimeter window by total size					
Point Total	**Below 20,000 sf**	**20,000 to 30,000 sf**	**30,000 to 40,000 sf**	**40,000 to 50,000 sf**	**Above 50,000 sf**
8.1a - 1 point total	48%	44%	40%	37%	34%
8.1b - 2 points total	56%	51%	46%	42%	38%
8.1c - 3 points total	64%	58%	52%	47%	42%

From GGHC Pilot V.2

Proper day-lighting also allows for decreases in energy costs by utilizing solar energy for heat during the winter as well as lessen the heat given off by artificial lights during the summer. Utilizing natural lighting techniques and strategies has been estimated to reduce lighting energy use by 50 to 80% and decrease HVAC loads by 10 to 20%. It is essential for the building envelope to be closely coordinated with the mechanical system designs to take full advantage of these loads to decrease the sizes of HVAC components and relevant costs. The glass and glazing utilized for the exterior skin needs to have the correct design properties in reflectance, transmittance, and UV protection as well as construction issues such as properly caulked connections and joints to ensure the savings in energy consumption and day-lighting aspects are at the estimated levels.

Building Envelope and the Center for Health Research and Rural Advocacy

Since the façade selection is critical for proper utilization of LEED credits and associated costs, it should be taken into account for every project. The Center for Health Research and Rural Advocacy should take careful considerations in selecting the building envelope design and construction. As this is the first LEED certification the Geisinger Health System is pursuing, careful decisions where made when selecting which criteria to achieve. Geisinger Facilities project manager is pursuing 26 of the 69 credits for a LEED sustainable facility. Please reference the figure on the following page which outlines the credits to be garnered.

The building envelope selected for the Center for Health Research and Rural Advocacy is influential in the success of the LEED certification. With cost premiums upwards of $150,000, it is essential that the exterior skin design is closely coordinated with construction processes. Many of these cost premiums were offset by design criteria, locally accessible materials, and proper management. Figure R.1 outlines the challenges associated with the LEED credits and management steps taken.

LEED Credit	Center for Health Research and Rural Adocacy Checklist	Credit Pursuit		Envelope Considerations		Premium Costs
SS: Site Selection		Yes	No	Yes	No	
SS 4.1	Public Transportation Access	x			x	$0
SS 4.2	Alternative Transportation: Bicycle rack coverage	x			x	$0
SS 5.2	Maximize Open Space	x			x	$0
SS 6.1	Stormwater Design: Quantity Control	x			x	$0
SS 6.2	Stormwater Design: Quality Control	x			x	$0
SS 7.2	Heat Island Effect: Roof	x		x		$0
WE: Water Efficiency						
WE 1.1	Water Efficient Landscaping (50%)	x			x	$0
WE 3.1	Water Use Reduction (20%)	x			x	$0
WE 3.2	Water Use Reduction (30%)	x			x	$0
EA: Energy and Atmosphere						
EA 1	Optimize Energy Performance	x (2)		x		$50,000
EA 5	Measurement and Verification	x			x	$0
MR: Materials and Resources						
MR 1.3	Building Re-Use (Maintain 50% of non-structural interior elements)	x			x	$0
MR 2.1	Construction Waste Management (50% Diverted)	x			x	$0
MR 4.1	Recycled Content (10%)	x		x		$0
MR 5.1	Regional Materials (10% Processed, Manufactured Regionally)	x		x		$50,000-$150,000
MR 5.2	Regional Materials (20% Processed, Manufactured Regionally)	x		x		$0
EQ: Indoor Environmental Quality						
EQ 4.1	Low-Emitting Materials: Adhesives & Sealants	x		x		$0
EQ 4.2	Low-Emitting Materials: Paints & Coatings	x		x		$0
EQ 4.3	Low-Emitting Materials: Carpet Systems	x			x	$0
EQ 6.1	Controllability of Systems: Lighting	x			x	$0
EQ 6.2	Controllability of Systems: Thermal Comfort	x		x		$0
EQ 7.1	Thermal Comfort: Design	x		x		$0
EQ 7.2	Thermal Comfort: Verification	x		x		$0
ID: Innovation & Design Process						
ID 2	LEED Accredited Professional	x			x	$50,000
	Totals	**26 Credits**		**10**	**16**	**$150,000 - $250,000**

Credit Challenges and Control Methods		
Credit	**Credit Description**	**Control Method**
SS 7.2	Heat Island Effect: Roof	Green/Garden Roof Above Auditorium
EA 1	Optimize Energy Performance	Incorporate MEP Design w/ Weis Research Center Curtain Wall Utilizes Insulating Glass to Minimize Heat Loss
MR 4.1	Recycled Content (10%)	Only Pursue 10% Since Recycling Costs Expensive in Danville
MR 5.1	Regional Materials (10%)	Extruded Aluminum Readily Available
MR 5.2	Regional Materials (20%)	Architectural Pre-cast Contractor Within 10 Mile Radius
EQ 4.1	Low-Emitting Materials: Adhesives & Sealants	Design Selection
EQ 4.2	Low-Emitting Materials: Paints & Coatings	Design Selection
EQ 6.2	Controllability of Systems: Thermal Comfort	Radiant Heaters At Expansive Areas of Glass
EQ 7.1	Thermal Comfort: Design	Minimize Glare With Spandrel Glass in Curtain Wall
EQ 7.2	Thermal Comfort: Verification	Inc. With Design

Figure R.1 Credit Challenges and Control Methods

As seen in the above figure, there are many ways that a management team can address the additional costs associated with LEED certification. These range from subcontractor selection to simple decisions based on adding value to the project. For example, the garden roof is used to combat the heat island effect, but since it is incorporated as a garden roof it can be a pleasant place for health care workers and patients to frequent. Another interesting decision was the pursuit of only 10% recycled content in lieu of the 20% for two credits. This is due to the high costs of refuse removal and tipping fees, and by only achieving 10% the workers can recycle the easy and cheap materials and not worry about the difficult ones.

Façade Decision Making Guide

After exploring the implications the building envelope design and construction has on LEED credits and their respective costs, it is easy to see a decision making framework needs to be addressed. Different factors and choices need to be made during certain stages of a projects development. This can range from design development decisions, to 100% contract documents, to project close-out. These choices need to be conducted between multiple entities including but not limited to construction managers, architects, designers, subcontractors, and owners. Flow of information is critical for a successful project and this aspect is even more critical in LEED certified facilities. The guideline can be utilized by project participants to gauge what decisions need to be made regarding façade selection at certain design and construction milestones.

A sample of the guideline is shown below with the remainder in the format of a newsletter in Appendix A.1

Façade Decision Making Guide

Project Timeline	Issue	Envelope & LEED Implications
Conceptual Design		
Owner & Architect	Building Orientation	Numerous areas of glazing facing west will have large solar heating loads
	Footprint	% of floor area within 15' of perimeter promotes healthy environment and credits towards GGHC
	Mix Use Area	Combine green and garden roof types for healthy environment and LEED credits
Building System Design		
Owner, Architect, Engineers	Design Iterations	Promote iterations so other systems utilize curtain wall advantages (mechanical and day light)
	Material Selection	Skin materials designated by local conditions and re-used materials
	Energy Savings	Incorporate energy consumption analyses to ensure premium costs are recovered over time
Complete Construction Documents		
Owner, Architect, Eng, CM	Value Engineering	Ask each bidding CM for value engineering ideas, save money and healthier building
	Budget	Consult GSA: Cost Study for determining if credits require premium costs
Pre-Construction		
Architect, Eng., CM, Subcontractors	Subcontractor Selection	Regionally manufactured and readily available materials key to control cost and schedule
	Value Engineering Implimentation	Implement value adding ideas for building envelope, credit points for innovation in design
	System Interfaces	Coordinate shop drawings of different skin systems at interfaces of the systems
Construction		
CM, Subcontractors	Waste Management	Recycle envelope materials which are cheap and easy to recycle
	Indoor Air Quality Mgmt Plan	Early finish of building enclosure minimizes possible contamination of indoor air quality
Project Closeout		
Owner, Architect, Eng, CM	LEED Accredite Professional	Ensures proper verification and paperwork process
Subcontractors	Verification of Energy Efficiency	Engage in process to guarantee energy savings for owner, worth an additional LEED credit

Conclusion

After exploring the various dimensions and roles the building exterior plays in health care and sustainable designs, it is easy to see the implications this system has on the success of LEED certified projects. Not only is the façade the barrier between the harsh exterior world and the inner confines of the comfortable health care facility, but it requires thought and consideration for all the design elements. The building envelope affects mechanical loads and system efficiency, structural integrity, day lighting requirements, as well as construction sequencing and building enclosure.

As was seen during the investigation, health care facilities can greatly be affected by the design of the envelope system. Hospitals often operate 24 hours a day the entire year and a rather small decrease in energy efficiency correlates to large savings in operation costs. Patient and worker physical and psychological health is affected by the amounts of natural light and thermal comfort.

The largest LEED aspect which is affected by the façade design is the Energy and Atmosphere criterion, with 45% of the credits residing in the EA section. It is extremely critical to recognize the cost premiums associated with these credits as outlined by the GSA: Cost Study. These costs can be neutralized during conceptual design of the facility by closely coordinating the exterior skin design with the MEP systems and the subsequent savings in energy costs. Health care facilities can take advantage of the Indoor Environmental Quality credits at relevantly low premium costs. These credits which affect day-light and thermal comfort can add significant value to the facility at minimal costs. If the designs are incorporated with energy efficiency of the building envelope, these credits can be achieved simultaneously with the Energy and Atmosphere credits.

LEED certification may be achieved on any construction project with cautious and diligent attention to decision making during the entire construction process. This type of approach is guaranteed to have success with all the resources that are now available.

SPRING 2006

Analysis: Prefabrication of Curtain Wall System

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Construction Management

Dr. David Riley

Analysis: Prefabrication of Curtain Wall System

Introduction

With new building construction designs becoming more complex and unorthodox, the way construction managers and subcontractors sequence and erect building envelopes will need to adapt. The days of square facades consisting of primarily masonry units and windows are a thing of the past. With the implementation of CAD systems and sophisticated cutting applications for steel members utilized on such projects as Walt Disney Concert Hall, designs which were once thought impossible can now be made easily and efficiently at locations not on the project site. The Walt Disney Concert Hall project could not have been completed without the use of integrated CAD systems for the designers and contractors. As is seen in this example, current building skins can have an array of materials, elevations, and curvatures. These systems can range from architectural pre-cast, full glass and glazing, metal panels, and even outlandish materials such as wood blades at the New Census Bureau Headquarters. Since designers and owners always desire their new facilities to stand alone, especially in commercial construction, different and unique skin systems are being developed everyday.

Figure 1.1: Walt Disney Concert Hall, California

These often unique and challenging systems require thorough planning and sequencing of the different trades working on the façade, as well as deliveries, crane locations, safety, and even productivity concerns. As with any other building system under construction, unforeseen issues equate to losses in time, money, and worker morale. There are many new problems which were not even considered previously. If these concerns are not properly addressed and corrected the project may end up costing more than originally budgeted. Some examples include:

- Radius point of curved curtain walls is often located outside of the project site.

- Urban construction where space needed to erect these systems is limited.
- Shakeout areas for large members prior to erection.
- Curvatures of support members can not be achieved by on site means, advanced equipment is a requirement.
- New designs require field tests to ensure compliance with codes and regulations.
- Many trades working on the façade require large workspaces and proper sequencing to prevent stacking, re-work, and crane usage.

To alleviate many of these problems, construction managers are often employing prefabricated components to the façade systems. These can range from window systems, to pre-cast concrete, to masonry units. Panels or units are constructed off-site at warehouses, plants, or facilities either rented or owned by the subcontractors. The capabilities of the facilities can range from production of complete panels, or simply fabricated the components which could not be erected on site. Many subcontractors are embracing this change in philosophy and opening permanent prefabrication facilities to attract new and rewarding opportunities. One company which is using utilizing this new approach is Harmon Inc., and their work will be referenced numerously in this analysis. Figures 1.2 and 1.3 are from Harmon's prefabrication facility located in Glen Burnie, Maryland.

Figure 1.2: Component Delivery

Figure 1.3: Unitizing Stations

This enormous 100,000 square foot facility can handle prefabricated efforts from delivery of materials to final shipment of unitized pieces. Located in close proximity to the management headquarters, project engineers and managers can quickly and easily check production of components and ensure proper manufacturing techniques. Figure 1.4 shows some of the positive and negative aspects of a prefabricated approach to envelope construction.

Figure 1.4: Advantages vs. Disadvantages of Prefabricated Systems

	Advantages	*Disadvantages*
Productivity	Warehouse facilities can operate during inclimate weather and winters Workers are more productive in controlled environment Components fabricated more efficiently, does not require cutting or measuring on-site	Double handling of materials from material manufacturers to project site
Labor Cost	Warehouse workers have lower wages than skilled curtain wall workers on-site Skilled curtain wall employees are utilized only for difficult construction processes	May require more labor in order to fully operate the warehouse facility (i.e. material handling) Additional engineering and management costs of project to properly manage facility operations Associated design costs of each component for fabrication
Material Cost	Buy in bulk and fabricate appropriate lengths in warehouse, no cutting costs from manufacturer Deliveries to warehouse may be large and not require small incremental shipments to jobsite	Related costs of double handling materials from manufacturer to prefab facility to site
Equipment Cost	Mobilization costs of specialized equipment such as cutters, adhesive devices, etc. Possibility to buy equipment in lieu of paying high rental costs for each project	Costs of crane or large capacity lifting mechanisms (if not provided by GC/CM) Hire expertise to maintain equipment if purchased
Quality	Customer can tour facility and be guaranteed of the final product, not just a mock-up Closely monitor unitized components for quality issues Numerous tests can be completed prior to full scale installation Closed environment eliminates chaos of erection on-site and possible mistakes	Erected by less qualified labor under management supervision, must be closely monitored Small changes due to construction issues are difficult to manage once in production Finished panels may be damaged or destroyed during transportation

Advantages	***Disadvantages***
Schedule	***Schedule***
Accelerate schedule by starting production before erection begins	Small delays in warehouse production can cause idle workers at the jobsite
Erection on-site much quicker with unitized panels, building enclosed faster	Changes of on-site systems may cause production changes
Minimizes on-site field test, eliminates wasted days	
Safety	***Safety***
Warehouse activites may be closely monitored by management team	Dangers associated with using a crane for erection of panels
Hazardous activities may be seperated from other labor forces	Must have separate safety programs for warehouse facility and jobsite
Ability to enforce all safety issues, does not have to worry about other workers	
Sustainability	***Sustainability***
Recycle materials back to manufacturer directly, decrease costs	Additional energy consumption of prefabrication facility
Minimize environmental impact at jobsite	Double handling of material by trucks or other methods of transportation

As is seen in the previous figure, there are numerous advantages and disadvantages to imposing this aspect of construction. There are an assortment of benefits in areas such as cost, safety, schedule, logistics, and many others; however, the decision is still one that needs to be carefully considered and evaluated. The focus of this analysis will be to utilize a prefabricated envelope system for the aluminum curtain wall construction of the Center for Health Research and Rural Advocacy. The analysis will include a description of the unitized panel and prefabrication facility, and address impacts on the schedule and cost estimates. Along with these issues, the structural integrity of the façade retention systems will be checked to ensure adequate support to the increased mass of the system and a mechanical analysis of increasing the R-value of the building skin.

Background

The curtain wall for the Center for Health Research and Rural Advocacy is the defining characteristic of the North and East facades. In comparison to the other envelope system employed on the project, this aluminum curtain wall is the most expensive and has the longest schedule duration. Construction of highly glazed curtain wall systems is very labor intensive, this aspect allows for the possibility of some savings in a prefabricated approach. Figures 1.5 and 1.6 display the costs and schedules of the different exterior skin systems.

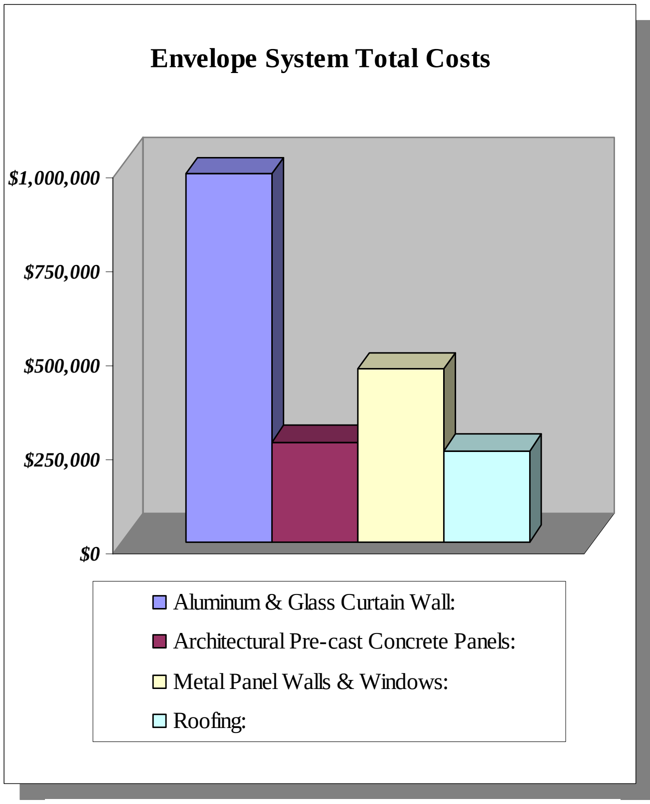


Figure 1.5: System Costs

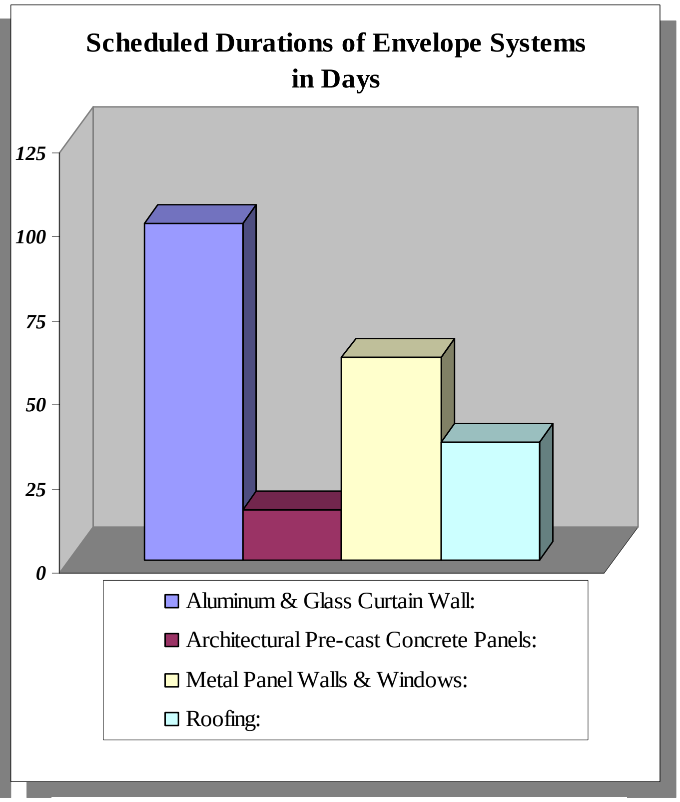


Figure 1.6: Construction Durations

Please reference Appendix B.1 for specific system costs of material and labor. The main feature of this expansive glazing is it allows for large amounts of natural light to inhabit the structure and promote a healthy work environment. One-eighth inch thick extruded aluminum 6063-T5 is the main component of the framing system with common dimensions of 2-1/2” x 7-1/2”. The sizing is of fairly common sizing so as to not require new dyes for the manufacturer. Costs of unique dye molds can be expensive and require a long submittal verification process. Glazing consists of insulating glass of ¼” float heat strengthened glass exterior lite; ½” air space, and ¼” clear float glass interior lite. Spandrel glass consists of ¼” tinted heat strength glazing with reflective coating surface.

Since the façade curves and arcs along the Centre Street elevation, the construction manager has decided that it will be too difficult to prefabricate components. The conception of prefabrication being utilized only for highly repeatable units has mainly fueled this decision. Site logistics is also an extremely challenging aspect and additional crane usage may have a negative impact on the unitized effort. Once the structural steel and floor slabs are complete, maneuvering the boom around the Weis Research and Geisinger Hospital will be challenging and hazardous. These issues and more will be discussed in the impact discussion of the analysis.

Prefabricated Units

When developing a unitized system, the contractor must employ engineering resources and additional planning of the system under construction. These extra resources are used to create more specific tools and techniques for sequencing, erection, and quality of the desired components. As is typical for commercial construction projects, the subcontractor creates shop drawings for submittal and on-site erection purposes. These shop drawings are expanded upon for a unitized system and morph into highly specific production sheets as would be seen in a manufacturing facility. Each window or system is tagged with its own individual number for easy reference and labeling. The following figure demonstrates which entities create the additional tools utilized during a prefabricated approach.

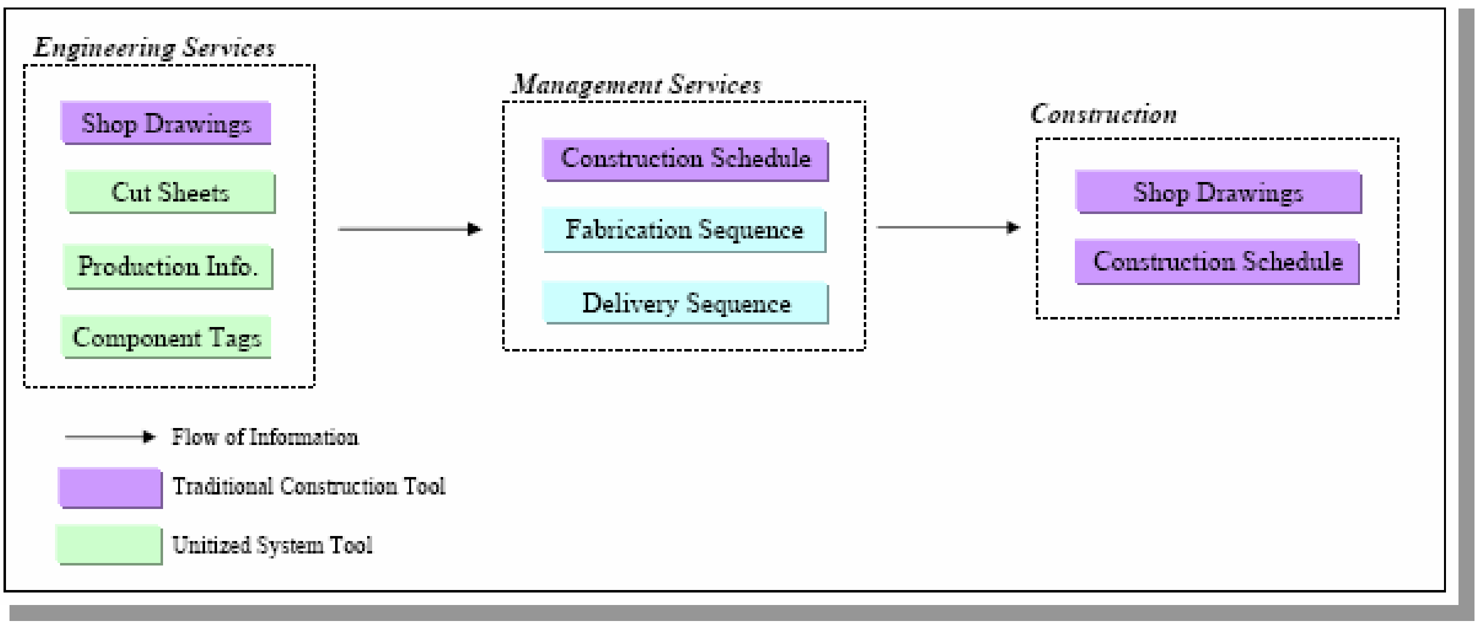


Figure 1.7: Tools Utilized for Typical Construction Projects and Unitized Systems

Harmon Inc. utilizes all of these additional tools to ensure a smooth production and erection of the façade system. The subsequent figures are examples of documentation for one of their projects which is currently under production.

