New Regional Medical Center

East Norriton, PA

Senior Thesis Final Report

Implementing VDC tactics to add value in design, preconstruction, construction, and document turnover

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Construction Management Option

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AE 482 | Spring 2012

EAST NORRITON, PA

NEW REGIONAL MEDICAL CENTER

PROJECT OVERVIEW

Owner:	New Regional Medical Center, Inc.
Construction Manager:	Gilbane Building Company
Architect:	Perkins + Will, Inc.
Structural Engineer:	O'Donnell & Naccarato
Civil Engineer:	Bohler Engineering, Inc.
MEPF Engineer:	PWI Engineering
Project Cost:	$147 million
Size & Height:	366,780 SF | 5 Stories
Duration:	July 6, 2010 - August 31, 2012

ARCHITECTURAL FEATURES

- 96 medical & surgical | 22 ICU | 20 obstetrical | 8 neonatal beds
- 5 story glass atrium with smoke management system
- Curtain wall composition: precast concrete panels & glazing
- LEED Certified Rating

MECHANICAL SYSTEM

- 10,800 square foot Central Utility Plant
- 9 AHU's | 3 water chillers (two 825 ton, one 450 ton) | three boilers (two 500 HP, one 400 HP)
- Variable air volume systems located in each patient room to provide personalized heating and cooling needs
- Double Interlocked Deluge Preaction Sprinkler System

ELECTRICAL SYSTEM

- 500A, 480/277V, 3 phase, 4 wire feed supplies the building through two redundant 3750 KVA 408/277V transformers
- Seventy-nine 480/277V | Ninety-six 120/208V panel boards feeding the building systems
- Two 100KW, 1250KVA generators

CONSTRUCTION

- 84-acre Greenfield Property | 30-acre preserved
- CM at Risk contract | Guaranteed Maximum Price
- Foundations phased North to South | Steel phased West to East | Finishes phased top-down, bottom-up meeting on 1st Floor
- Hospital staff training scheduled August 8 - October 15, 2012

STRUCTURAL SYSTEM

- Cast-in-place concrete column footings & foundation walls
- Structural steel frame | 30' x 30' grid
- W12 & W14 column with splices at 1st & 3rd Floors
- W24 girders & W14 beams with flexible moment connections at column connections
- All slabs consist of metal decking, shear studs, WWF & composite concrete

BRIAN J. NAHAS | CONSTRUCTION MANAGEMENT

HTTP://WWW.ENGR.PSU.EDU/AE/THESIS/PORTFOLIOS/2012/BJN5029/INDEX.HTML

Senior Thesis Final Report
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Executive Summary

This Senior Thesis Final Report includes the process development and outcomes derived through the analysis of the New Regional Medical Center. This facility is a new construction, 5 floors, 366,780 square foot hospital in East Norriton, Pennsylvania, and is associated with the Einstein Healthcare Network.

Through the four areas of technical analysis, investigation and applications have identified construction efficiency through information exchange. BIM utilization will streamline the construction estimating and planning processes on this project. An effective curtain wall modularization and architectural redesign of the atrium, in addition to a structural redesign of the concrete pour strips, will provide a strong comparison of the benefits in early designer and builder communication. Finally, the development of a facility management interface for building operation will identify innovative solutions and provide substantial benefits of a project-based document interface.

BIM in Preconstruction:

Model-based estimating is a growing VDC concept within construction firms. Over the past few years, industry leaders have begun developing internal processes in order to identify and understand the capabilities of this method. This analysis investigated the implementation of this strategy for estimating the structural bid packages -- identifying strengths, weaknesses, and industry growth. The structural steel Revit-based estimate produced a cost of $7,710,326, which is 0.50% above the schedule of values logged for this system. The cast-in-place concrete estimate was not as successful, resulting in a 10.70% deviation for the schedule of. It has been recommended that implementation of 5D estimating for a structural steel system is effective.