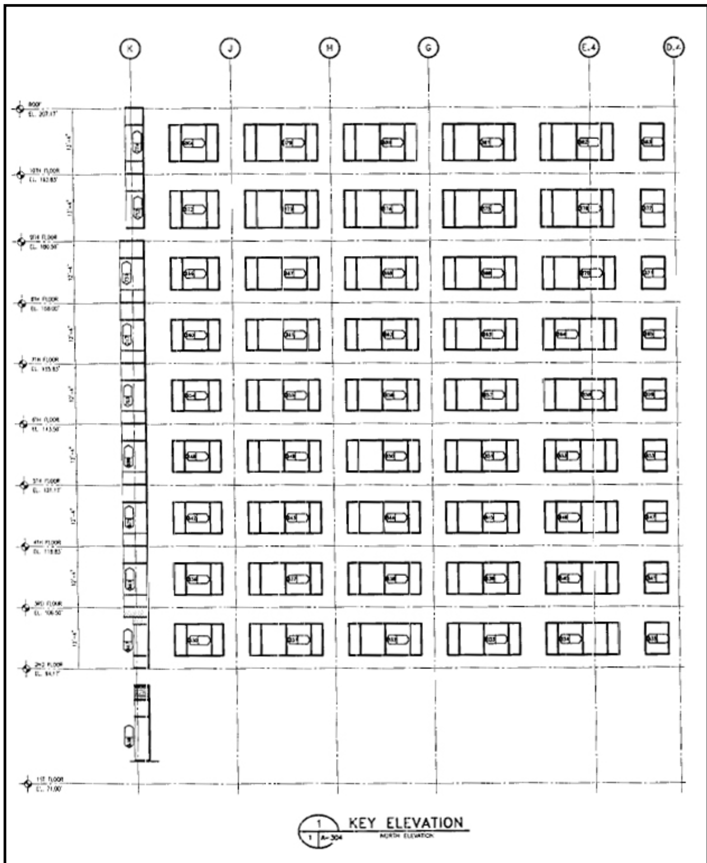


Figure 1.8: Key Elevation with Component Tags

This elevation has individual tags for each window component system to be manufactured in the prefabrication facility. Each tag is related to a specific production sheet of that component. Figure 1.9 shows an example of the individual window section and elevation referenced in the overall plan. Each tag also has a quantity related for production so that the components may be fabricated all at once. This minimizes having to change machinery and allows for a more lean type process. Figure 1.10 is an interface elevation for a unit. This section may be referenced numerous times throughout cut sheets.

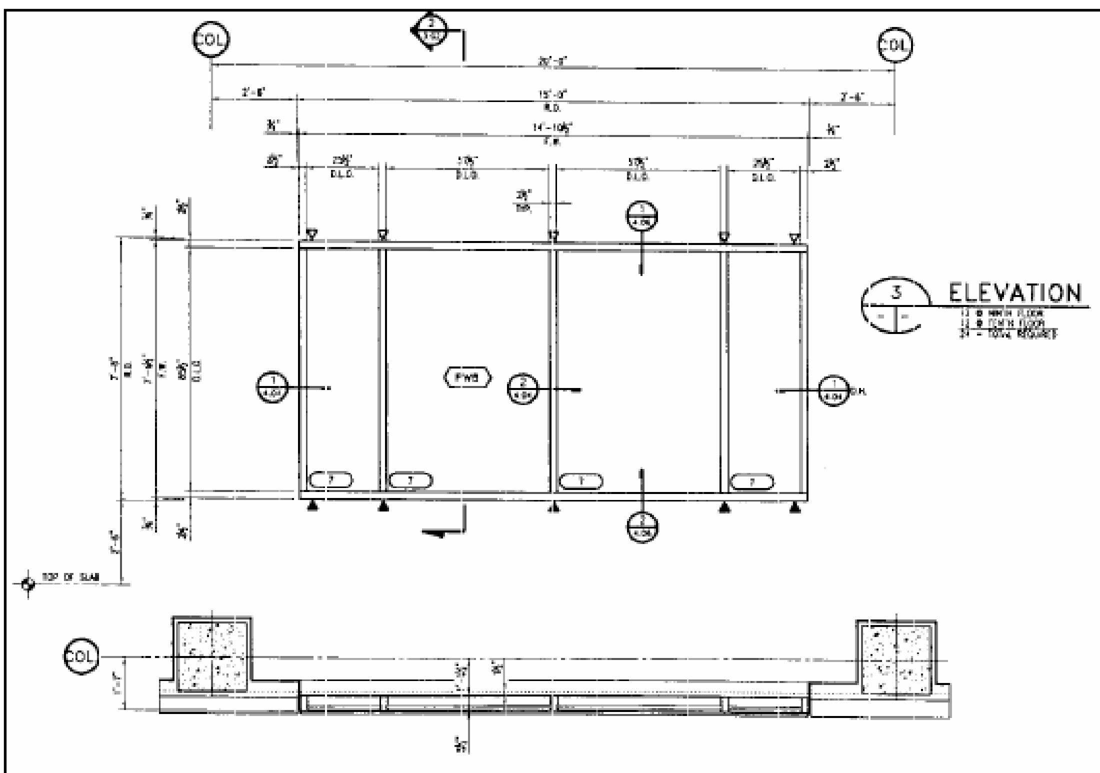


Figure 1.9: Referenced Panel Tag from Key Elevation

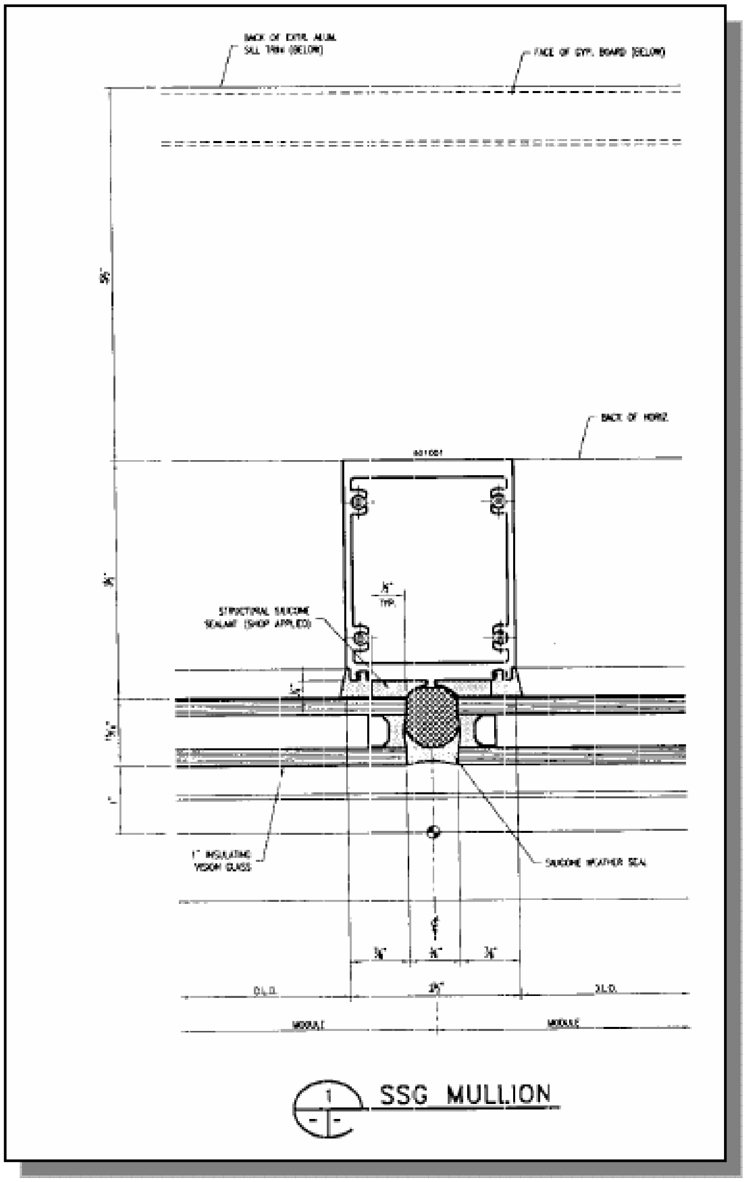


Figure 1.10: Referenced Section Detail from Cut Sheets

Using this technique for the Center for Health Research and Rural Advocacy, the 13,000 square foot aluminum curtain wall system will be broken up into manageable size elements. The design of the mullions is included in each of the panels to eliminate the framing system entirely. One extremely important aspect of a unitized construction is the usage of silicone to act as the adhesive agent and water tight component. The last thing an owner wants out of the envelope system is leakage, so applying the silicone in a controlled environment allows for proper sealing and hold. Silicone application requires testing of the batch through a sticky test. Silicone is applied to the material in a strip and allowed to set for an extended period of time. Once the silicone has hardened, it is removed and compared to the required forces. This testing is completed more easily in the fabrication environment than on-site.

Figure 1.11 displays a typical unitized component for the Center for Health Research and Rural Advocacy project. This would be one individual unit tag with approximately eighty repeated units. Additional panels would be engineered for corner locations, elevation changes, and the café atrium.

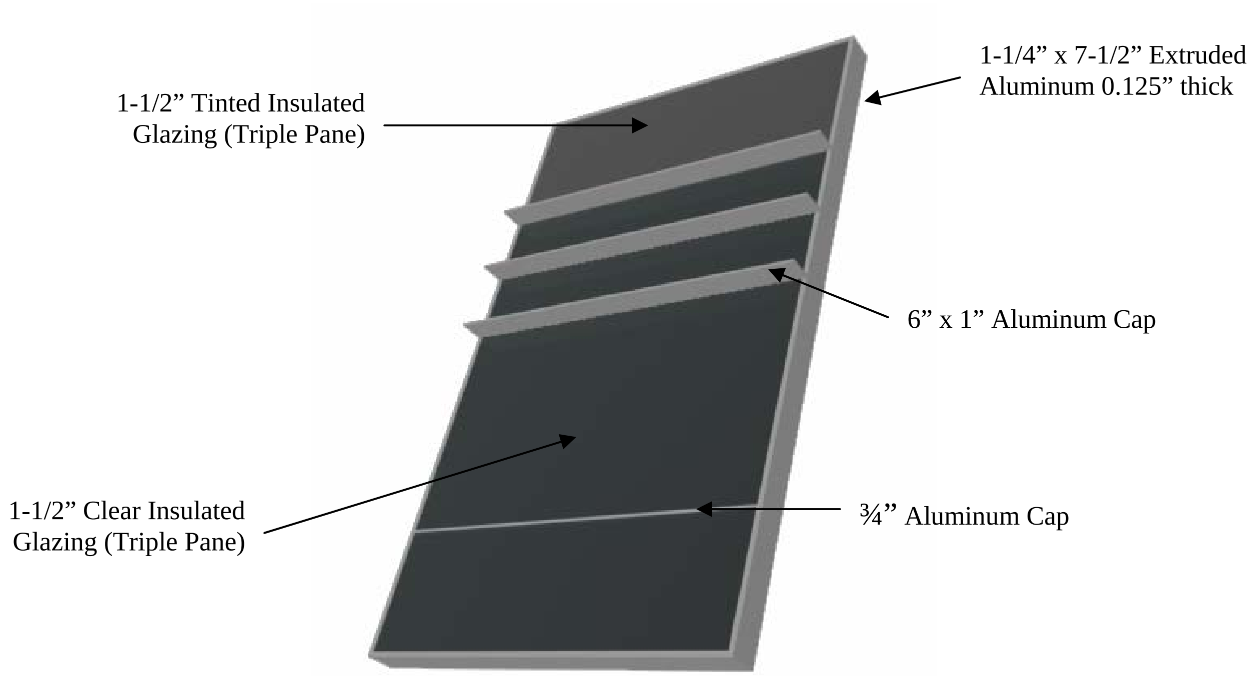


Figure 1.11: Typical Unitized Panel for Aluminum Curtain Wall

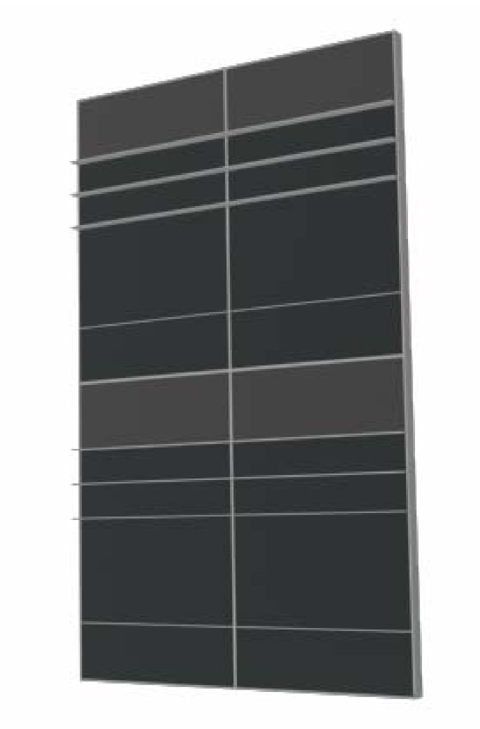


Figure 1.12: Finished Panel Arrangement

The 13' by 8' typical unit above is a repeated component throughout the project; however, as discussed earlier it does not represent all of the curtain wall pieces. This unit only accounts for 80 panels on the project, with an addition 38 panels required for corners, lobby and vestibule areas, and curved elevation locations. Since the panel consists of 70% of the curtain wall area, small savings in production and material costs can add up significantly.

The figure to the left is one of a string of panels erected together. This two story façade encompasses the south elevation and the main entrance lobby to the north. Spandrel glass at the top of each panel is tinted to minimize distracting glares from the midday sun. The clear insulated glass below provides a comforting view for the employees from their open air offices. Also noticeable in Figure 1.12 is the addition of triple pane insulated and tinted glazing. Triple pane glass is extremely heaving and difficult for stick-built installation; however, it has numerous thermal advantages which will be studied later in this analysis. Since the erection of these panels is in a fabrication facility where proper equipment may be utilized, the addition of the triple pane glass can be easily managed. The structural integrity of the entire system will also be checked to ensure this does not cause unwanted deflection or fracture of structural components.

Once a deliverable quantity of the prefabricated units is complete, they will be made ready for transportation. Transportation is most often on flatbed trucks with custom racks built to hold the unitized panels. Flat panels can be delivered prone, while corner and highly detailed panels will be delivered up-right. Of utmost importance is the proper sequencing of the panels on the trucks. This ensures that the crane will not need to unload panels in shakeout areas prior to erection. The crane can simply lift the panels into position directly off the flat bed.

Figure 1.13: Flat Bed Delivery Staging

Schedule Impact

One main advantage of the unitized system is the minimizing of on-site erection time. This has many benefits such as enclosing the facility faster from the weather, which may be a significant issue in areas of Pennsylvania and the Northeast. For crowded and difficult logistical sites, contractors can benefit from smaller crew sizes during erection of the curtain wall system and achieve similar if not better schedule results.

The project schedule developed by Geisinger Facilities for the curtain wall construction is highly detailed. Tasks are broken up between column lines with durations related to the square footage of glazing. This is an efficient way to separate out the activities since all four elevations are extremely diverse and would be difficult to assess if the tasks are on schedule. Aluminum framing takes approximately seventy days with an additional thirty days for installation of the glazing and sealants. With the curtain wall construction stipulating when the facility is permanently enclosed, it is essential these activities are completed in a timely manner. Drywall and additional interior work may begin as soon as the façade is completed. Please reference the schedule created for the CHRRA project on the next page.

The current curtain wall construction schedule has some interesting aspects. Five days are needed to field test the system to ensure compliance with codes and regulations. The majority of this field testing may be completed at an off-site testing facility saving a majority of those days. There are numerous companies which can perform the testing services at their facilities. One local company facility is Architectural Testing, Inc. located in York, Pennsylvania. This is a mere 100 miles from the subcontractor Kawneer's plant facility in Bloomsburg, Pennsylvania. A unitized component could be fabricated in Bloomsburg and shipped to York relatively inexpensively

Additionally, the glazing and sealant construction starts when framing is finished. If the project schedule becomes condensed, this aspect could easily be accelerated by adding another crew to perform the glass and glazing erection when framing moves to another column line. This would save an additional thirty days to the schedule and building enclosure milestone.

The schedule following the actual sequence schedule has been developed for the CHRRA project if a unitized construction approach was taken. These are activities which occur on site and do not include warehouse facility planning and sequencing which is completed by the contractor and not governed by the construction management team. Erection sequencing has been determined according to case study projects provided by Harmon Inc. On-site workforce includes one crane operator, three ironworkers, and two sealant installers. This labor crew can install 11 unitized panels in one day.

Since erection of the unitized components will be governed by the number of panels between column lines, it will be significantly easier to determine if the schedule is being met. The schedule of on-site activities has been reduced from almost 100 days to a little less than 13 days. Granted this number is misleading because many of those remaining 87 days will be spent in the fabrication facility, it however still displays the scheduling advantage of such a program. This would allow the construction manager to accelerate the schedule by 30 days, since the metal panel erection will still require 70 on-site days. A one month saving on the project duration can save a hefty amount of general conditions costs. Deliveries are easily organized by days with trucks comprised of 10 or 11 panels. Employing a three flat bed rotation, one flat bed can be fully loaded and awaiting delivery to site, while another is being loaded with panels, and finally the other is being unloaded at the project site. This ensures that the crew on-site will always have a delivery of panels ready for at least one day in advance which may help alleviate any unforeseen accidents.

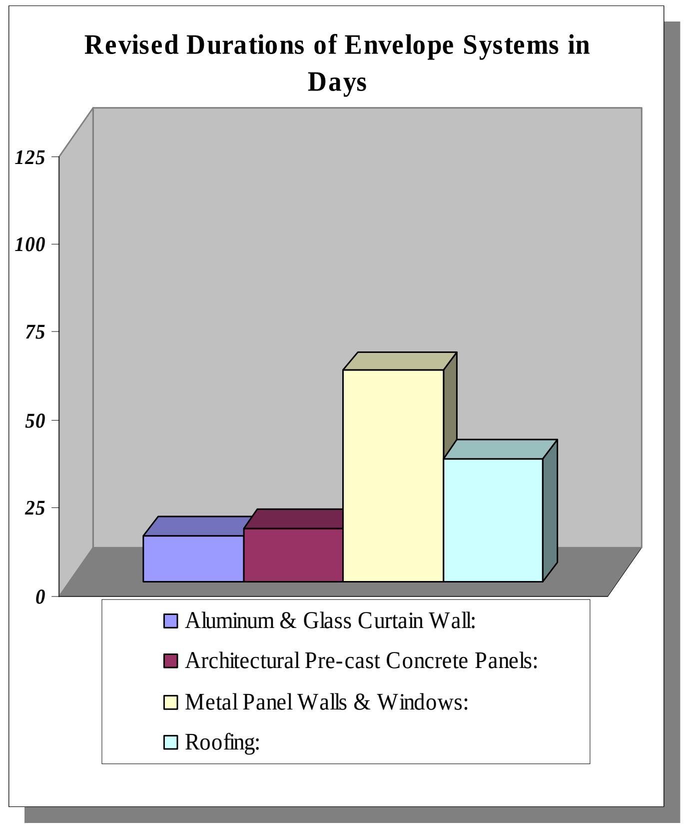


Figure 1.14: Revised Durations

The field test can also be reduced to one day since many of the testing procedures have already been conducted at a third party testing facility. Single day tests will be much less sophisticated and can be completed without disturbing the panel erection operation.

Cost Impact

Utilizing a prefabricated approach for curtain wall construction has some monetary advantages, especially if the activity is on the critical path. By minimizing on-site erection time for the aluminum curtain wall construction, the activity is no longer on the critical path. The metal panel walls and windows, which begin construction at the same time as the aluminum curtain wall, now becomes the controlling activity on the schedule. Since the final roofing tie-ins where scheduled to follow aluminum glazing, the tie-ins can now begin upon completion of the metal panel system. This simple recalculation of the critical path will save forty days on the project which is of considerable monetary value for general condition costs.

There are some additional costs associated with the unitized approach if the selected contractor does not already have the infrastructure set up to perform a job in this manner. Subcontractors need to be informed of this type of delivery prior to bidding to make sure that all parties are bidding on the same construction process. According to interviews with individuals at Harmon, Inc., the first costs of setting up a prefabrication facility can be made up quickly and easily in schedule and manpower savings. Harmon's preferred delivery method has shifted to almost 95% unitized systems manufactured off-site. Since Kawneer, the aluminum curtain wall subcontractor, was selected based on a stick-built system, the related costs of setting up a prefabricated system are going to be explored. Please reference the new budget costs for the Center for Health Research and Rural Advocacy on the following page.
Note: Triple pane glass for the unitized system is not included in this sheet. It is to be compared in a later section.

As is seen in the revised budget for the curtain wall, there is a savings of approximately $100,000 in manpower costs associated with using cheaper labor in a warehouse environment as opposed to skilled labor on-site. The skilled laborers are only needed for on-site erection of the panels which takes 13 days, which is much less than the originally 100 days needed. Costs linked with starting a prefabrication facility for a single job are included in the rental section and additional labor costs in the revised budget. These costs include renting a large facility which can accept material deliveries and have ample space for lay-down of completed panels before shipment. Since the on-site erection takes 13 days and the warehouse facility requires 40 days to unitize. These costs required to start the manufacturing facility equal the savings garnered through wage rates.

Revised Budget for Aluminum Curtain Wall Construction

Center for Health Research and Rural Advocacy
Danville, Pennsylvania

Item No.	Item Description	Unit	Total Units	Unit Cost	Total Cost	Original Budget	Deviation	Notes
Material								
M001	2-1/2" x 7-1/2" Extruded Aluminum 6063-T5 .125" Thic	LF	4280	$16	$68,480	$68,480	$0	
M002	5/8" Insulating & Spandrel Glazing	SF	13,750	$36	$495,000	$495,000	$0	
M003	Column Covers	EA	6	$2,700	$16,200	$16,200	$0	
M004	Aluminum Doors & Glazing	EA	8	$5,000	$40,000	$40,000	$0	
				Total	**$619,680**	$619,680	$0	
Labor								
L001	(6) Skilled Laborers for On-Site Construction ($48/Hr)	Days	15	$384	$34,560	$261,120	$226,560	(10) Laborers - 70 Days; (4) Laboreres - 30 Days
L002	(1) Superintendent On-Site ($55/Hr)	Days	20	$440	$8,800	$44,000	$35,200	(1) Superintendent - 100 Days
L003	(1) Project Manager ($60/Hr)	Days	120	$480	$57,600	$57,600	$0	
L004	(1) Warehouse Manager ($55/Hr)	Days	120	$440	$52,800	$0	($52,800)	Not Originally in Budget
L005	(8) Assembly Laborers for Warehouse ($42/Hr)	Days	40	$336	$107,520	$0	($107,520)	Not Originally in Budget
	*Hourly Rates from ISEC Incorporated; New Census Bureau Project			**Total**	**$261,280**	**$362,720**	**$101,440**	
Rentals: Equipment and Facility								
E001	Additional Crane Rental	Month	1	$12,200	$12,200	$0	($12,200)	
E002	Forklift	Month	3	$700	$2,100	$2,600	$500	Pneumatic Tire cheaper than All-Terrain
E003	Warehouse Rental (3 Months @ $1.1/SF)	SF	20,000	$1.5	$90,000	$0	($90,000)	
E004	Additional Equipment Rental Contingency	EA	1	$10,000	$30,000	$0	($30,000)	
	*From General Conditions Estimate in Existing Conditions			**Total**	**$104,300**	**$2,600**	**($101,700)**	
General Condition Savings ($37,456 per Month)								
GC001	General Condition Savings for Revised Schedule	Weeks	8	($9,364)	($74,912)	$0	$74,912	
	*From General Conditions Estimate in Existing Conditions			**Total**	**($74,912)**	**$0**	**$74,912**	
				Grand Total	**$910,348**	**$985,000**	**$74,652**	Cost savings using unitized construction method

The Center for Health Research and Rural Advocacy will use 130 unitized panels for the aluminum curtain wall which is about the breakeven point for a unitized façade. More units would increase the savings and fewer units would make the option more expensive to implement. For Geisinger Facilities, the major monetary funds which are saved using this prefabricated approach are in the general conditions costs accrued over the life of a project. By being able to delete 40 days from the critical path, this equates into two months of general conditions cost, including items such as temporary utilities and site facilities.

Savings from using a unitized system would have been even larger if subcontractors would have bid on this approach. This would ensure that the contracted entity could perform a unitized system at a competitive cost without the additional facility setup expenses. Without having to pay for change orders in regards to the manufacturing plant, the savings to the Geisinger Health System would have been in the area of $175,000, or a 1% savings on the project.

Mechanical Analysis of Extra Glazing

An additional area to differentiate between the two construction approaches is the mechanical savings of utilizing a triple-pane glass system. All glazing types have different rates for the amount of heat retained between the inside and outside panes. Single pane glass has very low R-values since most of the heat is transferred from the warm inside to the outside through direct contact. R-values of double pane alternatives range from 1 to 3, which can be considered as the windows ability to resist heat transfer. Triple pane glazing is even more efficient and can have a value as high as 9. This can equate to significant savings in energy usage as well as comfort of the building occupants. If the window promotes heat transfer, the inner side of the glass will be significantly warmer than the ambient air temperature in the facility. This will cause undesirable air currents moving throughout the project.

Triple pane glazing combines the use of three layers of lites with ½" air spaces filled with argon gas. The argon gas inhibits additional transfer of heat from glass to glass. UV transmittance is also significantly lower with triple pane glass and can be as low as 5%, compared to 20% transmittance of double pane alternatives.

Calculations

Simply comparing R-values does not adequately display the entire mechanical efficiency of the system. Using the equation for heat transfer:

$$Q_{Glass} = (T_o - T_i) * A / R_{Glass}$$

Where:

Q_{Glass} = *Heat Transfer Rate*
T_o = *Outside Ambient Air Temperature*
T_i =*Inside Ambient Air Temperature*
A = *Area of Glazing*
R_{Glass} = *Heat Transfer Coefficient*

Double Pane Glass:

Heating: Q = (10 – 68) * 13,750 SF / 2 = (398,750) BTU/hr
Cooling: Q = (88 – 72) * 13,750 SF / 2 = 110,000 BTU/hr

Triple Pane Glass:

Heating: Q = (10 - 68) * 13,750 SF / 9 = (88,611) BTU/hr
Cooling: Q = (88 – 72) * 13,750 SF / 9 = 24,450 BTU/hr

The indoor ambient air temperature for the summer is assumed to be 72^{0F} and the winter is 68^{0F}. Outdoor temperatures for Danville, Pennsylvania are taken from the 97.5 percentile temperature for that season.

Some interesting results come from the linear relationship of the R-value and the heat transfer rate. A 400% increase in R-value equates to more than 1/4 the heat transfer rate during the winter, or gained during the summer. Upon adding one additional pane of glass and ½" air space with argon, the R-value of the system went up by a factor of 4.

Since large aluminum curtain walls utilize large panes of glass, large amounts of heat are lost through this medium as well as the additional headaches caused by drafts and cold glass. One remedy for this is installing a radiant heating system around the base of the curtain wall to reduce unwanted drafts and heat loss. The Center for Health Research and Rural Advocacy design team offset this aspect with the use of a Sterling/VB-AR-PM finned tube radiation system. Figure 1.16 is an example of a finned tube radiation system. Two specific types of these are used around the curtain wall; one of which employs two rows of coils and the other only a single row. The double row gives off 1,540 BTU/HR*FT and the single gives off a relative 1,010 BTU/HR*FT. By performing a take-off of the linear feet of each type of radiant heat application, it can be determined if the additional triple pane glass can offset the need for the radiant heating system, or at least to size them down.

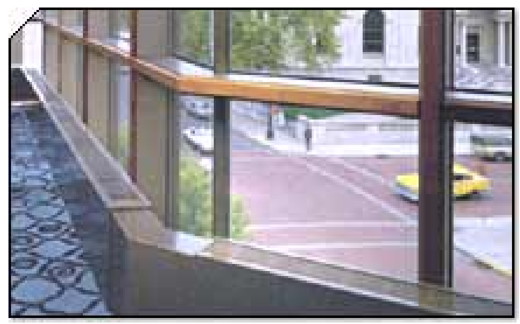


Figure 1.16: Finned Tube Radiation System

Finned Tube Radiation Take Off

Type	LF	BTU/HR*FT	Total BTU/HR	$ Cost/LF	$ Cost
1 Row	380	1,010	383,800	$82	$31,160
2 Row	202	1,540	311,080	$101	$20,402
		Total	694,880		$51,562

Glazing Calculations

Type	SF	Total BTU/HR
2 Panes	13750	(398,750)
3 Panes	13750	(88,611)
	Savings	(310,139)

All 1 Row Radiation

Type	LF	BTU/HR*FT	Total BTU/HR	$ Cost/LF	$ Cost
1 Row	382	1,010	385,820	$82	$31,324
3 Panes			310,139		
		Total	695,959		$31,324
		Difference	**(1,079)**		**$20,238**

Figure 1.17: Mechanical Costs of Replacing 2-Row Finned Tube Radiation

As can be seen in the preceding calculations, approximately $20,000 would be saved by using the 1-Row radiant heaters coupled with the triple pane glass; however, this must be compared with the additional costs in material for triple pane glazing. The total LF of radiant heaters can be minimized in order to maintain a properly sized system.

Many triple pane glass costs can be competitively priced with low-e double pane glass, but since a high quality gas filled glazing is needed to achieve the R-value of 9, there is a price premium. Triple pane will cost approximately 5% more than its high quality double-pane counterpart. With the 1-1/4" glazing costing 5% more than the traditional 2-pane glass, this equates to an additional $24,750 in material costs on top of the budgeted $495,000. The net costs of the proposed system are an additional $4,750.

Conclusion

After engaging in the mechanical analysis of utilizing the triple pane panelized system, it is difficult to make a distinction based on the cost of the triple pane glazing. Triple pane also has several mechanical advantages over traditional double pane, including lower UV transmittance, heat transfer, and comfortable areas for users, which may help garner the additional funding. Cooling load will also decrease due to less solar heat gain during the summer months. This will create a more efficient system and allow for savings in energy costs during the life-cycle of the facility. Since the triple pane is still a viable option, the integrity of the structure must be checked to ensure system compliance with codes and safety requirements.

Structural Analysis of Extra Glazing

When checking for alternative construction approaches or system alterations, it is important to ensure that the integrity of the system has not been jeopardized. This can range from structural impacts to mechanical changes and even to acoustical issues. The proposal of the triple pane glass in lieu of the insulated glazing will increase the weight of the curtain wall system on the structural frame. Figure 1.18 is a detail of the curtain wall connection at typical locations.

The typical connection to the prefabricated aluminum panels at the curtain wall occurs through a 4" wide by ½" thick steel plate welded to the flange of the column. Two ¾" bolts are fitted in the slots, which allow for vertical correction if floor to ceiling heights are not correctly field verified. As is the case with unitized systems, the interfaces between the panels and other systems are often the most difficult field conditions, thus flexibility must be built into each panel assembly. These flexible aspects must be included since steel and concrete contractors have tolerances in erection which the curtain wall contractor must interact with.

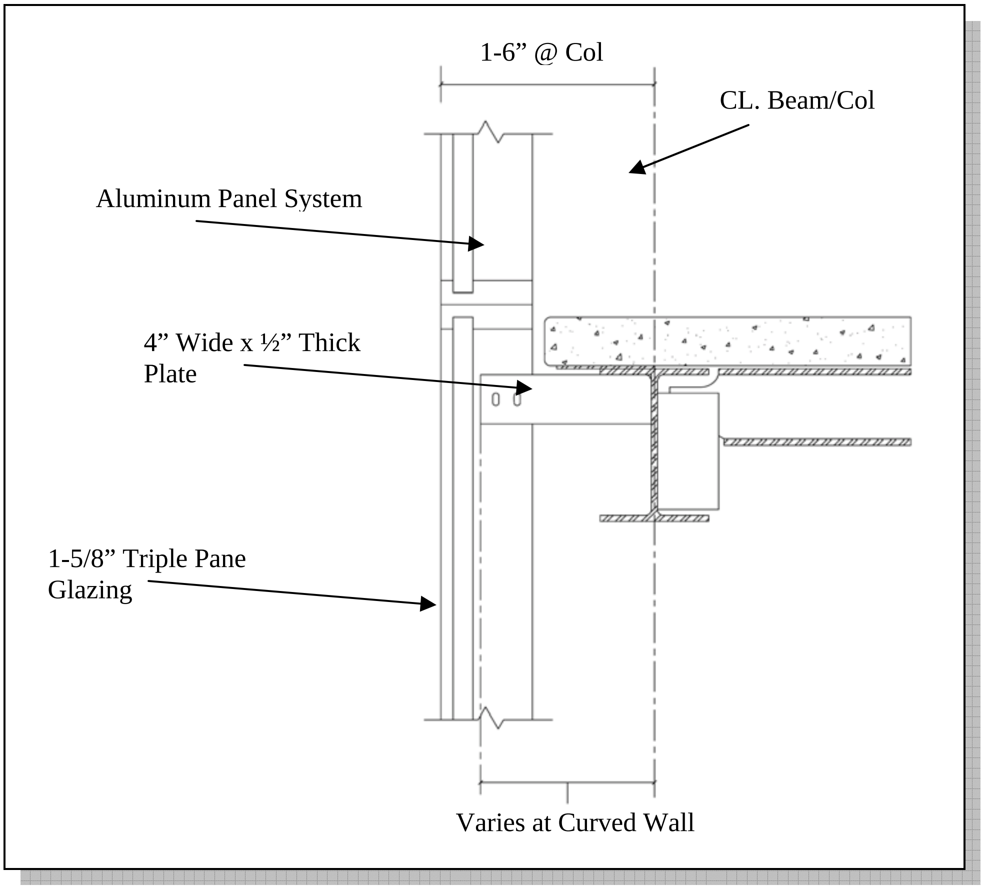


Figure 1.18: Structural Detail at Curtain Wall Connection

One of the disadvantages of triple pane glazing is the additional weight imposed on the structural members. With ¼" double pane glazing weighing 7.0 lbs/SF without the framing members, the additional sheet of glass brings the weight of the glazing up to 10.4 lbs/SF. Aluminum 6063 T-5, 2-1/2" x 7-1/2" and .125" thick framing members weigh 1.76 lbs/SF which equates to 96.8 lbs of aluminum framing. The structural system must support the weight of typical panel consisting of 13' x 8' triple pane glazing and 55 SF of .125" thick aluminum equal to panel weighing 1,178.4 lbs. This compared to the original design of double pane glazing weighing 824.5 lbs. An additional 354 lbs of force imposed on the bolt and weld connections may cause some structural instability.

The first structural analysis will involve checking the ¾" bolt connections between the curtain wall and the steel beams. Checking the bolts for direct shear from the 1.18 kips of force from each aluminum frame; each bolt needed to support .6 kips. Using the AISC Manual of Steel Construction: Third Edition, the A325 bolt, with exclusion of threads from shear plane, is able to withstand 15.9 kips of direct shear force. Following the direct shear, both the bearing and tear-out of the bolt arrangements were checked to see the force able to withstand. Both tests yielded positive results with the strength of the plate far outweighing the load on the bolt arrangement. Appendix B.2 has the calculations for the bolt shear, bearing, and tears out.

Since the connection of the panel to the frame will not fail, the next analysis will be to determine if the structural columns supporting the curtain wall will withstand the additional loading. This will be determined by calculating the total loads on a column with the additional weight of the panelized triple pane system included. Column F-10.1 will be used for the calculation since it is one of only four columns which are required to carry three stories of the panelized curtain wall. If the additional weight does not require resizing the member, the additional columns will assume to be compliant. This column is also required to support the open space office area with a 70 PSF live load. Appendix B.3 has the structural calculations for the column. The following figures are the summary of the calculations for the structural impacts.

Bolt Connections

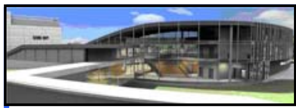
Property	*Design Load*	*Actual Load*	
Shear	15.9 Kips	0.589 Kips	**ok**
Bearing	52.2 Kips	0.589 Kips	**ok**
Tear Out	53.3 Kips	0.589 Kips	**ok**

Column

Property	*Design Load*	*Actual Load*	
Compression	569 Kips	55.6 Kips	**ok**
Buckling	50 Ksi	28.11 Ksi	**ok**
Flexure	1	0.46	**ok**

Figure 1.19 Structural Analysis Results

Upon checking the structural system for impacts regarding the addition of triple pane glazing, the implications are not major. The structural integrity of the design has not been jeopardized and actually passes the major tests. Since triple pane only accounts for an additional 4 lbs/SF of the curtain wall area, the major design systems are not affected. This additional weight on the structural column is only a small percentage of the total compressive load it supports.



Conclusion

The aluminum curtain wall construction was an obvious area for analysis based on its large cost and schedule constraints. Comprising six percent of the total project cost and a duration of 100 days, small savings in cost or schedule acceleration would greatly influence the flow of the construction project. Performing simple value engineering ideas like prefabrication proved to be a valuable asset for the construction management team.

Many preconceived notions of prefabricating systems were discussed in this analysis, ranging from cost and schedule data, to mechanical and structural implications. Often it is difficult to draw a concrete conclusion from so many different areas of analysis, but the unitizing of the curtain wall for the Center for Health Research and Rural Advocacy appears to be a winning combination. The schedule of on-site construction alone is a strong argument for implementation, with related savings in general conditions costs the topping on the cake. Since Geisinger Facilities operates on a budget from the parent Health Services, these savings can be held to counteract unforeseen conditions, change orders, or extreme quality issues. At the end of the day, if the monetary savings are not used, the funds will go back to Geisinger Health Services and another successful project would have been completed.

In addition to the unitized panels, adding triple pane glass and deleting the radiant heaters around the aluminum curtain wall is a wash. Since the mechanical heat loss was not reduced enough to completely eliminate the radiant heaters, at least 1-Row finned tube radiation would be required at some locations. Ultra-violet transmittance would be decreased, which has some benefits in the large open air work areas, but would building occupants notice the difference between 20% transmittance and 5%. The weight of the triple pane system does not cause any additional requirements for the structure, so its implementation is purely based on the owner’s perception of the advantages. After performing the analysis, the standard conclusion would be to simply use the original design intent of the insulated glazing with double pane technology. This would alleviate any additional headaches with approval of new shop drawings and design criteria.

Analysis: 4D Visualization of Envelope Construction

SPRING 2006

Michael W. Vergari

Construction Management

Dr. David Riley

Technical Analysis:

4-Dimensional Visual Study of Building Envelope Construction

Introduction

The Center for Health Research and Rural Advocacy employs an expansive aluminum curtain wall system wrapping around the façade facing Centre Street. Numerous times in urban construction the curtain wall requires extra coordination to keep everyone safe and the workers productive. This curtain wall will be one of the signature aspects of the project and what most pedestrians, hospital employees, and researchers will notice everyday. Since the façade is in such close proximity to Centre Street, which is to remain fully operational during construction, workers and equipment have barely ample space to operate. Close coordination of erection, delivery sequencing, and even safety issues must be monitored by the management team and disclosed to other contractors on-site.

As a result of this curved design and proximity to the thoroughfare, a great deal of time and effort needs to be utilized in order to maintain proper construction sequencing and hazard control. Shop drawings provided by the curtain wall subcontractor coupled with the CPM schedule produced by Geisinger facilities accounts for the main management plan for the curtain wall construction. The development of the schedule and management plan most likely was developed by an engineer and took many aspects into consideration from the construction documents for the project. While the information contained in safety plans, schedules, and sequencing is extremely useful for on-site workers and superintendents who have experience reading them, often times the information is hard to comprehend by other parties.

Since buy-in by all project participants is extremely important to the project's success, utilizing a virtual reality application to display all the construction issues will be beneficial. The 4-dimensional analysis of the building envelope can be used as a tool to help convey construction and safety issues easily to other contractors. This analysis will take a look at the benefits a 4-D CAD model would display for building envelope construction of the Center for Health Research and Rural Advocacy.

Construction Sequencing

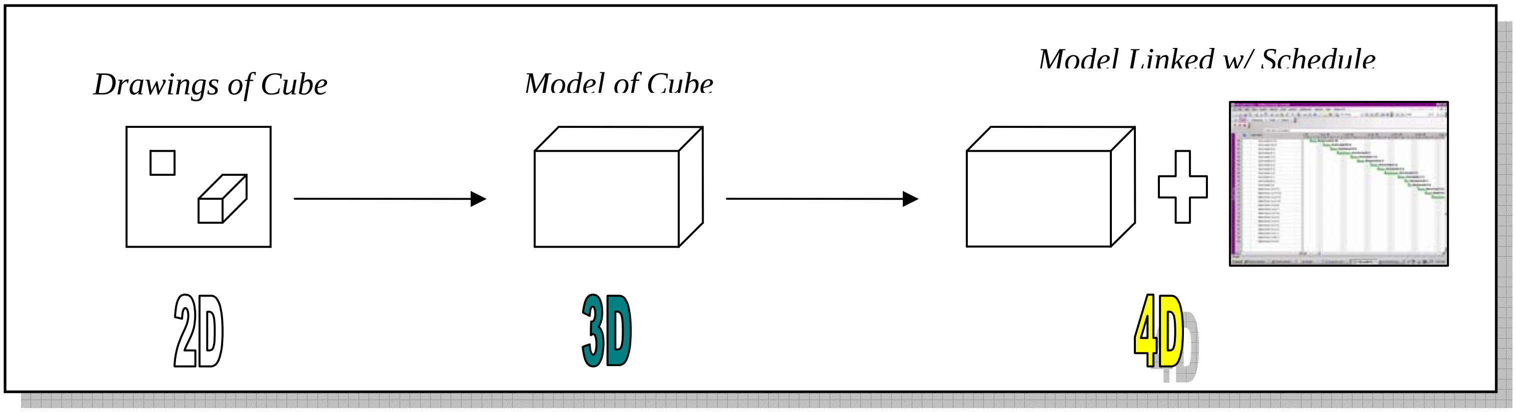
Developing an adequate management plan to properly coordinate all construction, safety, and even material delivery issues can be time consuming and difficult to display to other project participants. The pre-cast panel contractor may not understand the curtain wall contractors shop drawings and scheduling details. If these contractors are working in adjacent areas, it will be beneficial to visually show hazardous safety areas, crane locations, staging areas, and even sequencing.

The sequence developed contains pertinent information provided by the subcontractor, as well as the overall project knowledge possessed by the construction manager. Curtain wall construction will be done by column lines with the aluminum framing materials erected first, followed by the glass and glazing. Pre-cast architectural concrete is sequenced by elevation since the activity has the smallest duration of the envelope system. The relationships of the different envelope trades are difficult to picture visually as the sequence proceeds around the facility. Issues such as safety hazards and staging areas, which are not seen on a CPM schedule, can be visually identified easily through the use of a 4D site logistics study. Please reference the project schedule for the exterior skin located in Appendix C.1.

Development of 3D/4D Virtual Simulation of Building Envelope Construction

For help analyzing the building envelope construction sequence, a 3D model of the project has been developed as well as a 4-dimensional model for the façade construction. The 3D and 4D models will be used to justify changes in sequencing, site logistics, safety areas, and other concerns which may arise while viewing the model. To develop an accurate 4D model, the user must start with the 2-dimensional drawings of the project. From the drawings and specifications, a model of the building can be erected in a drafting program. To link this 3D model with time, building components are attached to their activities and durations in the project schedule. The facility can now be viewed and displayed for all relevant parties so they can comprehend the sequencing issues. This is a very effective way to help owners visualize the construction sequence without showing them a two-thousand activity schedule. Figure 2.1 graphically shows how to develop a 4-D model.

Figure 2.1 Development of a 4D Model



The 3-dimensional model for the Center for Health Research and Rural Advocacy was developed through the use of AutoCAD 2006 software. Aspects of the model are representations of the construction documents with emphasis on the envelope systems. The different façade types are displayed differently in order to conceptualize the interaction between trades. Interior modeling was used to identify proper elevations, connection locations, and accurate geometry. The model was developed in order to portray the following attributes:

- Temporary facilities, i.e. jobsite trailer, temporary fences
- Crane locations during envelope construction
- Access roads and site restrictions of adjacent buildings
- Staging areas
- Facility façade representations
- Trade interaction

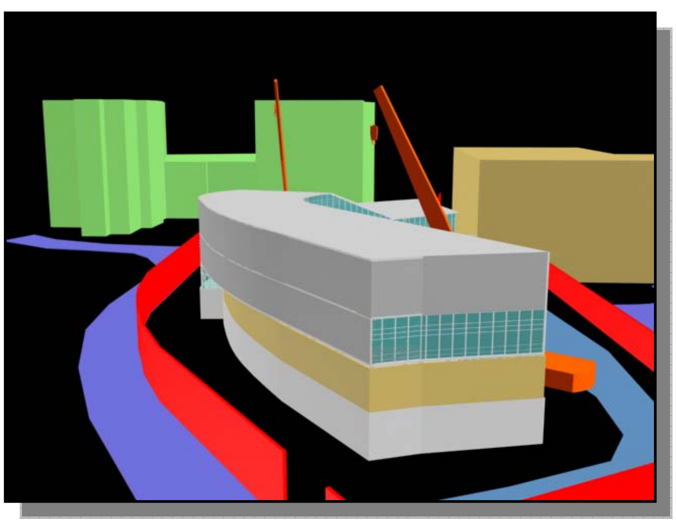


Figure 2.2 Perspective of West Elevation

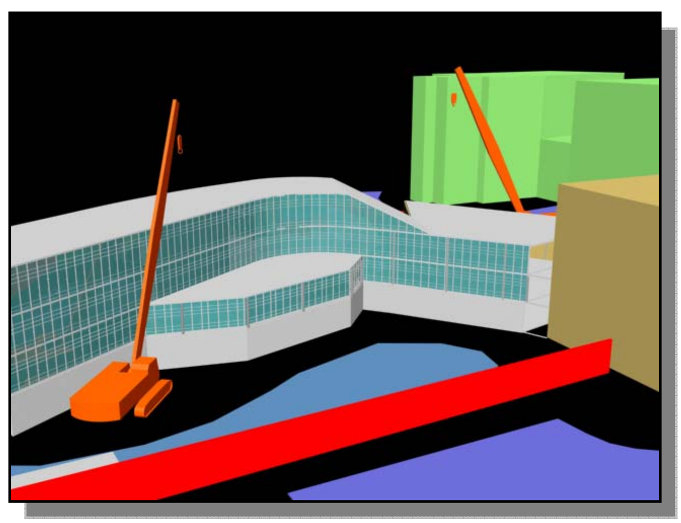


Figure 2.3 Perspective of South Elevation

Viewing the model may be completed within AutoCAD or by using virtual reality software. Exporting into a VRML file type allows users to interactively view and navigate the model easily over the internet or perhaps across a project website. Project websites can have these models of different construction activities available for all contractors to view and understand prior to starting their sequence of work on-site. Updates or changes in sequencing issues can be displayed and available for all subcontractors. This has potential benefits as revisions to CPM schedules require attention and time to determine changes. The model can simply be re-linked to the updated schedule and viewed instantly.

As seen in the figure below, the modeler can locate all site logistical issues such as adjacent facilities and staging areas. Shake-out areas for mullions and glazing will be virtually placed on the CHRRA project site to view possible challenges and sequencing issues. This is very beneficial for the management team since the site is extremely tight and space is not a luxury. Different logistic ideas can be modeled and discussed by project team members to determine the best location for all the temporary needs, thus eliminating the need to re-organize the site during construction due to discrepancies. Even through viewing the rendering of the project site some logistical issues can be derived. Deliveries will need to maneuver around the rear of the crane which will need to be monitored to ensure safety for all on-site personnel.