As VDC gains speed within the industry in traditional applications, developments were made to identify a logical workflow, extracting data from the structural steel model to identify the most cost effective erection process. It was recognized that the workflow of the structural erection of the New Regional Medical Center contained an oversize crane for 77% of the duration. Through this visual analysis of Revit-based data, it was recognized that construction by sector is a more efficient process. This analysis identified a new VDC method in order to highlight trending data within a structural steel model, and resulted in a savings of two weeks on the construction schedule, in addition to $315,727 of the project cost.

Redesign of Atrium Enclosure Process

Prefabrication and unitization of glazing systems have been recognized for developing higher quality, faster installation, and a safer working environment. This analysis investigates the consideration of unitization of the atrium's curtain wall and a related architectural redesign to improve construction logistics and enhance the utilization of open space in the facility. At $123,455, the architectural redesign included the addition of floor levels and corridor access along the curtain wall at the 1st and 3rd levels. The cost savings are minor for the unitization of the curtain wall; however, it would provide a safer work environment, higher quality, and a tighter work schedule.

This analysis created an aesthetically pleasing space to improve constructability and eliminate a high-risk construction process on the site, while also providing a space for patient and visitors to enjoy the greenfield

landscape surrounding the hospital. It was recognized that the unitization of the curtain wall system would reduce field assembly duration; however, require a 20-week lead-time to procure and assemble the units. Unitization would have only been logical if the glazing subcontractor was brought into the project earlier to assist with design development.

Redesign of Structural Pour Strip

Constructability issues versus design decisions are consistently reviewed in order to understand the implication of a chosen system. This analysis preforms a cost comparison of the expansion system of the facility to identify if the selected system is the best option for the owner. It has been identified that the building's pour strip system is a more cost effective design decision. The choice to utilize the pour strips over expansion joints saved the project approximately $57,800. The analysis also clarified that the building's pour strip system is a more aesthetically pleasing system and is preferred by the Owner.

It is recommended that other design teams and Owners investigate the implications of a pour strip within their facility in lieu of an expansion joint. Although the expansion joint provides a simpler construction method, the aesthetic results and additional costs may not be worthwhile. Through the utilization of design alternative in Autodesk Revit, the design team or construction management firm can quickly analyze the cost benefits and cross-reference these outcomes with the intentions and goals of the Owner and facility user group.

Document Management for the Owner

This analysis focused on the research into the development of an accessible, easy to use, and updatable, document management system for the facility management team after the construction of the building. Through industry discussion, interface development, and continued feedback from the user group, it was identified that this system is critical to streamlining the workflow of a facility management team.

This analysis confirms the capabilities of new approaches to document controls and turnover packages for an owner. Although a digital turnover interface is not included with the original package of the New Regional Medical Center, with development, the concepts shared through this research will permit the Owner to incorporate the ideas into their new healthcare campus in East Norriton, PA. By providing new methods such as an FM Dashboard and FM Interact to host BIM packages and construction documents in a simple interface, the user group can easily sort through great quantities of documents to find applicable items.

It is recommended that Owners, notably from Universities and Healthcare Systems, need to develop their internal goals of document management. Although construction companies will be capable of developing a web based interface and document controls for turnover, larger Owners should outline their own method in order to streamline and combine all of this facilities into a common system.

Acknowledgements

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Dr. Craig Dubler & the Facility Management Staff at Penn State's Office of Physical Plant

PACE Industry Members

My Family & Friends

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The New Regional Medical Center

Owner: The New Regional Medical Center, Inc.