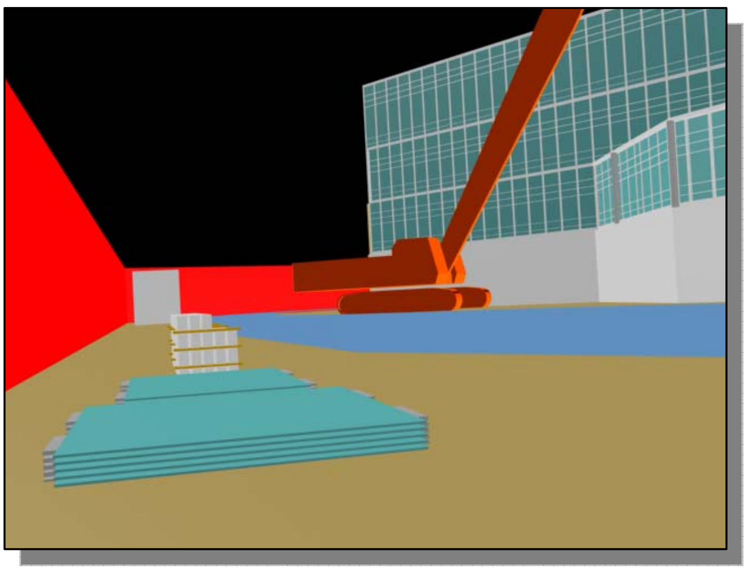


Figure 2.4 Crane and Staging Areas

The façade construction is grouped into manageable sections based on column lines, identical to the construction schedule developed for the project. These clusters will be employed by the 4D model to link portions of the construction process with the schedule. Each trade will have a different color representing their construction activity so the management team can easily see where the crew should be working on any given day.

Upon completion of the 3D model of the CHRRA, the linking of the schedule with the façade parts became the next priority. Development of the 4D model was completed in the Navisworks Jetstream application, to create a representation of the envelope erection sequence. This application allows the modeler to create separate visual representations for each trade. For the Center for Health Research and Rural Advocacy project, the aluminum framing and glazing is shown as a transparent red when under construction, pre-cast is a transparent green, and metal stud and paneling is a transparent purple. Viewers can easily identify which crews are working in the designated area at any moment in time during the project schedule.

Implementing and using the 4D model can be done in a variety of ways. Project managers can print snapshots of the virtual project for a specific date and tape it to the trailer wall. Superintendents for the subcontractors can quickly and easily see what the project should look like on that date, and can quickly assess if they are on schedule or behind. This type of visual feedback is beneficial, not only for the management teams, but also for the laborers who can see their progress without the difficulties of navigating through a project schedule. Depending on the extent and detail of the 4D model created, mangers can simply take a laptop during their daily walk-through and quickly see if the sequence is being followed or deviated from. The model can also help alleviate complications with an owner who is worried the project is not on schedule. By showing the 4D model coupled with pictures of actual construction the owner can easily comprehend how the schedule is derived and implemented. This will eliminate some major issues with percent complete arguments during payment application.

The following section depicts the 4D model developed for the Center for Health Research and Rural Advocacy with brief descriptions of the process under virtual construction.

4D Virtual Simulation for Building Envelope Construction

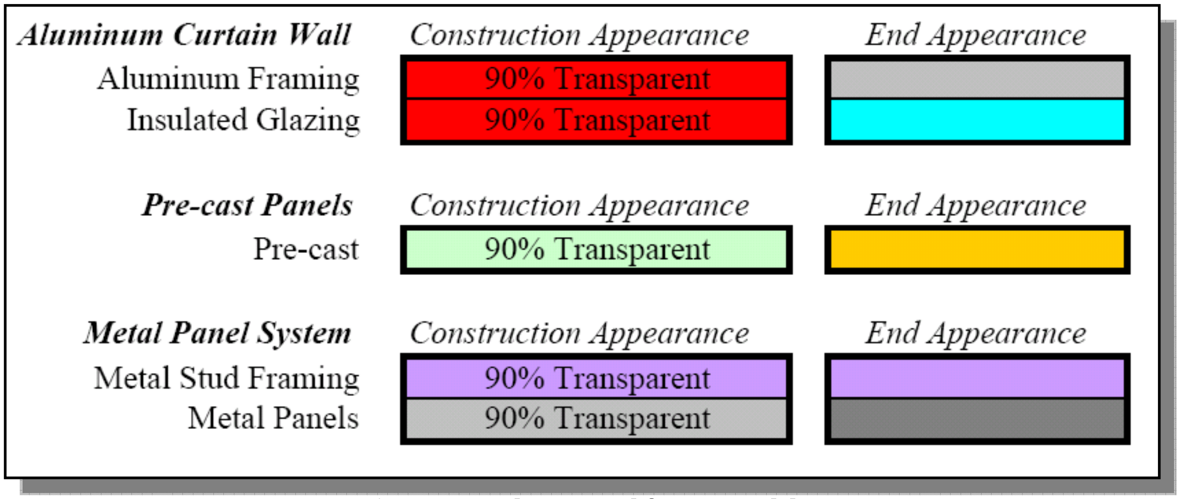
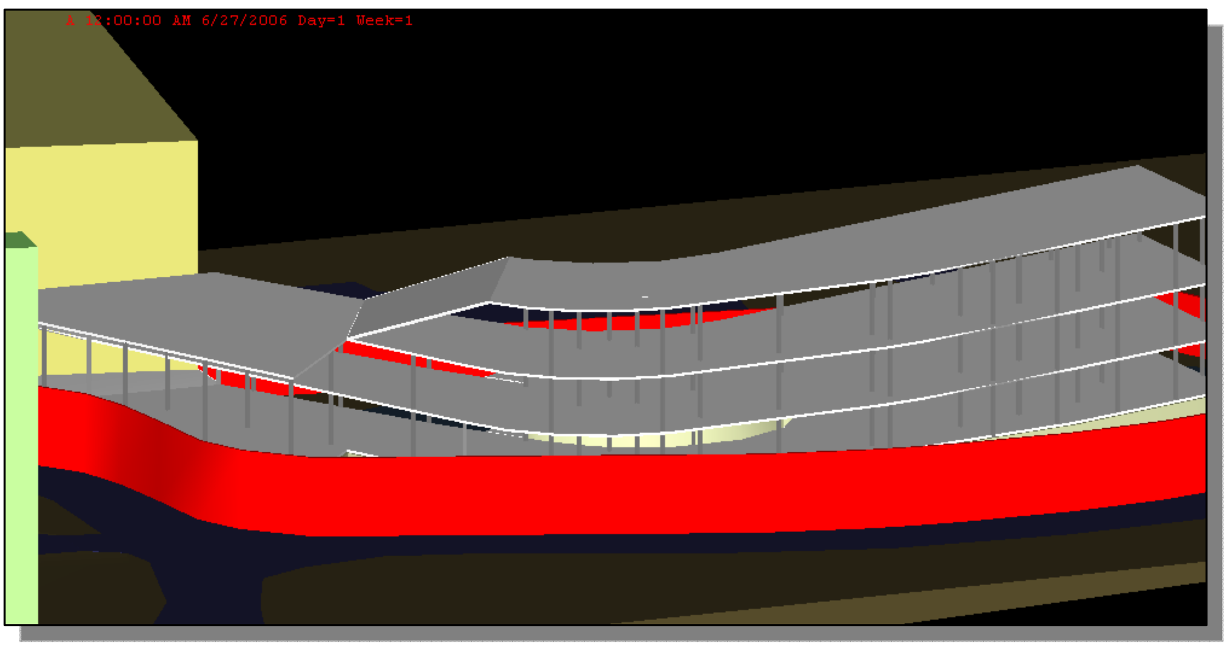
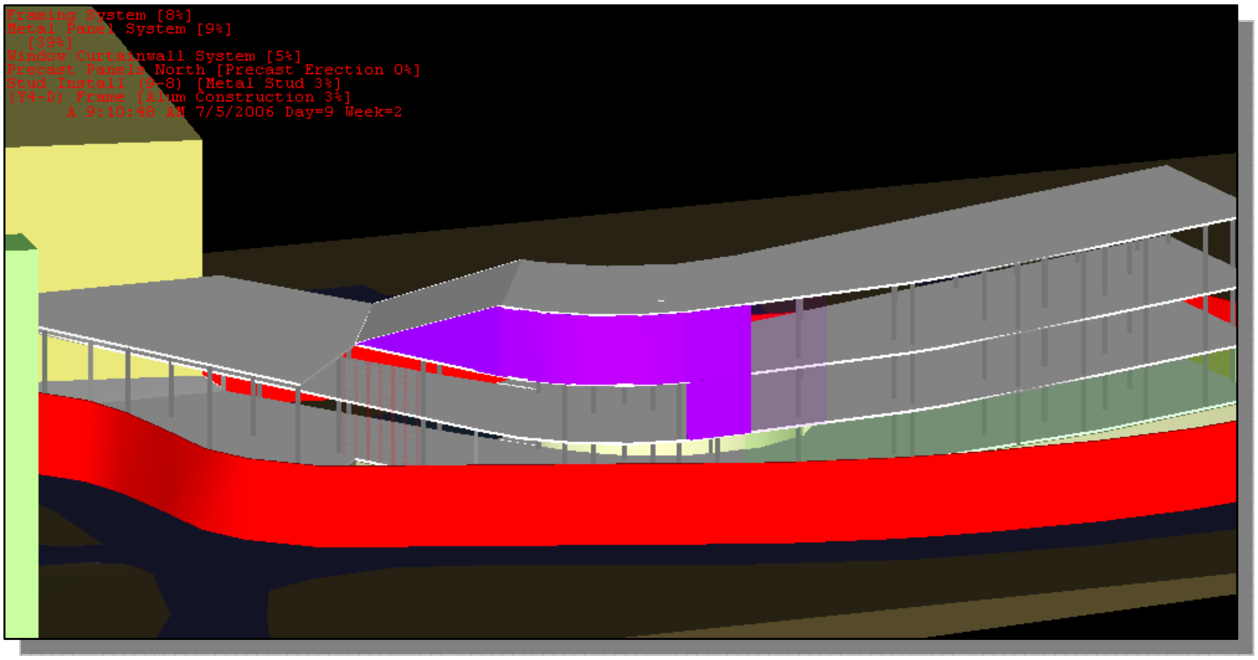


Figure 2.5 Color Legend for 4D Model



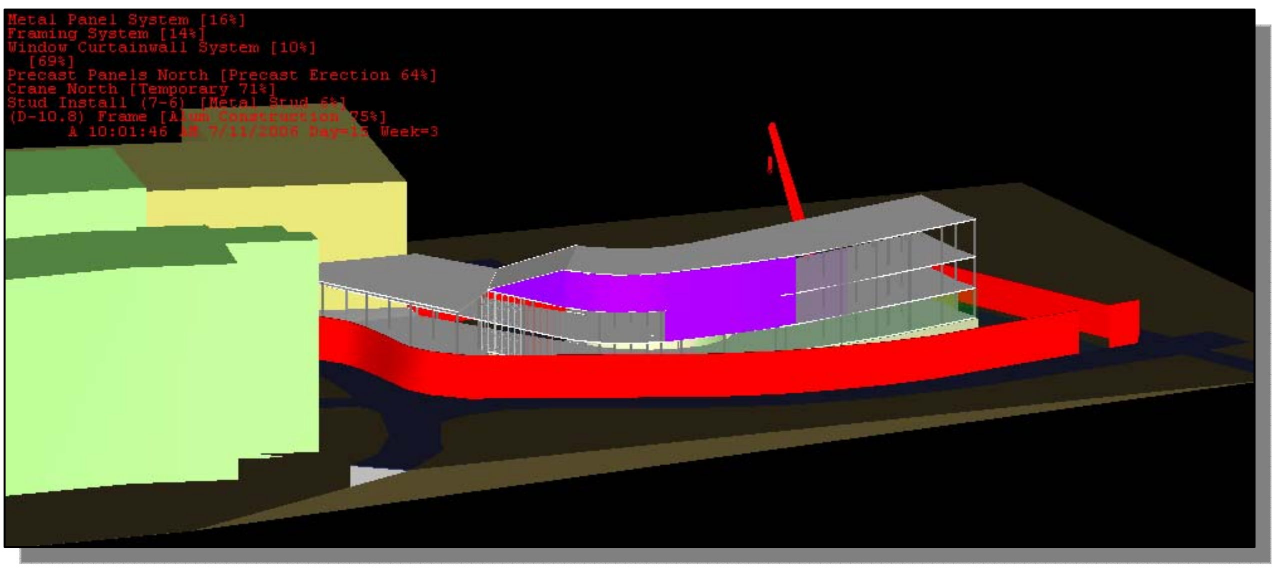
(6/27/06)

The figure above shows the project at completion of the structural frame on June 27, 2006. The fence is represented by the eight foot red line running perpendicular to the north face of the building. In front of that fence in the foreground is Centre Street, which as stated earlier, is to remain fully operational throughout construction. Construction will begin on the North elevation of the project which is the one shown above.



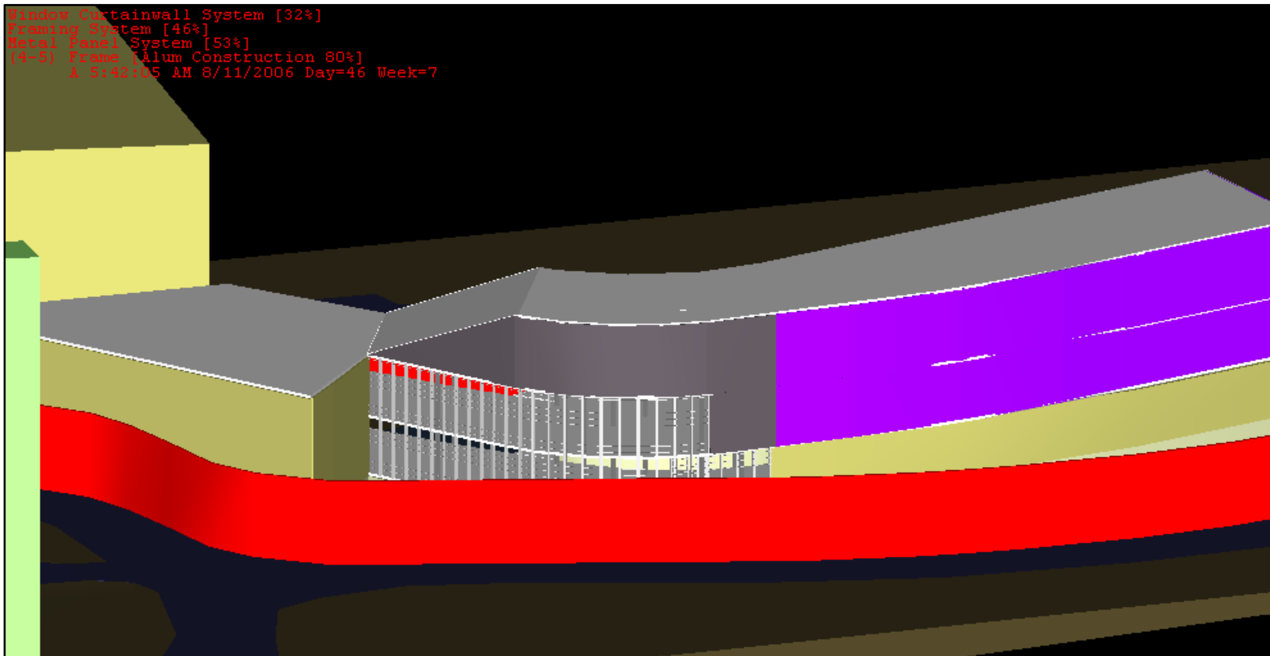
(7/5/06)

Construction has begun on the North elevation with all three of the façade systems starting to be installed. Metal studs have been erected across the third floor space, with the aluminum curtain wall framing constructed underneath the finish studs. Pre-cast installation has started on the first floor as well.



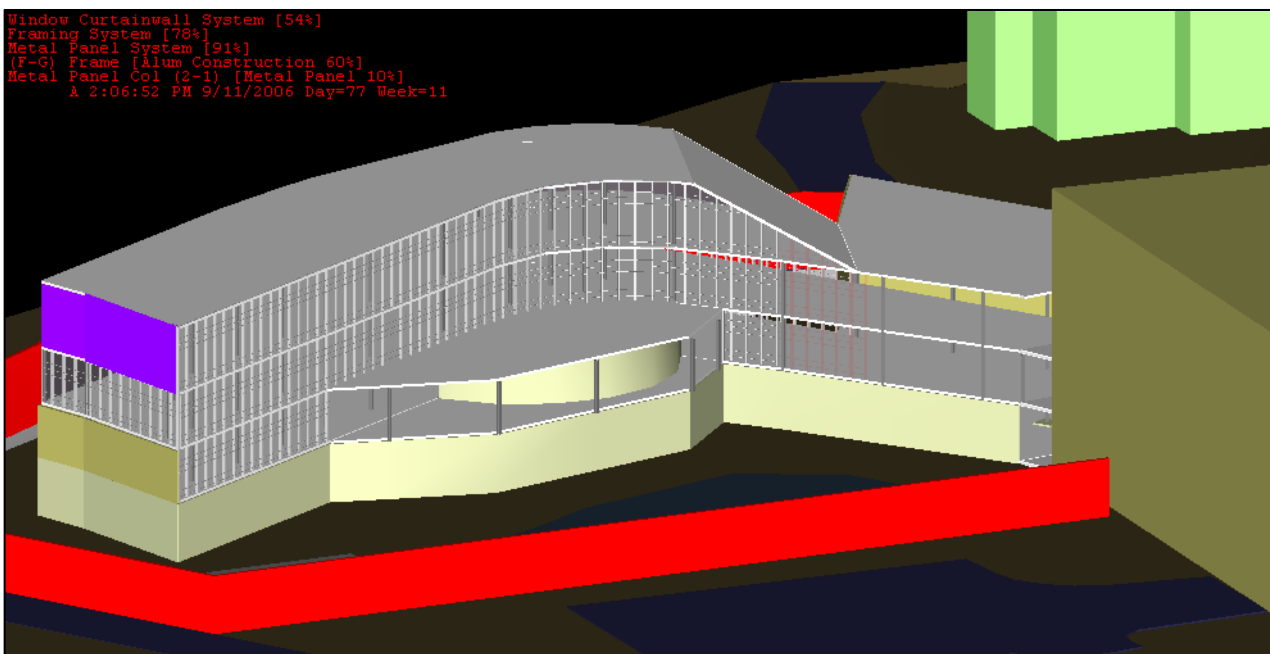
(7/11/06)

The crane has been mobilized for the pre-cast panel erection. Stud framing is being installed on the second and third floors of the north elevation and the aluminum framing is still being erected near the lobby entrance. There is a flurry of activity on the north elevation and this may cause some headaches for the crew foreman for each of the subcontractors.



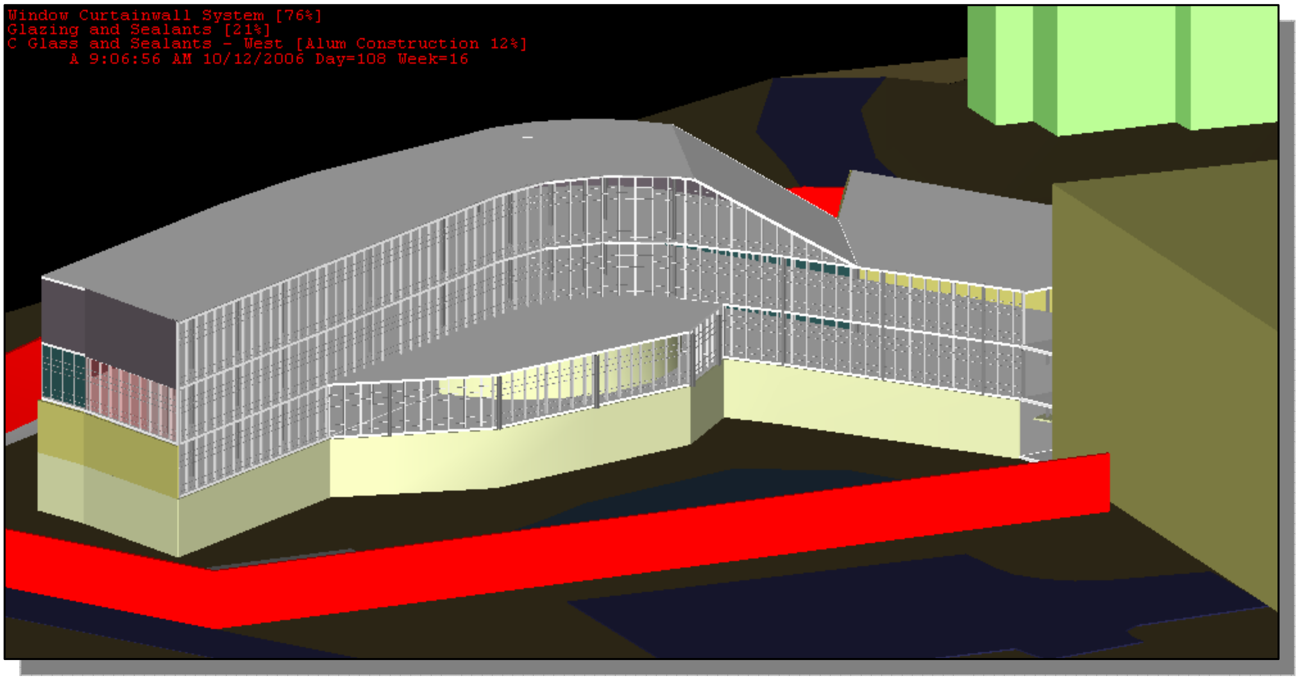
(8/11/06)

Envelope construction has gotten into full swing with the completion of the pre-cast panel installation on the North and West elevations. Aluminum framing has been completed at the lobby area and is waiting for glazing and sealants. Metal panels are being installed on the third and second floors of the North Elevation.



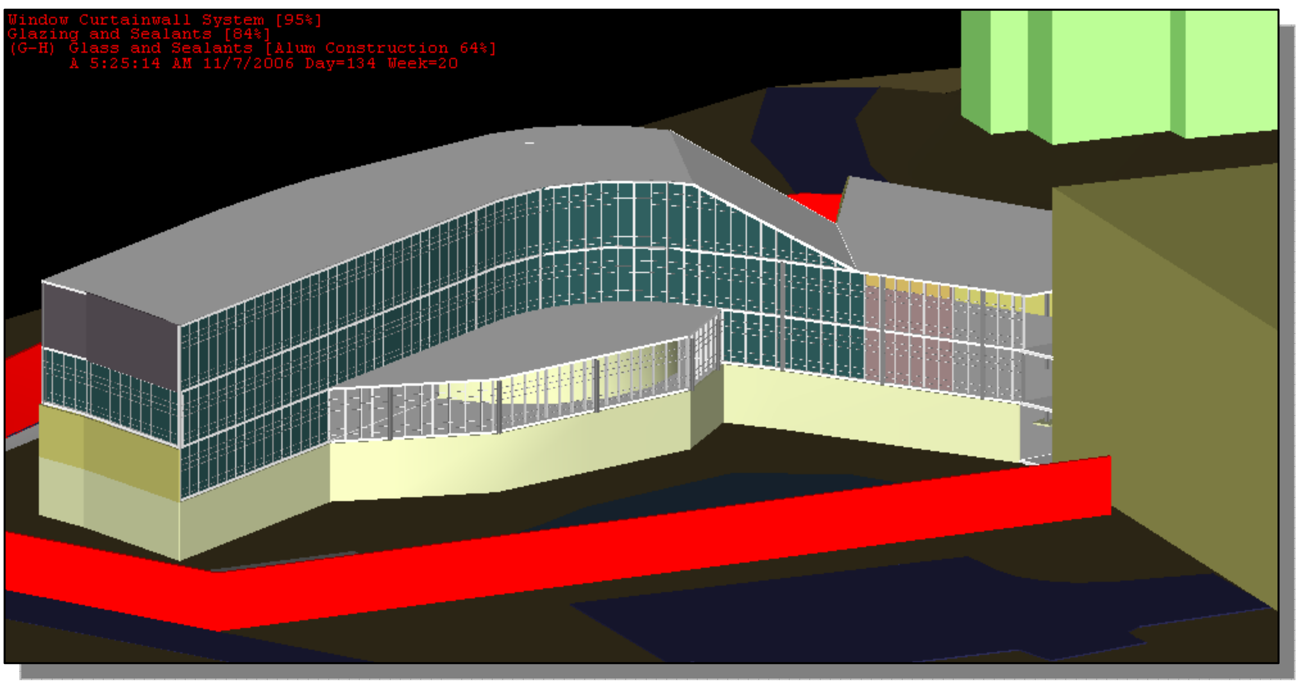
(9/11/06)

Framing for the expansive aluminum curtain wall system on the South elevation of the project is almost completed. Metal panels need to be installed on the third floor of the East elevation.