Building Introduction

Site Overview

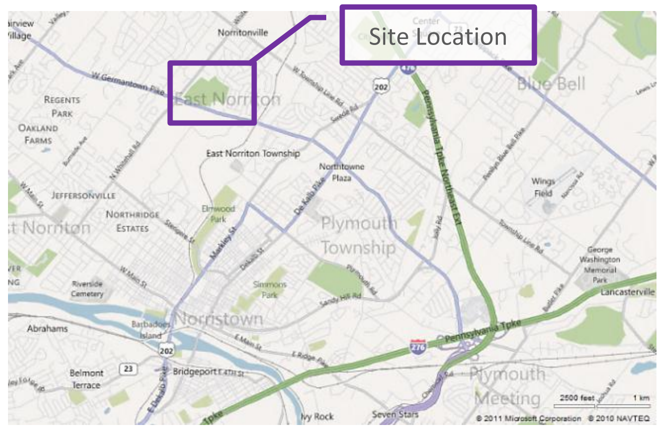


Figure 1: Regional Map | Bing.com

The New Regional Medical Center is located at 559 West Germantown Pike in East Norriton, Pennsylvania (Figure 1). The selected site is an 84-acre greenfield property, which was previously occupied by an 18-hole golf course, miniature golf course, and auxiliary buildings; this site provides a very accessible and open plan for development. It is located directly off of a main arterial road (Germantown Pike) which bisected half of Montgomery County, and provides access to major roadway systems of neighboring counties. The site design shall preserve over one-third of the property as open green space for patients, visitors, and public walking trails. Along Germantown Pike, on the Southwest and Southeast corners of the property, there are existing establishments that range from restaurants, drugstores, and retail services, as shown in Figure 2.

Architectural Design

Figure 2: Birds-Eye View (Looking North) | bing.com

The facility's architectural design includes 146 beds: 96-bed medical/surgical, 22-bed intensive care unit, 20-bed obstetrical unit, and an 8-bed neonatal intensive care unit. It also includes a state-of-the-art 24-hour emergency department, advanced cancer care, advanced cardiac services, in addition to cutting-edge catheterization and electro-physiology laboratories (Wooley, 2010). Future campus development plans include direct on-site access to primary care at the adjacent medical office building. The main architectural feature of the project is the five-story central patient tower atrium. This atrium serves as the location of the main entrance, and the vertical conveyance systems for the hospital. It also provides a sun-filled space, in which each floor's balcony steps back from the curtain wall to provide an open, large, panoramic view of the surrounding green space and across Germantown Pike onto the preserved lands of the Norristown Farm Park.

Architectural Materials

The primary building enclosure is a curtain wall system that incorporates precast panels and glazing units, as shown in Figure 3. The architectural precast concrete panels are located on the North, South, and East façade of the patient tower, and feature linear windows of consistent size. In order to create aesthetic variation and texture across the surfaces, sandblasting of varying degree was requested. In addition to this, split-faced concrete masonry units are located on the building at the West, North, and East sections of exterior wall at the Emergency Department and the Central Utility Plant. Metal panel components are located on the building at the West facade of the patient tower in addition to the screen wall surrounding the rooftop mechanical systems for the low roof.

Sustainability

The New Regional Medical Center is dedicated to implementation of sustainability features within design, construction, and lifecycle of the facility. With consideration for the patients, the community, and the environment, countless steps have been taken by the Einstein-Montgomery Partnership and project team to achieve their goal of a LEED Certified rating for the medical campus. Sustainability features include a land preservation and waste management program, management of solar gain through architectural design and building placement, and design development for implementation of future sustainable technologies.

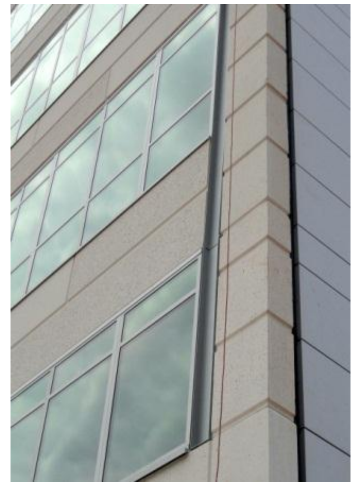


Figure 3: Facade System | Gilbane Building Co.

Construction Programming

The New Regional Medical Center includes 4 stories above grade, with a partial sub-grade ground floor. It will stand at 90'-8" tall, and have a gross building area of approximately 360,000 square feet. The project is being delivered through a construction management at risk contract, under an approximate construction cost of $147 million using a guaranteed maximum price contract.

Construction began on July 6, 2010 and is scheduled to be completed on August 31, 2012.

PROJECT TEAM DIRECTORY

OWNER:	NEW REGIONAL MEDICAL CENTER, INC. [THE PARTNERSHIP OF ALBERT EINSTEIN HEALTHCARE NETWORK & MONTGOMERY HEALTHCARE SYSTEM]
CONSTRUCTION MANAGER:	GILBANE BUILDING COMPANY
ARCHITECT:	PERKINS + WILL
STRUCTURAL ENIGNEERS:	O'DONNELL & NACCARATO
CIVIL ENGINEER:	BOHLER ENGINEERING
MEP & FIRE PROTECTION ENGINEERS:	PWI ENGINEERING
TRAFFIC ENGINEERS:	TRAFFIC PLANNING & DESIGN, INC
LANDSCAPE ARCHITECT:	WELLS APPEL

CLIENT INFORMATION

The Owner of the New Regional Medical Center consists of the collaboration and partnership of the Albert Einstein Healthcare Network (AEHN) and the Montgomery Hospital Medical Center (MHMC). The Einstein-Montgomery Partnership is referred to as the New Regional Medical Center, Inc. for the purposes of this report.

Individually, AEHN and MHMC have strong, rich histories regarding healing, healthcare, and service to the Philadelphia region. In 1865, AEHN was founded, and is now regarded as one of the most comprehensive healthcare providers in the region. MHMC has been proving medical care to the region since 1894, in addition to representing the market share in Central Montgomery County community. The partnership is based off common mission statements, focusing on serving the community and hosting excellence in clinical care. It was carried out through AEHN's long-term strategic growth initiative (Partnership Vision).

DRIVER FOR HEALTHCARE DEVELOPMENT

Within the past decade, there has not been a new medical center built in southeastern Pennsylvania (Wooley, 2010). The only previous healthcare work during this period consisted of facility renovations and interior upgrades. Currently residents of the Central Montgomery County region must travel to neighboring regions or into the City of Philadelphia to receive care. In order to permit residents to remain in this area and have accessible services, the New Regional Medical Center, Inc. realized that the southeastern Pennsylvania was lacking a modern, technologically advanced, healthcare campus capable of providing comprehensive care. In addition to meeting the facility needs, through this programming Einstein is able to harness their internal teaching experience in order to provide the latest clinical treatments and a highly skilled staff of physicians in the most advanced hospital in the region.

FACILITY EXPECTATIONS

In order to meet the void in healthcare services for this region, the New Regional Medical Center will feature the leading-edge clinical services and programs. This facility will operate as a full-service, acute care hospital. The program includes a 24-hour emergency care and trauma response, an advanced cancer center, cardiac surgery services, general surgery, and medical offices for primary care and specialist. The New Regional Medical Center is associated with Phase 1 of the medical campus. Additional installations, such as the medical office building will supplement the hospital's services, and provide convenient, on-site access to primary practices and specialists.

The campus is designed as a suburban hospital campus. By working with design professionals and local residents, the site design preserves one-third of the 84 acre property, providing a vast green space setting, complementing the Norristown Farm Park across the street. Through consideration of setting within the architectural design, 75% of hospital rooms will overlook the park.

Due to the high expectations for the facility's performance, the construction's quality and safety are two of the Owner's most valued aspect of the project. Through a GMP contract, any cost risks or concerns have been alleviated. In order to keep the project on schedule and uphold the delivery date of the project, strict liquidated damages have been incorporated to help emphasize the importance of a timely delivery; however, necessary time extensions may be negotiated in order to deliver a high-quality facility under safe working conditions. Due to the greenfield site, very few sequencing concerns are present for the project, permitting a very accurate work flow, in addition to timely building turnover. The facility will undergo a single occupancy phase in addition to an Owner and staff-training period. In order to provide complete transparency between the Owner, construction manager, and site activities, the Owner has representatives on site to monitor and assist in the daily activities and approvals required for the project.