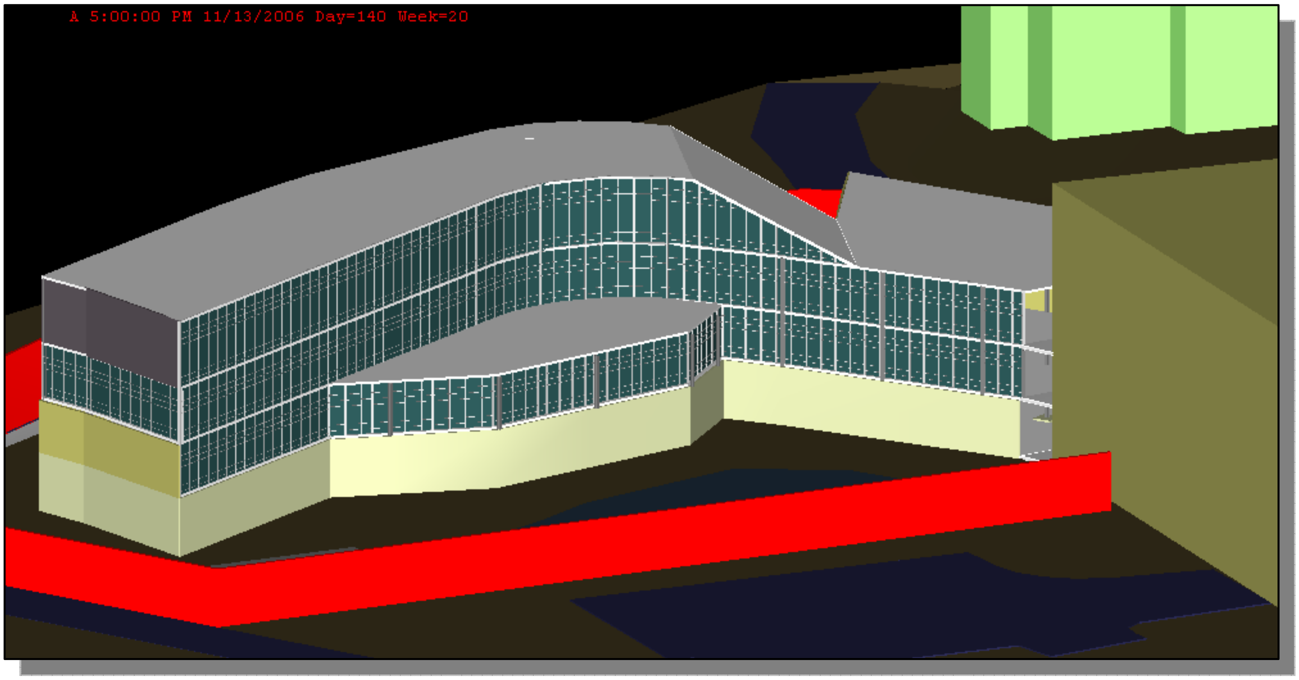
(10/12/06)

Glazing is currently being placed on the second floor on the East elevation. The framing of the aluminum curtain wall is completed and awaiting the remainder of the glazing to finish the exterior envelope system.



(11/7/06)

The signature aspect of the project is starting to come together. Four months since starting the façade construction the CHHRA skin system is almost completed. The South elevation needs to be finished as well as the open café area on the first floor.



(11/13/06)

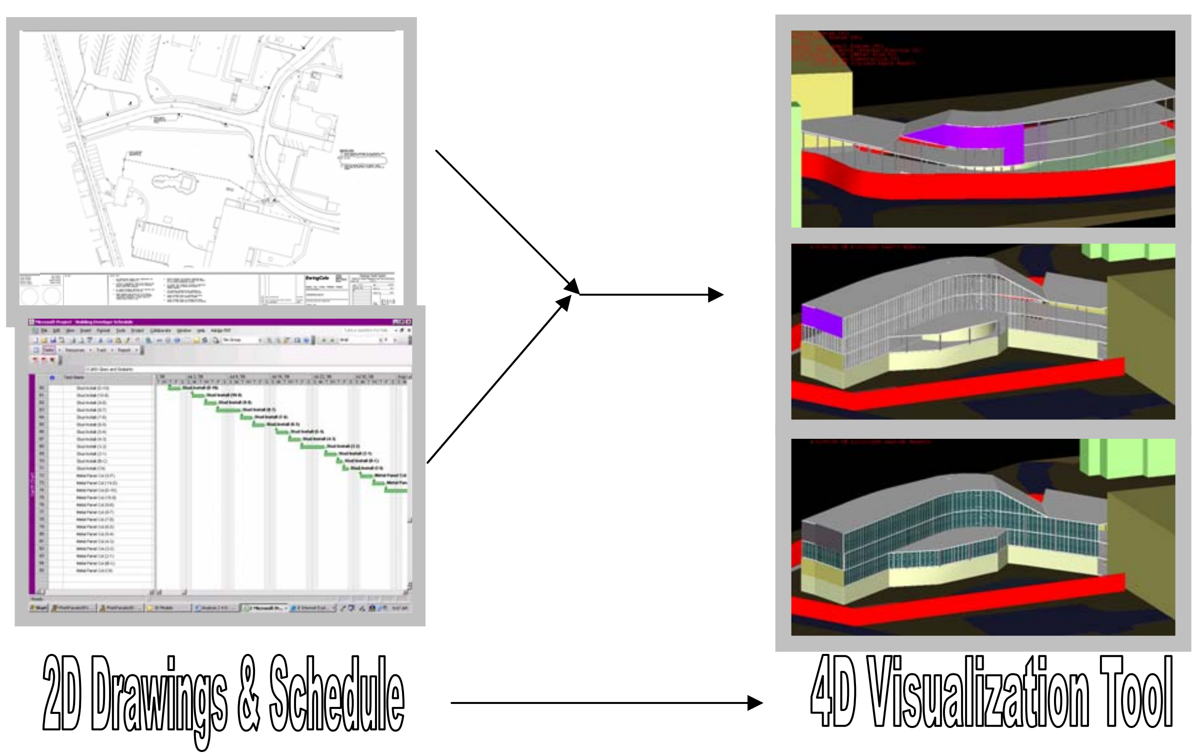
Building envelope has been completed for the Center for Health Research and Rural Advocacy and thus completed the enclosure of the facility. All interior work can begin on schedule and with protection from the harsh Pennsylvania winters.

Any project participant can take a look at this representation of the sequence and quickly see the progression of trades around the building perimeter. To reach the same conclusion would take some intuition and experience reading architectural plans and the project schedule. This example demonstrates the ease of displaying a linked schedule to a 3D model for a project. 4D models can be used for any sort of construction activity, ranging from site development and foundations, to MEP installation or finishes. The limits of this type of application are endless, and can bring even more benefits to complex projects.

2D Drawings & CPM Schedule vs. Developed 4D Model

Even with all the potential benefits of utilizing a 4D model on every project, some construction managers still believe the costs outweigh the potential advantages. So why is this misconception leading to the underutilizing of such a powerful tool? Some team members may just be intimidated by the technology and are worried about relying on a computer instead of personal experience. These models are developed to assist with project management on construction projects, and to find issues that may have not been addressed. 4D models can act as a check to

the schedule to ensure that many of the challenges are considered and addressed. Others still insist that developing the model and linking the schedule will be too expensive. This may be true if a construction manager is requiring all activities in a two-thousand plus activity schedule be linked to an object or solid in a CAD model. Compiling all that information is time consuming and costly, and most likely will not outweigh the benefits accrued. Creating summary activities and linking them to a basic model can be done relatively quickly and can have large impacts on a project sequence. The model created for the Center for Health Research and Rural Advocacy project took approximately 15 hours by one individual. Linking the model created to a cut-down version of the CPM schedule already developed for the project is quick and easy. Once the model is linked with activities on the schedule, changes or multiple iterations on that schedule can be done virtually instantaneously. The 4D model can be viewed interactively with all party members, to ensure that everyone is looking at the same conflict. As is seen in the following diagram, the combination of the 2D drawings with the schedule allows the management team to view the building at any moment in time and from any location.



Along with the added value of visualizing the sequence of trades, materials, deliveries, etc. is determining future challenges and taking steps to prevent or alleviate future headaches. There have been numerous examples where 4D CAD models have saved contractors weeks from the schedule, such as the Shirlington Condominium project in Viriginia. Building construction was behind schedule and the interaction of project participants with a 4D CAD model help to initiate positive ideas to gain time on the project. This interaction between project members in a closed environment with a tool such as a 4D model fosters innovation and fresh ideas.

Utilizing the 4D Model

A few issues were prevalent while viewing the façade sequencing for the Center for Health Research. With all the flurry of activity occurring on the North Elevation at the start of the façade construction, there will most likely be space related issues such as material lay down or adequate work space. This can easily be addressed by starting the erection of the aluminum framing on the South Elevation which is predominately made up of the aluminum curtain wall. Moving opposite of the metal panels and pre-cast, the curtain wall crew will be able to work with adequate material and work areas.

Another issue is related to possible hazardous work areas which are often difficult to find when simply comparing the schedule with the contract drawings. As is seen on the following Figure 2.6, the crane which is utilized to place the architectural pre-cast panels must make the lift from the opposite side of the facility, since there are no acceptable crane locations on the North side of the building. Thus the crane will be placing the pre-cast panels while the metal panel crew is installing studs on the floor directly above. This will create a hazardous work environment for the metal panel crew working above. Proper safety precautions need to be addressed before July 12, 2006 or the crew will need to move to a different location on the building. Not taking care of this issue will result in slower production rates for the week the crane is operating or worst case a stoppage of work for one of the crews.

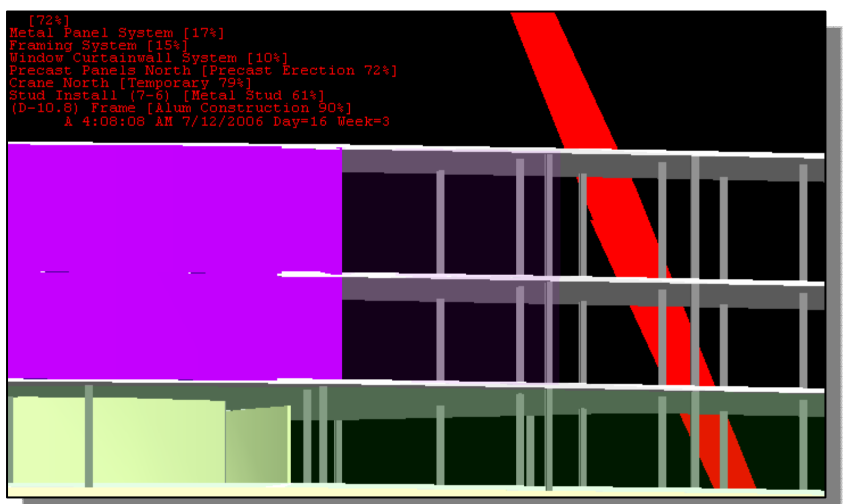


Figure 2.6 Crane Interaction

Conclusion

With the trend of owners and building operators requiring 3D models or building information models with standard operation and maintenance documentation, the industry will have to deal with the new role the 3D model will play in the construction process. Developing 4D models may be a typical role designated to a project engineer and utilized by upper management to make difficult decisions regarding the success of a project. Since creating the model of the project is the most time and labor intensive activity when developing a 4D model, if an owner requires a 3D model for the facility the additional time required to merge the schedule is minimal. With the steps GSA is taking to require building information models on all their projects, it may be soon that the industry embraces the possibilities with virtual documentation.

Since some issues were already addressed on the Center for Health Research and Rural Advocacy project, it is easy to see that the tool can be implemented on any aspect of construction. Simply modeling and linking the schedule for the envelope construction raised some issues of safety and trade congestion.

All the advantages associated with implementing a 4D CAD model on commercial and government projects are hard to ignore. Whether using the tool for trade sequencing, project documentation, safety and hazard analysis, or just for owner visualization, the price tag on this technology will be minimal compared to the value added to the project. The impacts on project scheduling for phased projects may be even more significant, since they require the most diligent of schedule and sequencing attention. With the slow evolution of technology through the construction industry, it will be exciting to see the impacts that 4-dimensional models have on construction projects worldwide.

Conclusions & Recommendations

After exploring the various dimensions and roles the building exterior plays in health care and sustainable designs, it is easy to see the implications this system has on the success of LEED certified projects. Sustainable aspects of the building façade are contained in more than half of the total LEED credits. To properly manage the envelope design and functionality it takes diligence from all project participants from conceptual design to closeout. The building envelope affects mechanical loads and system efficiency, structural integrity, day lighting requirements, as well as construction sequencing and building enclosure. As was seen during the investigation, health care facilities can greatly be affected by the design of the envelope system. Hospitals often operate 24 hours a day the entire year and a rather small decrease in energy efficiency correlates to large savings in operation costs. Patient and worker physical and psychological health is affected by the amounts of natural light and thermal comfort. The Green Guide for Health Care is an excellent tool and should be used for all new health care construction since it has such numerous advantages for owners and building occupants.

Many preconceived notions of prefabricating systems were discussed in this analysis, ranging from cost and schedule data, to mechanical and structural implications. Often it is difficult to draw a concrete conclusion from so many different areas of analysis, but the unitizing of the curtain wall for the Center for Health Research and Rural Advocacy appears to be a winning combination. The schedule of on-site construction alone is a strong argument for implementation, with related savings in general conditions costs the topping on the cake. Since Geisinger Facilities operates on a budget from the parent Health Services, these savings can be held to counteract unforeseen conditions, change orders, or extreme quality issues. Prefabrication for building components is a legitimate approach with the advantages becoming more numerous as more firms become qualified to perform this type of service. Many companies have embraced the unitized delivery method and more will once the benefits and case studies become more affluent.

4D CAD models have such profound advantages for complex and traditional projects alike; implementation of these tools will be seen more often. The tool can be used for trade sequencing, project documentation, safety and hazard analysis, or just for owner visualization. With owners requiring 3D models for construction projects and the related ease of linking the already developed CPM schedule, the additional costs incurred to create a 4D model will be minimal. As seen on the Center for Health Research and Rural Advocacy, even a simple analysis of the 4D model by project participants brings about positive innovation. The impacts on project scheduling for phased projects may be even more significant, since they require the most diligent of schedule and sequencing attention. With the slow evolution of technology through the construction industry, it will be exciting to see the impacts that 4-dimensional models will have on construction projects worldwide.

SPRING 2006

Appendices

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April 3, 2006

Volume 1, Issue 1

FAÇADE DECISION MAKING GUIDE CONT.

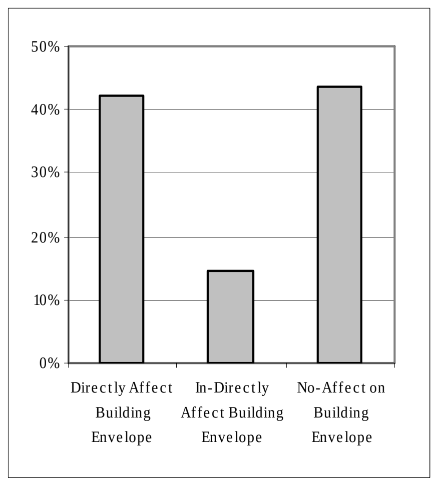
INSIDE THIS ISSUE:

Misc. Building Info

- Sustainable LEED projects add less than 0.1% to the project cost.
- Buildings in the U.S. account for 65% of the electricity consumption.
- Commercial buildings also account for 30% of the greenhouse gas emissions.

BUILDING ENVELOPE DESIGN HAS LARGE IMPACT ON LEED CERTIFIED PROJECTS

Green buildings are no longer a new idea and are quickly becoming the trend in the slowly changing industry of building construction. Even though the essence of LEED (Leadership in Energy and Environmental Design) rating systems are understood more universally throughout construction disciplines than a decade ago, the integration of design, engineering, and construction of systems to be "greener" needs to be more streamlined. Running parallel with the sustainable buildings trend is the design of more complex building facades. The new building envelope systems combine aesthetically pleasing mixtures of materials and finishes with high-tech functionality. To properly design and build a LEED certified project, one must efficiently manage the design and construction of these skin systems. Design considerations include issues such as recycled and locally available materials, thermal comfort, day-lighting requirements, and even green roof systems. LEED credits capture the importance of envelope systems as the design and construction are related to 57% of the LEED criteria. Credits which directly affect the envelope design are categorized as related to design, construction, and use. In-directly affecting the envelope relates to project regulations, waste management systems, or workers and material utilized for temporary construction issues.



LEED Credits Affect on Building Envelope

LEED PREMIUM COSTS ASSOCIATED WITH BUILDING ENVELOPE DESIGN?

So how much does this new trend cost? In 2005, GSA released a study outlining cost premiums for pursuit of LEED credits. This study is especially beneficial for owners or designers who are new to the green building industry. New facilities can be erected to a budget without cost premiums; however, there are credits which require additional funds to implement. GSA: LEED Cost Study outlines the premium costs associated for commercial projects. Building envelope selection is critical in order to ensure the project is completed within the owners budget. Façade selection can equate to an additional $150,000 to $250,000 in project cost in areas such as material, labor, and project management.

April 3, 2006
Volume 1, Issue 1

Façade Decision Making Guide Cont.

Façade Decision Making Guide

Project Timeline	Issue	Envelope & LEED Implications
Conceptual Design		
Owner & Architect	Building Orientation	Numerous areas of glazing facing west will have large solar heating loads
	Footprint	% of floor area within 15' of perimeter promotes healthy environment and credits towards GGHC
	Mix Use Area	Combine green and garden roof types for healthy envrionment and LEED credits
Building System Design		
Owner, Architect, Engineers	Design Iterations	Promote iterations so other systems utilize curtain wall advantages (mechanical and day light)
	Material Selection	Skin materials designated by local conditions and re-used materials
	Energy Savings	Incorporate energy consumption analyses to ensure premium costs are recovered over time
Complete Construction Documents		
Owner, Architect, Eng.,CM	Value Engineering	Ask each bidding CM for value engineering ideas, save money and healthier building
	Budget	Consult GSA: Cost Study for determining if credits require premium costs
Pre-Construction		
Architect, Eng., CM, Subcontractors	Subcontractor Selection	Regionally manufactured and readily available materials key to control cost and schedule
	Value Engineering Implimentation	Implement value adding ideas for building envelope, credit points for innovation in design
	System Interfaces	Coordinate shop drawings of different skin systems at interfaces of the systems
Construction		
CM, Subcontractors	Waste Management	Recycle envelope materials which are cheap and easy to recycle
	Indoor Air Quality Mgmt Plan	Early finish of building enclosure minimizes possible contamination of indoor air quality
Project Closeout		
Owner, Architect, Eng., CM	LEED Accredite Professional	Ensures proper verification and paperwork process
Subcontractors	Verification of Energy Efficiency	Engage in process to guarantee energy savings for owner, worth an additional LEED credit

Issues relating to the design and construction of envelope systems are outlined in the first dotted region in relation to the phase the project is in. LEED and skin implications of these issues are discussed in the second region.

The Façade Decision Making Guide was developed utilizing the Green Guide for Health Care, GSA: LEED Cost Study, and the LEED-NC V2.2. The views and implications expressed in this guideline are for educational purposes and do not represent the views and opinions of Pennsylvania State University and/or The Department of Architectural Engineering. The Façade Decision Making Guide is for educational use only.

Appendix B: Analysis 1: Prefabrication

B.1 Exterior Skin Costs

Aluminum & Glass Curtain Wall	Qty	Unit	Mat Cost/Unit	Material	Labor Cost/Unit	Labor	Total
2-1/2" x 7-1/2" Extruded Aluminum 6063-T5 .125" Thicl	4,280	LF	$16	$68,480	$12	$51,360	$119,840
5/8" Thick Insulated & Spandrel Glazing	13,750	SF	$36	$495,000	$22	$302,500	$797,500
Column Covers	6	EA	$2,700	$16,200	$300	$1,800	$18,000
Aluminum Doors & Glass	8	EA	$5,000	$40,000	$500	$4,000	$44,000

Aluminum & Glass Curtain Wall: $979,340

Architectural Pre-cast Concrete Panels	Qty	Unit	Mat Cost/Unit	Material	Labor Cost/Unit	Labor	Total
Precast Panels	7,386	SF	$21	$155,106	$11	$81,246	$236,352
Furring, Insulation, & Gypsum Wallboard	7,386	SF	$3	$18,465	$2	$11,079	$29,544

Architectural Pre-cast Concrete Panels: $265,896

Metal Panel Walls & Windows	Qty	Unit	Mat Cost/Unit	Material	Labor Cost/Unit	Labor	Total
5/8" Thick Insulated & Spandrel Glazing	3,054	SF	$32	$97,728	$18	$54,972	$152,700
2" Metal Panel Walls	6,912	SF	$21	$145,152	$11	$76,032	$221,184
Metal Stud Framing	6,912	SF	$6	$41,472	$4	$27,648	$69,120
Gypsum Wall Board	6,912	SF	$2	$10,368	$1	$6,912	$17,280

Metal Panel Walls & Windows: $460,284

Roofing	Qty	Unit	Mat Cost/Unit	Material	Labor Cost/Unit	Labor	Total
Membrane Roof, Insulation, & Flashing	19,861	SF	$5	$99,305	$3	$59,583	$158,888
Auditorium Roof, Future Green Roof	4,855	SF	$10	$48,550	$4	$19,420	$67,970
Metal Stud Framing	600	SF	$18	$10,800	$7	$4,200	$15,000

Roofing: $241,858

B.2 Bolt Connection Calculation

Reference Figure 1.18 for Structural Detail

Direct Shear on Each Bolt

R = 1.178^{Kips} / 2 bolts = $.589^{Kips/Bolt}$

Galvanized A325 ¾" Threads Excluded From Shear Plane AISC:LRFD Table 7-10

Shear Strength = $15.9^{Kips} > 0.589^{Kips}$ <u>(OK)</u>

Bearing on Each Bolt

2.4 db(t)(F_u) = 2.4 (¾")*(0.5")*58ksi = $52.2^{Kips/bolt}$ <u>(OK)</u>

Tear Out of Each Bolt

1.2 L_c (t)*(F_u) =

L_c = 2" – (3/4"+1/16")*1/2 = 1.59

1.2 (1.59) * 0.5 * 58 = $55.3^{Kips/Bolt}$ <u>(OK)</u>

B.3 Structural Column Calculations

Design Criteria: IBC 2003

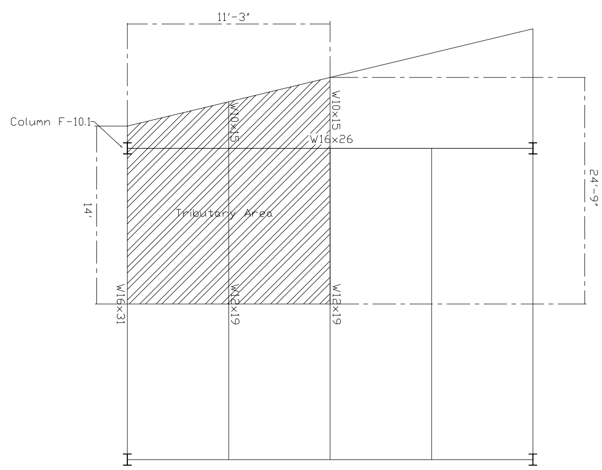
Design Live Loads
Floor Design Live Loads ………………………………………………… 50 PSF
Partition Load (Office Area) ……………………………………………... 20 PSF
Assembly Area ……………………………………………………...…… 100 PSF

Snow Load ……………………………………………………………….. 30 PSF

Roof Loads
Typical Roof Load ………………………………………………………….. 30 PSF
Green Roof Load ……………………………………………………………. 30 PSF

Lateral Loads
Basic Wind Speed ………………………………………………………… V=90 MPH
Wind Load Importance Factor ……………………………………………… I = 1.15
Wind Exposure ……………………………………………………………… C

Column F-10.2: W12x96 ASTM A992 Grade 50



<u>Starting with the roof loads</u>:

Tributary Area = 14'*11'-3" + 2'*11'-3" + ½*5'-6"*11'-3" = 210.9 SF

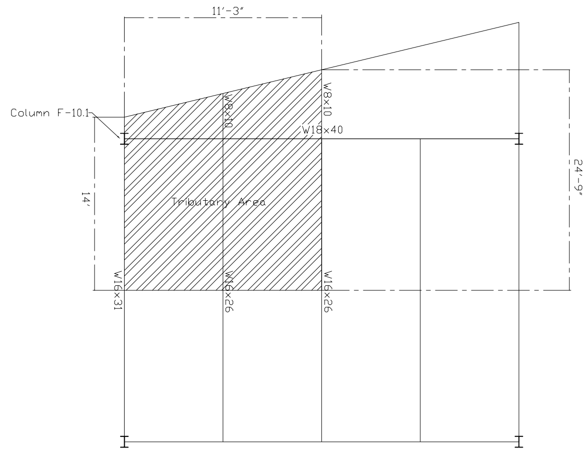
Compressive Column Load:
1.2D + 1.6L + 0.5S

1.2 (Deck + W-Shapes + MEP) + 1.6 (210.9*30PSF) + 0.5 (210.9*30PSF)

W-Shapes = 1.43^{Kips}
Deck = 210.9 SF*6 lbs/SF (Metal and Finish) = 1.27^{Kips}
MEP = 10 PSF

= 1.2 (1.27+1.43+10*210.9) +1.6(210.9*30PSF) + 0.5 (210.9*30PSF) = **15.8^{Kips}**

First floor loads:



Tributary Area = 210.9 SF

Compressive Column Load:
1.2D + 1.6L

1.2*(Deck + Slab + W-Shapes + MEP) + 1.6*(210.9*70PSF)

Slab = 210.9 SF * 5" = 87.9 CF * 150 lbs/CF = 13.2^{Kips}
W-Shapes = 14'*31+2*10*5'+ 2*14'*26 = 1.2^{Kips}

1.2*(1.27+13.2+1.2+10*210.9) + 1.6(210.9*70PSF) = **26.2^{Kips}**

Curtain Wall Compressive Loads:

1 - 13' x 8' Unitized Glazing = 1.18^{Kips}

6 Panels in Tributary Area = 6*1.18^{Kips} = **7.08^{Kips}**

Total Compressive Load:

Roof Load + First Floor + Panel + Weight of Column
15.8^{Kips} + 26.2^{Kips} + 7.08^{Kips} + 96 lbs/ft*38'/1000 = **55.6^{Kips}**

Lightest Service Column Size for Compressive Load:

KL = 26' (Two-story open space)

W12x96 @ KL=26' = $\varphi_c P_n = 569^{Kips} > 55.6^{Kips}$ (OK)

Checking Buckling Stress:

W12x96 (A = 28.2 in^2; r_x = 5.44 in; r_y = 3.09)

Minimum L/r = 26'*12 / 3.09 = 100.9

Critical or Buckling Stress = $F_e = (\pi^2 * (E*I)) / (100.9^2)$
$F_e = (\pi^2 * 29x10^3) / 100.9^2 = 28.11$ ksi < proportional limit of 50 ksi (OK)

Wind w/ Axial Compression and Flexure (Moment Frame):
Assumption: 26 PSF Wind Load on Column

W12x96: $A = 28.2\ in^2$; $Z_x = 147\ in^3$; $Z_y = 67.5\ in^3$
$I_x = 131\ in^4$; $r_x = 5.44$ in; $r_y = 3.09$

$\varphi_c P_n = 569^{Kips}$

$P/\ \varphi_c P_n = 55.6/569 = .097 < 0.2$

Therefore Equation H-1b Governs:

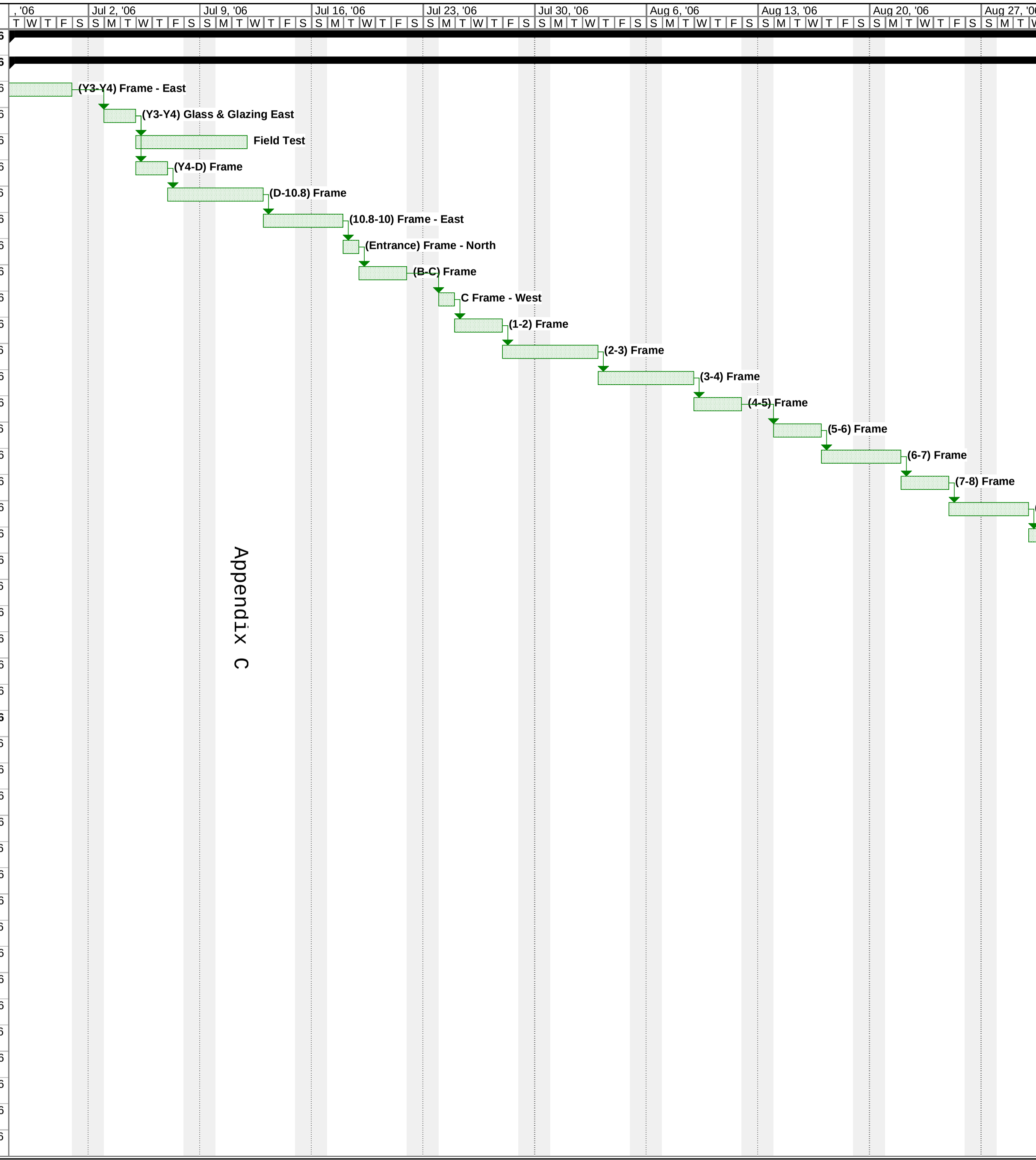
$½\ (P_u / \varphi_c P_n) + M_u / \varphi_b M_n \leq 1$

$M_u = WL^2/8 = 1.6*26PSF*14' * 38'^2 /8 = 105.1^{Kip\text{-}Ft}$

$\varphi_b M_n = 0.9\ F_y\ Z_y = 0.9*(50ksi)*(67.5in^3)*(1/12^{in/ft}) = 253.1^{Kip\text{-}ft}$

$½\ (55.6 / 569) + (105.1 / 253.1) = .46 < 1.0$ <u>(OK)</u>

ID		Task Name	Duration	Start	Finish
1		**Window Curtainwall System**	**100 days**	**Tue 6/27/06**	**Mon 11/13/06**
2		**Framing System**	**70 days**	**Tue 6/27/06**	**Mon 10/2/06**
3		(Y3-Y4) Frame - East	4 days	Tue 6/27/06	Fri 6/30/06
4		(Y3-Y4) Glass & Glazing East	2 days	Mon 7/3/06	Tue 7/4/06
5		Field Test	5 days	Wed 7/5/06	Tue 7/11/06
6		(Y4-D) Frame	2 days	Wed 7/5/06	Thu 7/6/06
7		(D-10.8) Frame	4 days	Fri 7/7/06	Wed 7/12/06
8		(10.8-10) Frame - East	3 days	Thu 7/13/06	Mon 7/17/06
9		(Entrance) Frame - North	1 day	Tue 7/18/06	Tue 7/18/06
10		(B-C) Frame	3 days	Wed 7/19/06	Fri 7/21/06
11		C Frame - West	1 day	Mon 7/24/06	Mon 7/24/06
12		(1-2) Frame	3 days	Tue 7/25/06	Thu 7/27/06
13		(2-3) Frame	4 days	Fri 7/28/06	Wed 8/2/06
14		(3-4) Frame	4 days	Thu 8/3/06	Tue 8/8/06
15		(4-5) Frame	3 days	Wed 8/9/06	Fri 8/11/06
16		(5-6) Frame	3 days	Mon 8/14/06	Wed 8/16/06
17		(6-7) Frame	3 days	Thu 8/17/06	Mon 8/21/06
18		(7-8) Frame	3 days	Tue 8/22/06	Thu 8/24/06
19		(8-9) Frame	3 days	Fri 8/25/06	Tue 8/29/06
20		(9-10) Frame	3 days	Wed 8/30/06	Fri 9/1/06
21		(10-Y4) Frame - South	4 days	Mon 9/4/06	Thu 9/7/06
22		(F-G) Frame	4 days	Fri 9/8/06	Wed 9/13/06
23		(G-H) Frame	4 days	Thu 9/14/06	Tue 9/19/06
24		(H-J) Frame	2 days	Wed 9/20/06	Thu 9/21/06
25		(Café) Frame	7 days	Fri 9/22/06	Mon 10/2/06
26		Frame Complete	0 days	Mon 10/2/06	Mon 10/2/06
27		**Glazing and Sealants**	**30 days**	**Tue 10/3/06**	**Mon 11/13/06**
28		(Y4-D) Glass and Sealants	2 days	Tue 10/3/06	Wed 10/4/06
29		(D-10.8) Glass and Sealants	2 days	Thu 10/5/06	Fri 10/6/06
30		(10.8-10) Glass and Sealants - East	1 day	Mon 10/9/06	Mon 10/9/06
31		(Entrance) Glass and Sealants - North	1 day	Tue 10/10/06	Tue 10/10/06
32		(B-C) Glass and Sealants	1 day	Wed 10/11/06	Wed 10/11/06
33		C Glass and Sealants - West	1 day	Thu 10/12/06	Thu 10/12/06
34		(1-2) Glass and Sealants	2 days	Fri 10/13/06	Mon 10/16/06
35		(2-3) Glass and Sealants	2 days	Tue 10/17/06	Wed 10/18/06
36		(3-4) Glass and Sealants	2 days	Thu 10/19/06	Fri 10/20/06
37		(4-5) Glass and Sealants	1 day	Mon 10/23/06	Mon 10/23/06
38		(5-6) Glass and Sealants	1 day	Tue 10/24/06	Tue 10/24/06
39		(6-7) Glass and Sealants	1 day	Wed 10/25/06	Wed 10/25/06
40		(7-8) Glass and Sealants	1 day	Thu 10/26/06	Thu 10/26/06
41		(8-9) Glass and Sealants	1 day	Fri 10/27/06	Fri 10/27/06
42		(9-10) Glass and Sealants	1 day	Mon 10/30/06	Mon 10/30/06
43		(10-Y4) Glass and Sealants - South	2 days	Tue 10/31/06	Wed 11/1/06

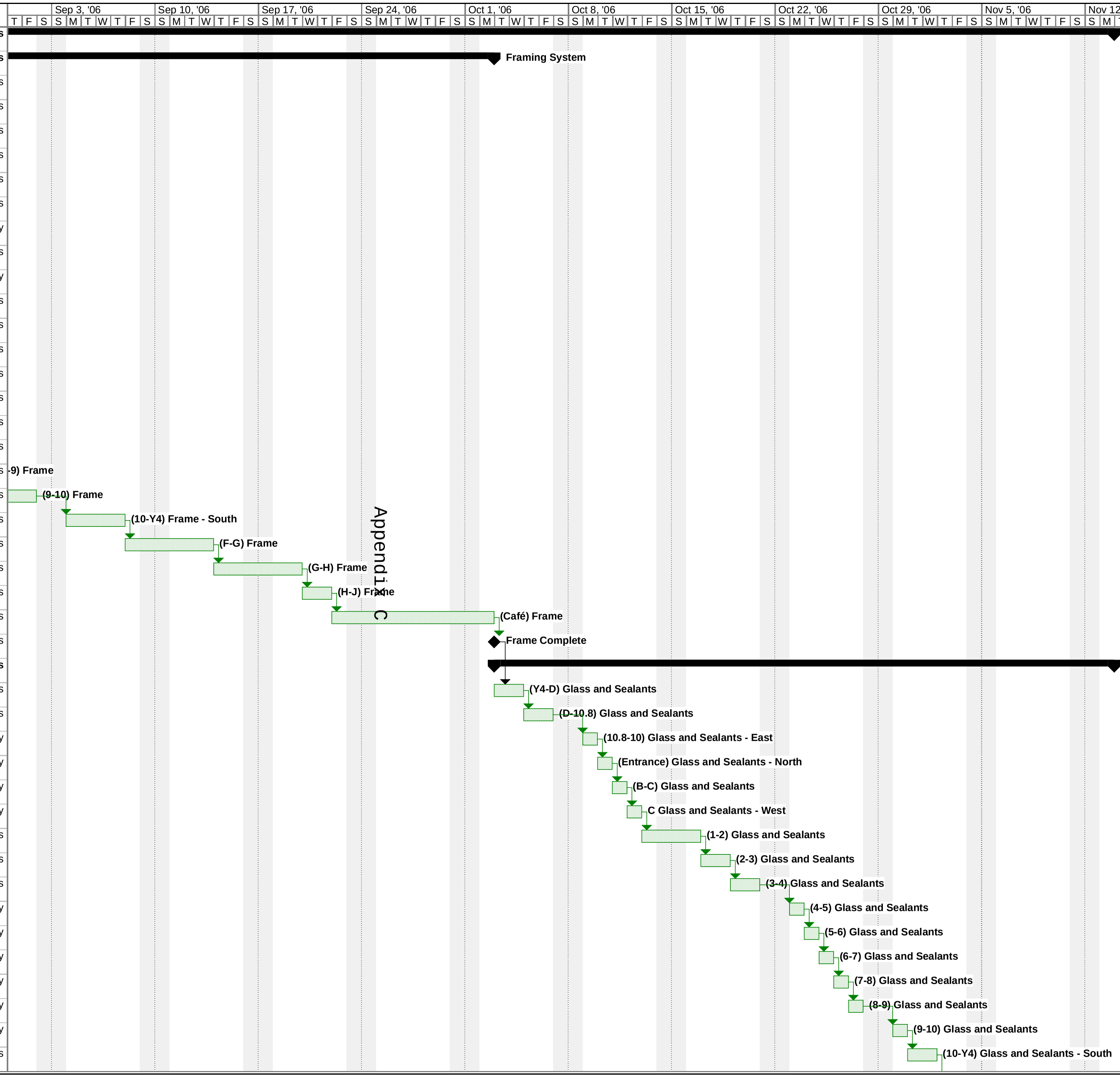


Appendix C

Project: Building Envelope Schedule
Date: Mon 4/3/06

Task	Milestone
Progress	Summary
Rolled Up Task	Rolled Up Progress
Rolled Up Milestone	Split
External Tasks	Group By Summary
Project Summary	Deadline

ID	Task Name	Duration
1	**Window Curtainwall System**	**100 days**
2	**Framing System**	**70 days**
3	(Y3-Y4) Frame - East	4 days
4	(Y3-Y4) Glass & Glazing East	2 days
5	Field Test	5 days
6	(Y4-D) Frame	2 days
7	(D-10.8) Frame	4 days
8	(10.8-10) Frame - East	3 days
9	(Entrance) Frame - North	1 day
10	(B-C) Frame	3 days
11	C Frame - West	1 day
12	(1-2) Frame	3 days
13	(2-3) Frame	4 days
14	(3-4) Frame	4 days
15	(4-5) Frame	3 days
16	(5-6) Frame	3 days
17	(6-7) Frame	3 days
18	(7-8) Frame	3 days
19	(8-9) Frame	3 days
20	(9-10) Frame	3 days
21	(10-Y4) Frame - South	4 days
22	(F-G) Frame	4 days
23	(G-H) Frame	4 days
24	(H-J) Frame	2 days
25	(Café) Frame	7 days
26	Frame Complete	0 days
27	**Glazing and Sealants**	**30 days**
28	(Y4-D) Glass and Sealants	2 days
29	(D-10.8) Glass and Sealants	2 days
30	(10.8-10) Glass and Sealants - East	1 day
31	(Entrance) Glass and Sealants - North	1 day
32	(B-C) Glass and Sealants	1 day
33	C Glass and Sealants - West	1 day
34	(1-2) Glass and Sealants	2 days
35	(2-3) Glass and Sealants	2 days
36	(3-4) Glass and Sealants	2 days
37	(4-5) Glass and Sealants	1 day
38	(5-6) Glass and Sealants	1 day
39	(6-7) Glass and Sealants	1 day
40	(7-8) Glass and Sealants	1 day
41	(8-9) Glass and Sealants	1 day
42	(9-10) Glass and Sealants	1 day
43	(10-Y4) Glass and Sealants - South	2 days

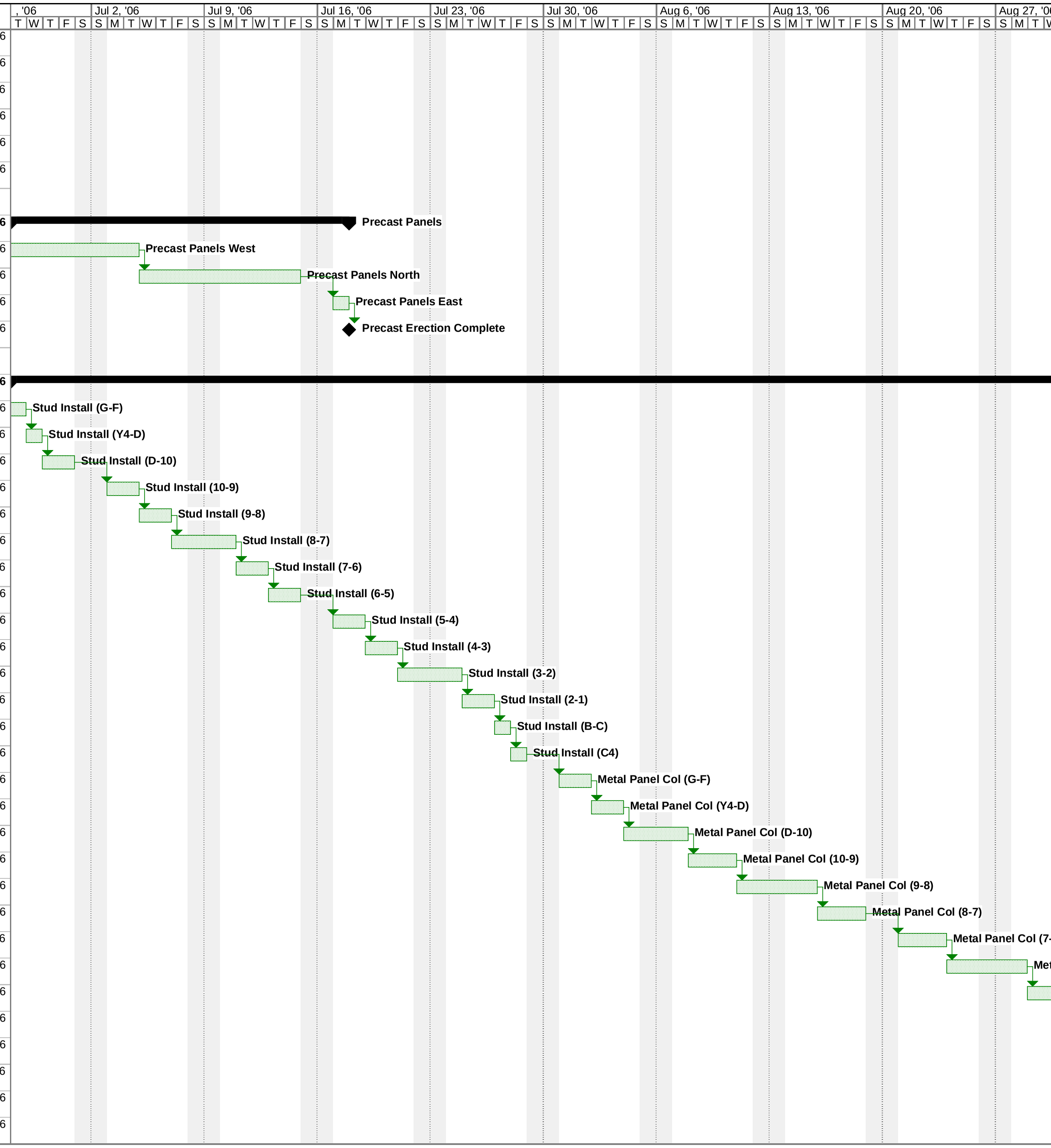


Appendix C

Project: Building Envelope Schedule
Date: Mon 4/3/06

Task · Progress · Milestone · Summary · Rolled Up Task · Rolled Up Milestone · Rolled Up Progress · Split · External Tasks · Project Summary · Group By Summary · Deadline

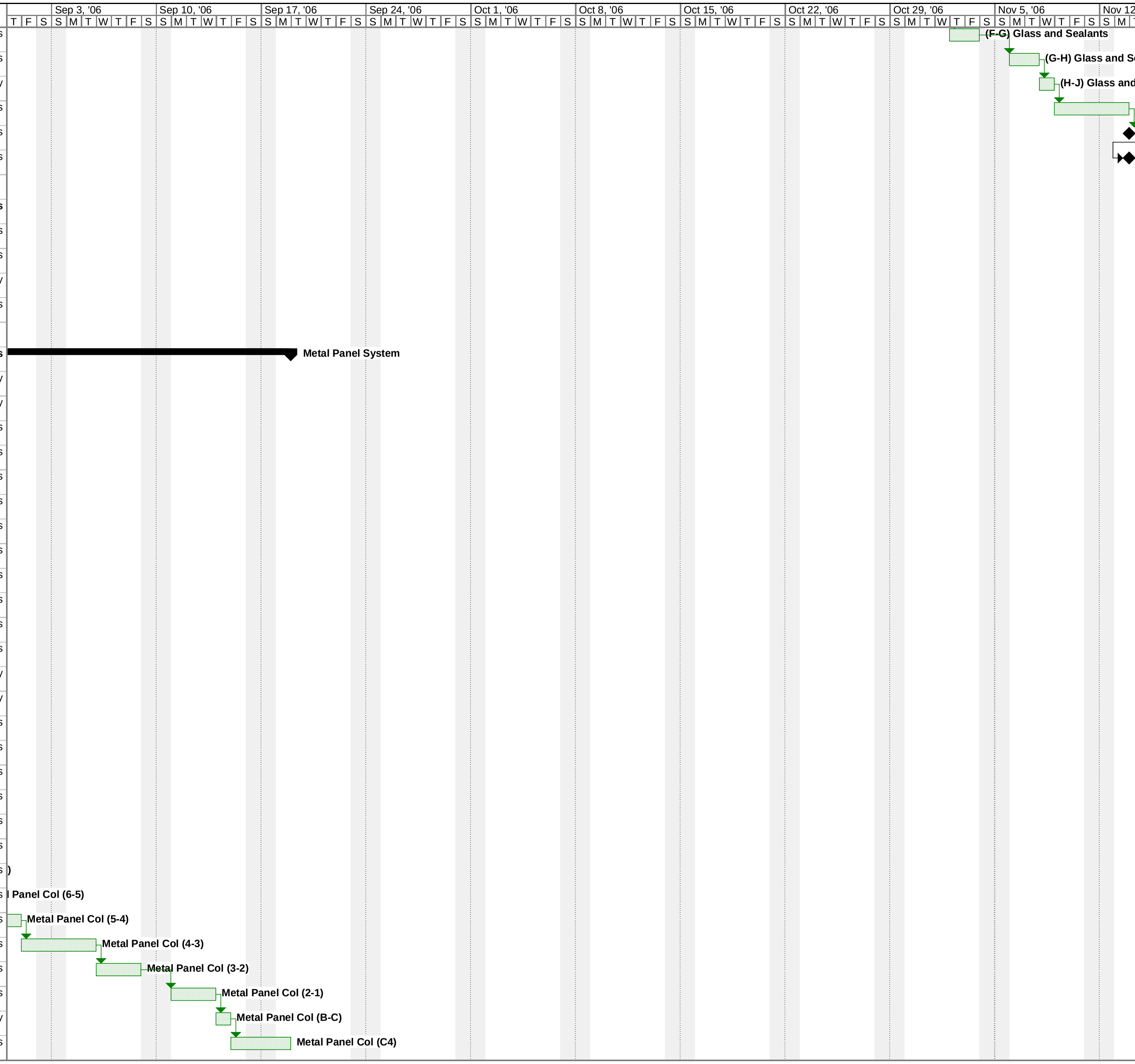
ID		Task Name	Duration	Start	Finish
44		(F-G) Glass and Sealants	2 days	Thu 11/2/06	Fri 11/3/06
45		(G-H) Glass and Sealants	2 days	Mon 11/6/06	Tue 11/7/06
46		(H-J) Glass and Sealants	1 day	Wed 11/8/06	Wed 11/8/06
47		(Café) Glass and Sealants	3 days	Thu 11/9/06	Mon 11/13/06
48		Glass and Sealants Complete	0 days	Mon 11/13/06	Mon 11/13/06
49		Aluminum Curtain Wall Complete	0 days	Mon 11/13/06	Mon 11/13/06
50					
51		**Precast Panels**	**15 days**	**Tue 6/27/06**	**Mon 7/17/06**
52		Precast Panels West	6 days	Tue 6/27/06	Tue 7/4/06
53		Precast Panels North	8 days	Wed 7/5/06	Fri 7/14/06
54		Precast Panels East	1 day	Mon 7/17/06	Mon 7/17/06
55		Precast Erection Complete	0 days	Mon 7/17/06	Mon 7/17/06
56					
57		**Metal Panel System**	**60 days**	**Tue 6/27/06**	**Mon 9/18/06**
58		Stud Install (G-F)	1 day	Tue 6/27/06	Tue 6/27/06
59		Stud Install (Y4-D)	1 day	Wed 6/28/06	Wed 6/28/06
60		Stud Install (D-10)	2 days	Thu 6/29/06	Fri 6/30/06
61		Stud Install (10-9)	2 days	Mon 7/3/06	Tue 7/4/06
62		Stud Install (9-8)	2 days	Wed 7/5/06	Thu 7/6/06
63		Stud Install (8-7)	2 days	Fri 7/7/06	Mon 7/10/06
64		Stud Install (7-6)	2 days	Tue 7/11/06	Wed 7/12/06
65		Stud Install (6-5)	2 days	Thu 7/13/06	Fri 7/14/06
66		Stud Install (5-4)	2 days	Mon 7/17/06	Tue 7/18/06
67		Stud Install (4-3)	2 days	Wed 7/19/06	Thu 7/20/06
68		Stud Install (3-2)	2 days	Fri 7/21/06	Mon 7/24/06
69		Stud Install (2-1)	2 days	Tue 7/25/06	Wed 7/26/06
70		Stud Install (B-C)	1 day	Thu 7/27/06	Thu 7/27/06
71		Stud Install (C4)	1 day	Fri 7/28/06	Fri 7/28/06
72		Metal Panel Col (G-F)	2 days	Mon 7/31/06	Tue 8/1/06
73		Metal Panel Col (Y4-D)	2 days	Wed 8/2/06	Thu 8/3/06
74		Metal Panel Col (D-10)	2 days	Fri 8/4/06	Mon 8/7/06
75		Metal Panel Col (10-9)	3 days	Tue 8/8/06	Thu 8/10/06
76		Metal Panel Col (9-8)	3 days	Fri 8/11/06	Tue 8/15/06
77		Metal Panel Col (8-7)	3 days	Wed 8/16/06	Fri 8/18/06
78		Metal Panel Col (7-6)	3 days	Mon 8/21/06	Wed 8/23/06
79		Metal Panel Col (6-5)	3 days	Thu 8/24/06	Mon 8/28/06
80		Metal Panel Col (5-4)	3 days	Tue 8/29/06	Thu 8/31/06
81		Metal Panel Col (4-3)	3 days	Fri 9/1/06	Tue 9/5/06
82		Metal Panel Col (3-2)	3 days	Wed 9/6/06	Fri 9/8/06
83		Metal Panel Col (2-1)	3 days	Mon 9/11/06	Wed 9/13/06
84		Metal Panel Col (B-C)	1 day	Thu 9/14/06	Thu 9/14/06
85		Metal Panel Col (C4)	2 days	Fri 9/15/06	Mon 9/18/06



Project: Building Envelope Schedule
Date: Mon 4/3/06

Task | Milestone | Rolled Up Task | Rolled Up Progress | External Tasks | Group By Summary
Progress | Summary | Rolled Up Milestone | Split | Project Summary | Deadline

ID	Task Name	Duration
44	(F-G) Glass and Sealants	2 days
45	(G-H) Glass and Sealants	2 days
46	(H-J) Glass and Sealants	1 day
47	(Café) Glass and Sealants	3 days
48	Glass and Sealants Complete	0 days
49	Aluminum Curtain Wall Complete	0 days
50		
51	**Precast Panels**	**15 days**
52	Precast Panels West	6 days
53	Precast Panels North	8 days
54	Precast Panels East	1 day
55	Precast Erection Complete	0 days
56		
57	**Metal Panel System**	**60 days**
58	Stud Install (G-F)	1 day
59	Stud Install (Y4-D)	1 day
60	Stud Install (D-10)	2 days
61	Stud Install (10-9)	2 days
62	Stud Install (9-8)	2 days
63	Stud Install (8-7)	2 days
64	Stud Install (7-6)	2 days
65	Stud Install (6-5)	2 days
66	Stud Install (5-4)	2 days
67	Stud Install (4-3)	2 days
68	Stud Install (3-2)	2 days
69	Stud Install (2-1)	2 days
70	Stud Install (B-C)	1 day
71	Stud Install (C4)	1 day
72	Metal Panel Col (G-F)	2 days
73	Metal Panel Col (Y4-D)	2 days
74	Metal Panel Col (D-10)	2 days
75	Metal Panel Col (10-9)	3 days
76	Metal Panel Col (9-8)	3 days
77	Metal Panel Col (8-7)	3 days
78	Metal Panel Col (7-6)	3 days
79	Metal Panel Col (6-5)	3 days
80	Metal Panel Col (5-4)	3 days
81	Metal Panel Col (4-3)	3 days
82	Metal Panel Col (3-2)	3 days
83	Metal Panel Col (2-1)	3 days
84	Metal Panel Col (B-C)	1 day
85	Metal Panel Col (C4)	2 days



Project: Building Envelope Schedule
Date: Mon 4/3/06

Task | Progress | Milestone | Summary | Rolled Up Task | Rolled Up Milestone | Rolled Up Progress | Split | External Tasks | Project Summary | Group By Summary | Deadline

Center for Health Research and Rural Advocacy
Danville, Pennsylvania
Cost and Methods Analysis
October 31, 2005

Michael Vergari
Construction Management Option
Advisor: Dr. Riley

ID	Task Name	Duration	Start	Finish
1	**Sitework & Utilities Relocation**	**321 days**	**Mon 7/18/05**	**Mon 10/9/06**
2	Utility Relocations	30 days	Mon 7/18/05	Fri 8/26/05
3	Center Street Relocation	50 days	Mon 7/18/05	Fri 9/23/05
4	Foundation Excavation	10 days	Mon 9/26/05	Fri 10/7/05
5	Sheeting / Shoring	40 days	Tue 9/20/05	Mon 11/14/05
6	Backfill East Side Building	10 days	Tue 4/4/06	Mon 4/17/06
7	Retaining Wall	20 days	Tue 4/18/06	Mon 5/15/06
8	Storm Piping	20 days	Tue 5/16/06	Mon 6/12/06
9	Medical Center Drive Reconstruction	30 days	Tue 5/16/06	Mon 6/26/06
10	Site Conduits / Site Lighting	10 days	Tue 7/11/06	Mon 7/24/06
11	Final Grading / Topsoil	10 days	Tue 8/8/06	Mon 8/21/06
12	Landscaping / Seeding	15 days	Tue 9/19/06	Mon 10/9/06
13	**Cooling Tower Relocation**	**95 days**	**Mon 8/8/05**	**Fri 12/16/05**
14	Remove Old Coiling Tower	5 days	Mon 8/8/05	Fri 8/12/05
15	Remove MEP Roof Equip	15 days	Mon 8/15/05	Fri 9/2/05
16	New Tower on Weiss Roof	20 days	Mon 9/26/05	Fri 10/21/05
17	Tower/System Shakeout	10 days	Mon 10/24/05	Fri 11/4/05
18	Relocate 2 Existing Towers	20 days	Mon 11/7/05	Fri 12/2/05
19	Remove CT UG Piping	10 days	Mon 12/5/05	Fri 12/16/05
20	**Building Structure**	**361 days**	**Mon 7/11/05**	**Mon 11/27/06**
21	**Foundations**	**160 days**	**Mon 7/11/05**	**Fri 2/17/06**
22	Auditorium Footings	18 days	Mon 7/11/05	Wed 8/3/05
23	Auditorium Walls - 2 Pours	35 days	Thu 8/4/05	Wed 9/21/05
24	Backfill Auditorium Area	5 days	Mon 7/11/05	Fri 7/15/05
25	Footings	100 days	Thu 8/4/05	Wed 12/21/05
26	Wall Pours	107 days	Thu 9/22/05	Fri 2/17/06
27	**Wall Pour 1**	**20 days**	**Thu 9/22/05**	**Wed 10/19/05**
28	Set Outside Face	5 days	Thu 9/22/05	Wed 9/28/05
29	Install Rebar	2 days	Thu 9/29/05	Fri 9/30/05
30	Set Inside Face	5 days	Mon 10/3/05	Fri 10/7/05
31	Pour	1 day	Mon 10/10/05	Mon 10/10/05
32	Cure	5 days	Tue 10/11/05	Mon 10/17/05
33	Strip	2 days	Tue 10/18/05	Wed 10/19/05
34	**Wall Pour 2**	**20 days**	**Tue 11/15/05**	**Mon 12/12/05**
35	Set Outside Face	5 days	Tue 11/15/05	Mon 11/21/05
36	Install Rebar	2 days	Tue 11/22/05	Wed 11/23/05
37	Set Inside Face	5 days	Thu 11/24/05	Wed 11/30/05
38	Pour	1 day	Thu 12/1/05	Thu 12/1/05
39	Cure	5 days	Fri 12/2/05	Thu 12/8/05
40	Strip	2 days	Fri 12/9/05	Mon 12/12/05
41	**Wall Pour 3**	**20 days**	**Tue 12/6/05**	**Mon 1/2/06**
42	Set Outside Face	5 days	Tue 12/6/05	Mon 12/12/05
43	Install Rebar	2 days	Tue 12/13/05	Wed 12/14/05
44	Set Inside Face	5 days	Thu 12/15/05	Wed 12/21/05
45	Pour	1 day	Thu 12/22/05	Thu 12/22/05
46	Cure	5 days	Fri 12/23/05	Thu 12/29/05
47	Strip	2 days	Fri 12/30/05	Mon 1/2/06
48	**Wall Pour 4**	**20 days**	**Tue 12/27/05**	**Mon 1/23/06**
49	Set Outside Face	5 days	Tue 12/27/05	Mon 1/2/06
50	Install Rebar	2 days	Tue 1/3/06	Wed 1/4/06
51	Set Inside Face	5 days	Thu 1/5/06	Wed 1/11/06
52	Pour	1 day	Thu 1/12/06	Thu 1/12/06
53	Cure	5 days	Fri 1/13/06	Thu 1/19/06
54	Strip	2 days	Fri 1/20/06	Mon 1/23/06
55	**Wall Pour 5**	**20 days**	**Mon 10/10/05**	**Fri 11/4/05**
56	Set Outside Face	5 days	Mon 10/10/05	Fri 10/14/05
57	Install Rebar	2 days	Mon 10/17/05	Tue 10/18/05
58	Set Inside Face	5 days	Wed 10/19/05	Tue 10/25/05
59	Pour	1 day	Wed 10/26/05	Wed 10/26/05
60	Cure	5 days	Thu 10/27/05	Wed 11/2/05
61	Strip	2 days	Thu 11/3/05	Fri 11/4/05
62	**Wall Pour 6**	**20 days**	**Mon 10/31/05**	**Fri 11/25/05**

Project: Project Schedule
Date: Mon 4/3/06

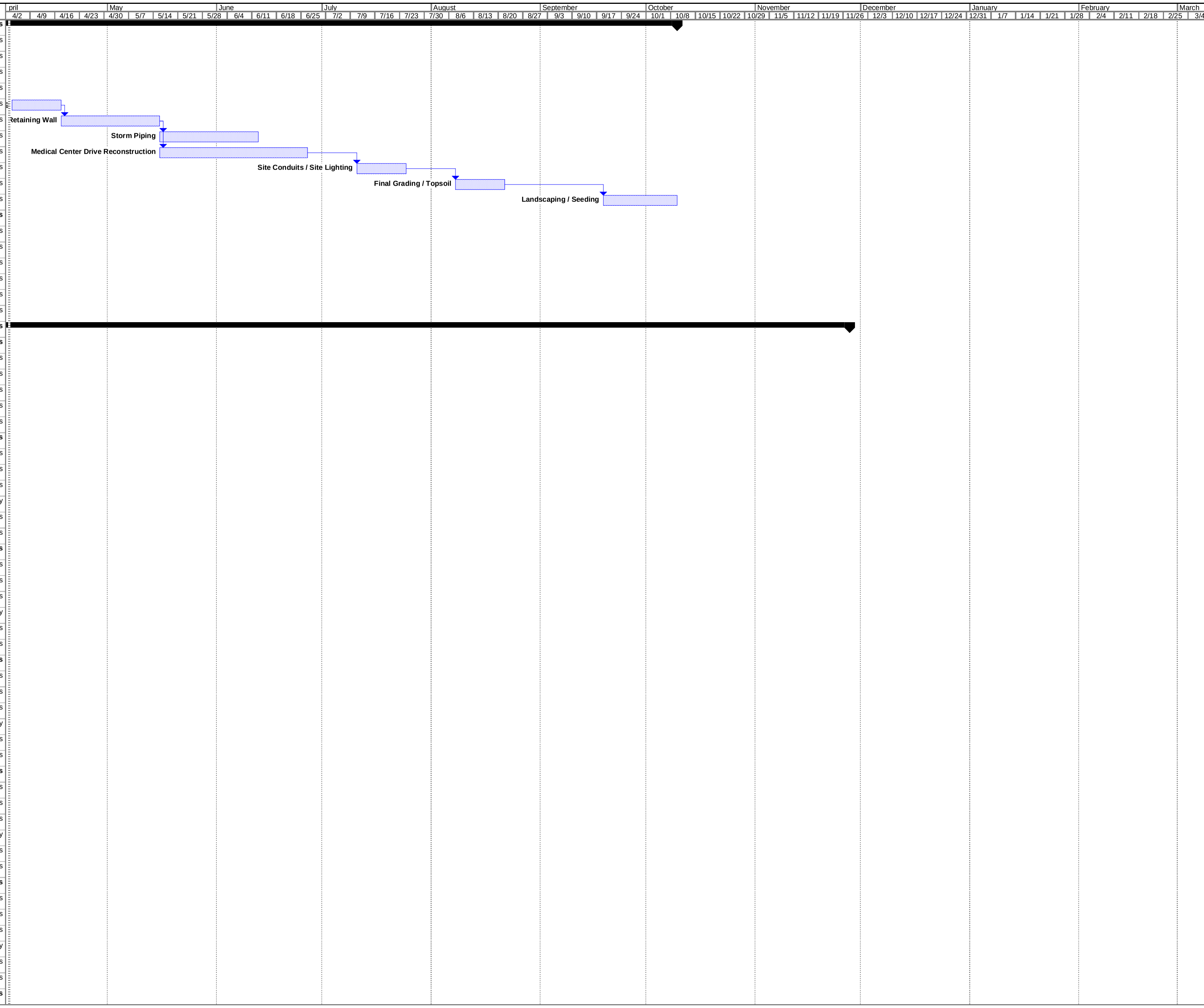
Task		Milestone		Rolled Up Task		Rolled Up Progress		External Tasks	
Progress		Summary		Rolled Up Milestone		Split		Project Summary	

Group By Summary
Deadline

Appendix D

Michael Vergari
Construction Management Option
Advisor: Dr. Riley

ID	Task Name	Duration
1	**Sitework & Utilities Relocation**	**321 days**
2	Utility Relocations	30 days
3	Center Street Relocation	50 days
4	Foundation Excavation	10 days
5	Sheeting / Shoring	40 days
6	Backfill East Side Building	10 days
7	Retaining Wall	20 days
8	Storm Piping	20 days
9	Medical Center Drive Reconstruction	30 days
10	Site Conduits / Site Lighting	10 days
11	Final Grading / Topsoil	10 days
12	Landscaping / Seeding	15 days
13	**Cooling Tower Relocation**	**95 days**
14	Remove Old Coiling Tower	5 days
15	Remove MEP Roof Equip	15 days
16	New Tower on Weiss Roof	20 days
17	Tower/System Shakeout	10 days
18	Relocate 2 Existing Towers	20 days
19	Remove CT UG Piping	10 days
20	**Building Structure**	**361 days**
21	**Foundations**	**160 days**
22	Auditorium Footings	18 days
23	Auditorium Walls - 2 Pours	35 days
24	Backfill Auditorium Area	5 days
25	Footings	100 days
26	Wall Pours	107 days
27	**Wall Pour 1**	**20 days**
28	Set Outside Face	5 days
29	Install Rebar	2 days
30	Set Inside Face	5 days
31	Pour	1 day
32	Cure	5 days
33	Strip	2 days
34	**Wall Pour 2**	**20 days**
35	Set Outside Face	5 days
36	Install Rebar	2 days
37	Set Inside Face	5 days
38	Pour	1 day
39	Cure	5 days
40	Strip	2 days
41	**Wall Pour 3**	**20 days**
42	Set Outside Face	5 days
43	Install Rebar	2 days
44	Set Inside Face	5 days
45	Pour	1 day
46	Cure	5 days
47	Strip	2 days
48	**Wall Pour 4**	**20 days**
49	Set Outside Face	5 days
50	Install Rebar	2 days
51	Set Inside Face	5 days
52	Pour	1 day
53	Cure	5 days
54	Strip	2 days
55	**Wall Pour 5**	**20 days**
56	Set Outside Face	5 days
57	Install Rebar	2 days
58	Set Inside Face	5 days
59	Pour	1 day
60	Cure	5 days
61	Strip	2 days
62	**Wall Pour 6**	**20 days**



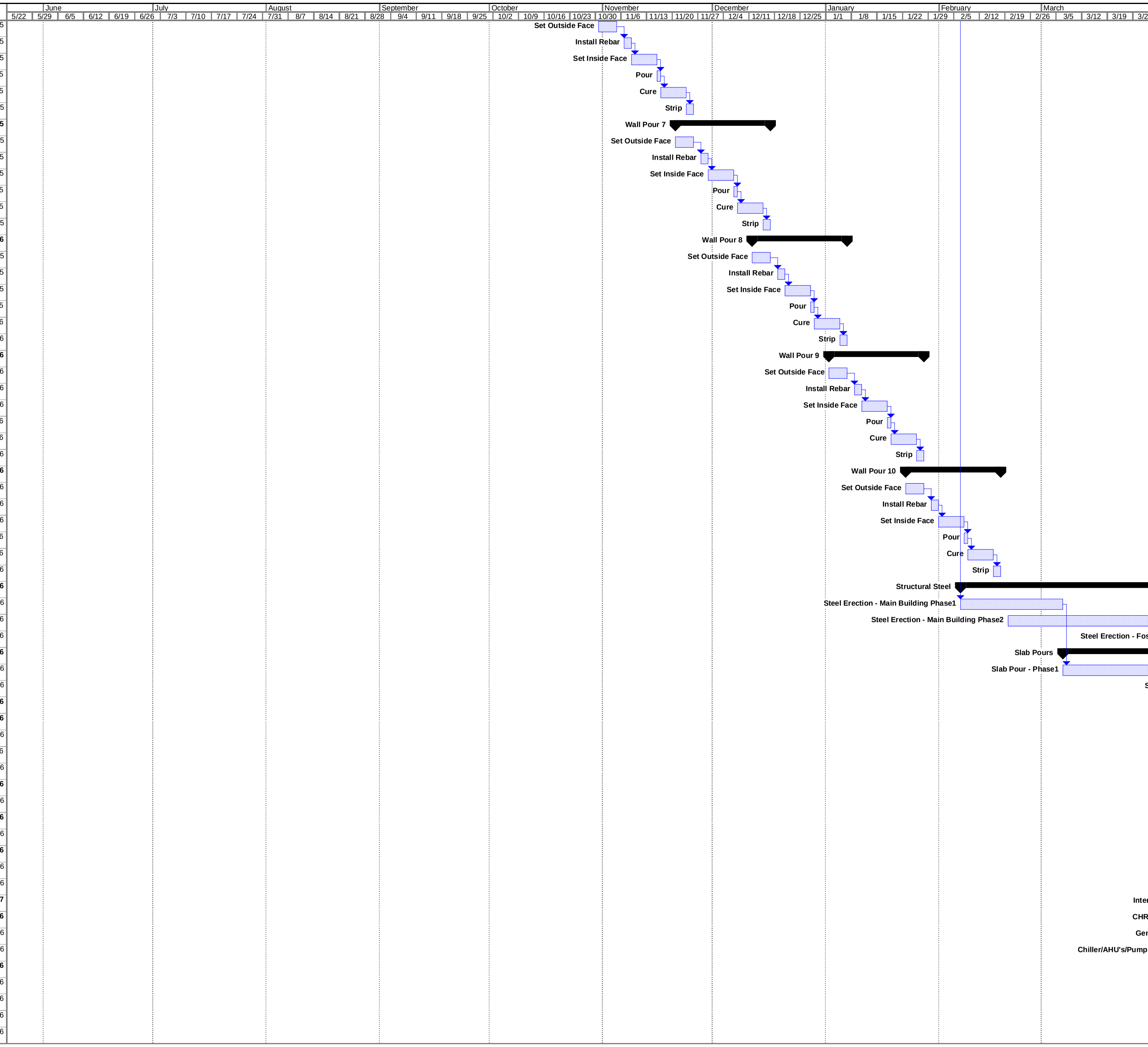
Project: Project Schedule Date: Mon 4/3/06	Task		Milestone		Rolled Up Task		Rolled Up Progress		External Tasks		Group By Summary
	Progress		Summary		Rolled Up Milestone		Split		Project Summary		Deadline

Appendix D

Center for Health Research and Rural Advocacy
Danville, Pennsylvania
Cost and Methods Analysis
October 31, 2005

Michael Vergari
Construction Management Option
Advisor: Dr. Riley

ID		Task Name	Duration	Start	Finish
63		Set Outside Face	5 days	Mon 10/31/05	Fri 11/4/05
64		Install Rebar	2 days	Mon 11/7/05	Tue 11/8/05
65		Set Inside Face	5 days	Wed 11/9/05	Tue 11/15/05
66		Pour	1 day	Wed 11/16/05	Wed 11/16/05
67		Cure	5 days	Thu 11/17/05	Wed 11/23/05
68		Strip	2 days	Thu 11/24/05	Fri 11/25/05
69		**Wall Pour 7**	**20 days**	**Mon 11/21/05**	**Fri 12/16/05**
70		Set Outside Face	5 days	Mon 11/21/05	Fri 11/25/05
71		Install Rebar	2 days	Mon 11/28/05	Tue 11/29/05
72		Set Inside Face	5 days	Wed 11/30/05	Tue 12/6/05
73		Pour	1 day	Wed 12/7/05	Wed 12/7/05
74		Cure	5 days	Thu 12/8/05	Wed 12/14/05
75		Strip	2 days	Thu 12/15/05	Fri 12/16/05
76		**Wall Pour 8**	**20 days**	**Mon 12/12/05**	**Fri 1/6/06**
77		Set Outside Face	5 days	Mon 12/12/05	Fri 12/16/05
78		Install Rebar	2 days	Mon 12/19/05	Tue 12/20/05
79		Set Inside Face	5 days	Wed 12/21/05	Tue 12/27/05
80		Pour	1 day	Wed 12/28/05	Wed 12/28/05
81		Cure	5 days	Thu 12/29/05	Wed 1/4/06
82		Strip	2 days	Thu 1/5/06	Fri 1/6/06
83		**Wall Pour 9**	**20 days**	**Mon 1/2/06**	**Fri 1/27/06**
84		Set Outside Face	5 days	Mon 1/2/06	Fri 1/6/06
85		Install Rebar	2 days	Mon 1/9/06	Tue 1/10/06
86		Set Inside Face	5 days	Wed 1/11/06	Tue 1/17/06
87		Pour	1 day	Wed 1/18/06	Wed 1/18/06
88		Cure	5 days	Thu 1/19/06	Wed 1/25/06
89		Strip	2 days	Thu 1/26/06	Fri 1/27/06
90		**Wall Pour 10**	**20 days**	**Mon 1/23/06**	**Fri 2/17/06**
91		Set Outside Face	5 days	Mon 1/23/06	Fri 1/27/06
92		Install Rebar	2 days	Mon 1/30/06	Tue 1/31/06
93		Set Inside Face	5 days	Wed 2/1/06	Tue 2/7/06
94		Pour	1 day	Wed 2/8/06	Wed 2/8/06
95		Cure	5 days	Thu 2/9/06	Wed 2/15/06
96		Strip	2 days	Thu 2/16/06	Fri 2/17/06
97		**Structural Steel**	**49 days**	**Tue 2/7/06**	**Fri 4/14/06**
98		Steel Erection - Main Building Phase	20 days	Tue 2/7/06	Mon 3/6/06
99		Steel Erection - Main Building Phase	35 days	Mon 2/20/06	Fri 4/7/06
100		Steel Erection - Foss Canopy	5 days	Mon 4/10/06	Fri 4/14/06
101		**Slab Pours**	**80 days**	**Tue 3/7/06**	**Mon 6/26/06**
102		Slab Pour - Phase1	30 days	Tue 3/7/06	Mon 4/17/06
103		Slab Pour - Phase2	50 days	Tue 4/18/06	Mon 6/26/06
104		**Exterior Building Envelope**	**110 days**	**Tue 6/27/06**	**Mon 11/27/06**
105		**Window Curtainwall System**	**100 days**	**Tue 6/27/06**	**Mon 11/13/06**
106		Framing System	70 days	Tue 6/27/06	Mon 10/2/06
107		Field Test	5 days	Thu 7/27/06	Wed 8/2/06
108		Glazing/Sealants	30 days	Tue 10/3/06	Mon 11/13/06
109		**Precast Panels**	**15 days**	**Tue 6/27/06**	**Mon 7/17/06**
110		Precast Panel Erection and Alig	15 days	Tue 6/27/06	Mon 7/17/06
111		**Metal Panel System**	**60 days**	**Tue 6/27/06**	**Mon 9/18/06**
112		Installation	60 days	Tue 6/27/06	Mon 9/18/06
113		**Roof System Installation**	**110 days**	**Tue 6/27/06**	**Mon 11/27/06**
114		Roof System Final Tie-Ins	25 days	Tue 6/27/06	Mon 7/31/06
115		Roof System Sealants	10 days	Tue 11/14/06	Mon 11/27/06
116		**Interior Construction**	**201 days**	**Tue 4/18/06**	**Tue 1/23/07**
117		**CHRRA Central Plant**	**80 days**	**Tue 4/18/06**	**Mon 8/7/06**
118		Generator Installation	15 days	Tue 4/18/06	Mon 5/8/06
119		Chiller/AHU's/Pumps/Ductwork/Pipir	80 days	Tue 4/18/06	Mon 8/7/06
120		**Ground Floor Construction**	**93 days**	**Fri 8/4/06**	**Tue 12/12/06**
121		Layout	3 days	Fri 8/4/06	Tue 8/8/06
122		Overhead MEP Rough-In	20 days	Wed 8/9/06	Tue 9/5/06
123		Metal Studs	15 days	Wed 8/23/06	Tue 9/12/06
124		Wall Rough-In	15 days	Wed 9/6/06	Tue 9/26/06



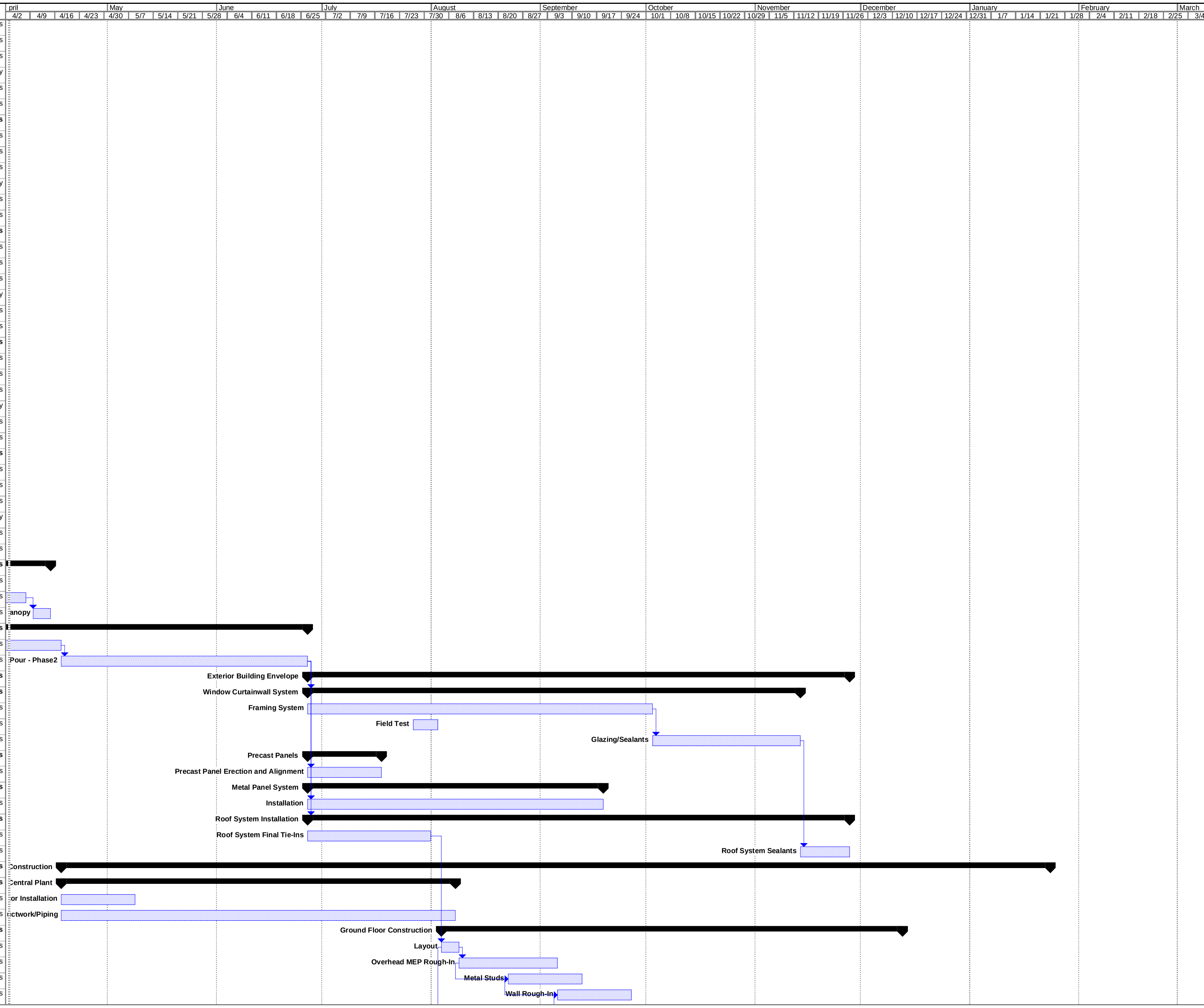
Project: Project Schedule
Date: Mon 4/3/06

Task		Milestone		Rolled Up Task		Rolled Up Progress		External Tasks		Group By Summary	
Progress		Summary		Rolled Up Milestone		Split		Project Summary		Deadline	

Center for Health Research and Rural Advocacy
Danville, Pennsylvania
Cost and Methods Analysis
October 31, 2005

Michael Vergari
Construction Management Option
Advisor: Dr. Riley

ID	Task Name	Duration
63	Set Outside Face	5 days
64	Install Rebar	2 days
65	Set Inside Face	5 days
66	Pour	1 day
67	Cure	5 days
68	Strip	2 days
69	**Wall Pour 7**	**20 days**
70	Set Outside Face	5 days
71	Install Rebar	2 days
72	Set Inside Face	5 days
73	Pour	1 day
74	Cure	5 days
75	Strip	2 days
76	**Wall Pour 8**	**20 days**
77	Set Outside Face	5 days
78	Install Rebar	2 days
79	Set Inside Face	5 days
80	Pour	1 day
81	Cure	5 days
82	Strip	2 days
83	**Wall Pour 9**	**20 days**
84	Set Outside Face	5 days
85	Install Rebar	2 days
86	Set Inside Face	5 days
87	Pour	1 day
88	Cure	5 days
89	Strip	2 days
90	**Wall Pour 10**	**20 days**
91	Set Outside Face	5 days
92	Install Rebar	2 days
93	Set Inside Face	5 days
94	Pour	1 day
95	Cure	5 days
96	Strip	2 days
97	**Structural Steel**	**49 days**
98	Steel Erection - Main Building Phase	20 days
99	Steel Erection - Main Building Phase	35 days
100	Steel Erection - Foss Canopy	5 days
101	**Slab Pours**	**80 days**
102	Slab Pour - Phase1	30 days
103	Slab Pour - Phase2	50 days
104	**Exterior Building Envelope**	**110 days**
105	**Window Curtainwall System**	**100 days**
106	Framing System	70 days
107	Field Test	5 days
108	Glazing/Sealants	30 days
109	**Precast Panels**	**15 days**
110	Precast Panel Erection and Alig	15 days
111	**Metal Panel System**	**60 days**
112	Installation	60 days
113	**Roof System Installation**	**110 days**
114	Roof System Final Tie-Ins	25 days
115	Roof System Sealants	10 days
116	**Interior Construction**	**201 days**
117	**CHRRA Central Plant**	**80 days**
118	Generator Installation	15 days
119	Chiller/AHU's/Pumps/Ductwork/Pipir	80 days
120	**Ground Floor Construction**	**93 days**
121	Layout	3 days
122	Overhead MEP Rough-In	20 days
123	Metal Studs	15 days
124	Wall Rough-In	15 days



Project: Project Schedule
Date: Mon 4/3/06

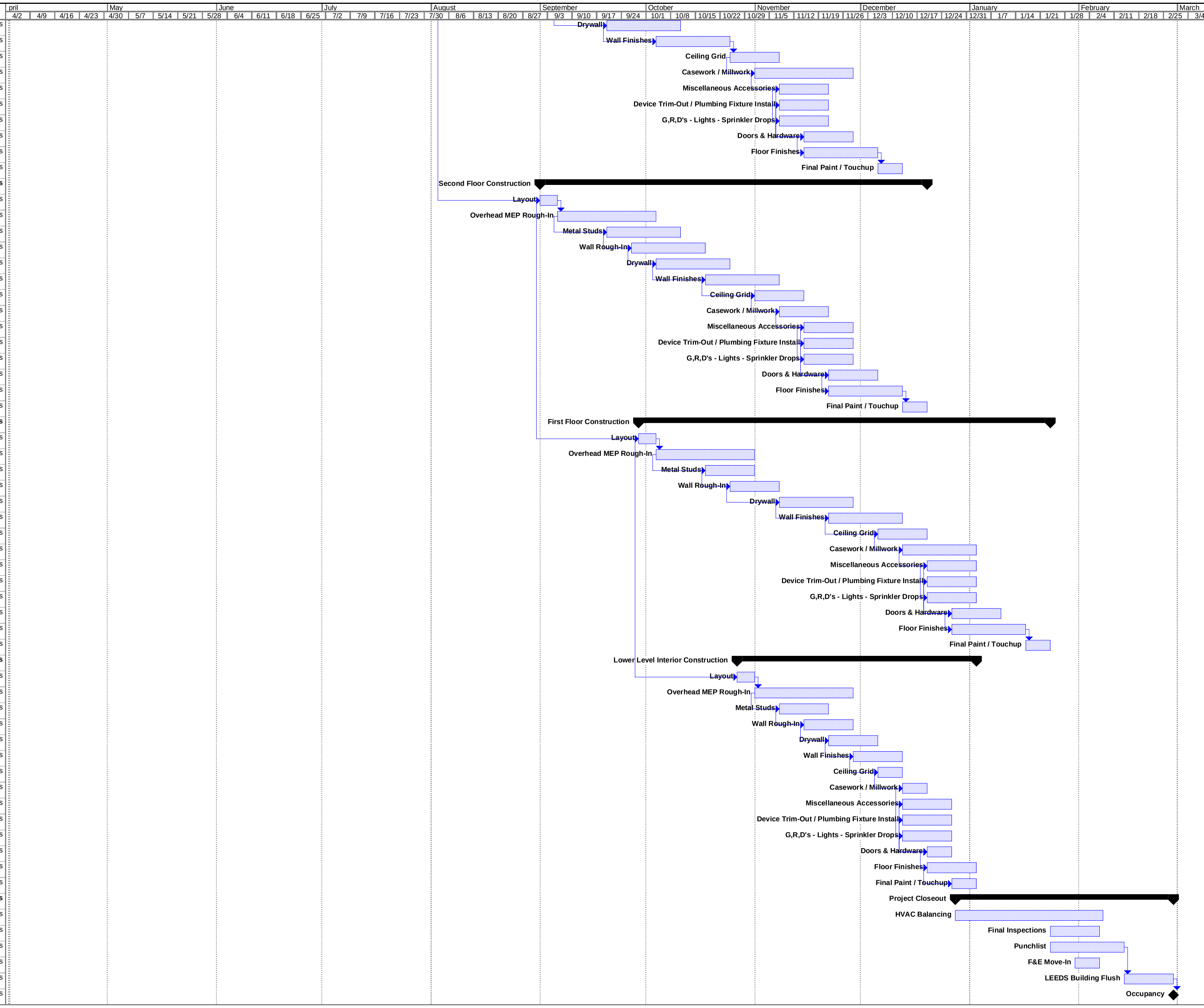
Task		Milestone		Rolled Up Task		Rolled Up Progress		External Tasks		Group By Summary	
Progress		Summary		Rolled Up Milestone		Split		Project Summary		Deadline	

Microsoft Project 2003

Center for Health Research and Rural Advocacy
Danville, Pennsylvania
Cost and Methods Analysis
October 31, 2005

Michael Vergari
Construction Management Option
Advisor: Dr. Riley

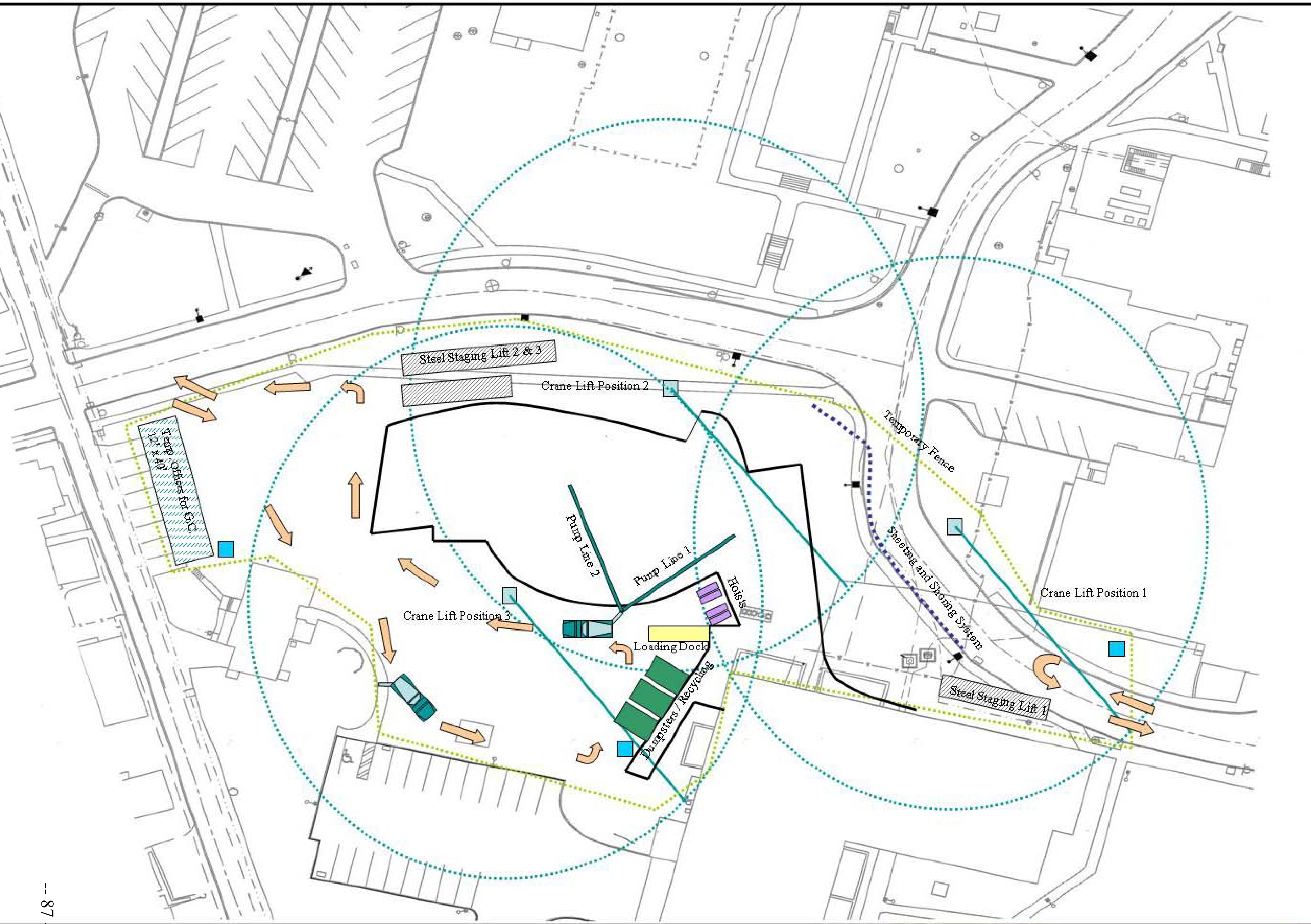
ID	Task Name	Duration
125	Drywall	15 days
126	Wall Finishes	15 days
127	Ceiling Grid	10 days
128	Casework / Millwork	20 days
129	Miscellaneous Accessories	10 days
130	Device Trim-Out / Plumbing Fixture	10 days
131	G,R,D's - Lights - Sprinkler Drops	10 days
132	Doors & Hardware	10 days
133	Floor Finishes	15 days
134	Final Paint / Touchup	5 days
135	**Second Floor Construction**	**78 days**
136	Layout	3 days
137	Overhead MEP Rough-In	20 days
138	Metal Studs	15 days
139	Wall Rough-In	15 days
140	Drywall	15 days
141	Wall Finishes	15 days
142	Ceiling Grid	10 days
143	Casework / Millwork	10 days
144	Miscellaneous Accessories	10 days
145	Device Trim-Out / Plumbing Fixture	10 days
146	G,R,D's - Lights - Sprinkler Drops	10 days
147	Doors & Hardware	10 days
148	Floor Finishes	15 days
149	Final Paint / Touchup	5 days
150	**First Floor Construction**	**83 days**
151	Layout	3 days
152	Overhead MEP Rough-In	20 days
153	Metal Studs	10 days
154	Wall Rough-In	10 days
155	Drywall	15 days
156	Wall Finishes	15 days
157	Ceiling Grid	10 days
158	Casework / Millwork	15 days
159	Miscellaneous Accessories	10 days
160	Device Trim-Out / Plumbing Fixture	10 days
161	G,R,D's - Lights - Sprinkler Drops	10 days
162	Doors & Hardware	10 days
163	Floor Finishes	15 days
164	Final Paint / Touchup	5 days
165	**Lower Level Interior Construction**	**48 days**
166	Layout	3 days
167	Overhead MEP Rough-In	20 days
168	Metal Studs	10 days
169	Wall Rough-In	10 days
170	Drywall	10 days
171	Wall Finishes	10 days
172	Ceiling Grid	5 days
173	Casework / Millwork	5 days
174	Miscellaneous Accessories	10 days
175	Device Trim-Out / Plumbing Fixture	10 days
176	G,R,D's - Lights - Sprinkler Drops	10 days
177	Doors & Hardware	5 days
178	Floor Finishes	10 days
179	Final Paint / Touchup	5 days
180	**Project Closeout**	**44 days**
181	HVAC Balancing	30 days
182	Final Inspections	10 days
183	Punchlist	15 days
184	F&E Move-In	5 days
185	LEEDS Building Flush	10 days
186	Occupancy	0 days

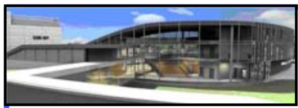


Project: Project Schedule
Date: Mon 4/3/06

Task | Progress | Milestone | Summary | Rolled Up Task | Rolled Up Milestone | Rolled Up Progress | Split | External Tasks | Project Summary | Group By Summary | Deadline

Microsoft Project 2003


Steel Staging Lift 2 & 3
Crane Lift Position 2
Temporary Fence
Temp. Offices for G.C.
12' x 40'
Pump Line 2
Pump Line 1
Hoists
Sheeting and Shoring System
Crane Lift Position 1
Crane Lift Position 3
Loading Dock
Dumpsters / Recycling
Steel Staging Lift 1



Appendix E: References

Personal Contacts

- ***Geisinger Facilities*** : Mitch Leiby
- ***Geisinger Health Services*** : Bill Gladish
- ***Harmon Inc.*** : Ron Mantegna
- ***ISEC Inc.*** : Jim Golemboski

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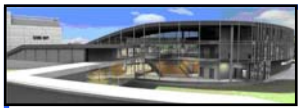
<http://www.glass.org/affprof/r_unitizedorstick.htm>

- U.S. Green Building Council <http://www.usgbc.org>
- U.S. General Services Administration <http://www.gsa.org>

Computer Resources

- Autodesk: AutoCAD 2006
- Autodesk: VIZ 2006
- CostWorks Version 8.0
- Navisworks Jetstream



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- *I would like to thank the following Industry Professionals for help with the following items:*

  Mitch Leiby …everything and anything I wanted to know about the CHRRA

  Ron Mantegna … everything and anything I wanted to know about aluminum glazing

  Bill Gladish … the overview of the Geisinger Health System

  Jim Golemboski … how to set up a prefabrication facility for a specific job

- *Fellow AE students for all the random help regarding computer programs, calculations, etc.*

  Noah Asbaugh ... I know I asked you three times how to print out my schedules

  Joe Bednarz … structural help and literature

  Sean Ehlers … thanks for the optimism

  Vivien Luo …the prefabrication extraordinaire

  Jason McFadden … the help with getting the right words and setting up ICON Lab

- *AE Faculty for all the assistance with formulating my ideas into a manageable thesis*

- *My friends and family for helping to cheer me up during those long hours and putting up with me during those crunch times. I could not have done it without you.*