Owner's Expectations

Figure 4: Patient Room Mockup | Gilbane Building Co.

Perkins + Will, Inc. and Gilbane Building Company, were selected by the New Regional Medical Center, Inc. for their design and construction services due to their previous success in the health care market. Perkins + Will is a commercial architecture firm which specializes in health care projects. Gilbane is currently ranked seventh on *Modern Healthcare's* list of top Construction Management companies. With a very strong team in place, various programs and processes were incorporated into the project in order to meet the expectations of the Owner, end-users, and the community. Assembly and room mockups are heavily utilized on the project in order to ensure the facility and systems meet the needs of the staff, in addition to proper workspace for the latest hospital equipment to be installed. Figure 4 provides an example of a mockup emergency patient room and a mockup of a general patient room. Three-dimensional modeling and coordination efforts were incorporated through the utilization of Building Information Modeling (BIM) in order to design and coordinate the mechanical, electrical, plumbing, and fire protection systems. These processes, in addition to strong Owner, A/E, and CM communication, will lead to a successful project and deliver the state-of-the-art New Regional Medical Center in accordance with the vision the Einstein-Montgomery Partnership set out to achieve (Figure 5).

Figure 5: New Regional Medical Center's Vision | Gilbane Building Co.

Project Delivery System

Construction Contract

The New Regional Medical Center project will be constructed under a single prime contract with Gilbane Building Company. The facility will compromise Phase 1 of the healthcare campus constructed on the 84-acre property. The Owner selected the construction manager through a Request for Proposal process resulting in a GMP selection. Gilbane Building Company was awarded the project and is delivering the project through a CM at Risk contract. The contract consists of a GMP of $146,741,834.00 for the construction dates of July 6, 2010 to August 31, 2012. The project is listed as tax exempt. Liquidated damage language includes a fee of $13,607 per day, applied to a late delivery after August 31, 2012. After sixty days late, liquidated damages increase to $50,000 per day. Per the contract, one-hundred percent of cost savings is returned to the Owner. In addition to this, ten percent of Gilbane's fee is retained throughout the project's duration. If the project requires a time extension for unforeseen conditions or at Owner's request, time will be granted for delay to critical path items. Compensation on general condition expenses for durations of requested extensions will be considered on a case-by-case basis.

Appendix A contains graphical representation of the project's contractual agreements.

This project delivery and contract method is appropriate for the New Regional Medical Center because the project funding has been acquired through the sale of Federal Housing Administration Insurance Bonds in the amount of $310,000,000. In addition to this, in August of 2010, the U.S. Department of Housing and Urban Development agreed to insure the bonds through FHA's Section 242 Hospital Mortgage Insurance Program (Wooley, 2010). Through utilization of private funding through bond sale, the guaranteed maximum bid process would permit the Owner to properly manage funding and meet the financial goals of the project without hidden or unknown construction costs.

Change orders and contract values are separately screened in order to ensure a tight project budget. Gilbane Building Company's experience with healthcare facilities of this size and delivery system produced a strong project team, innovate value engineering methods, and high standards on project safety, in addition to a competitive bid value. These elements assisted in the awarding of the contract.

Additional Contracts

Perkins + Will will prepare contract documents, with consultation from a team of design professionals. As shown in **Appendix A**, Perkins + Will operate by a lump sum and is in contract with their associates. In addition to the Architect, Program Manager, and Construction Manager working under contract of the Owner, three additional consultants are in direct contract with the Owner regarding specialty services.

The contract with Gilbane Building Company excludes the following concurrent construction operations at the project site: (1) Geotechnical & Testing Work, (2) Independent Testing, (3) Furniture, (4) Medical Equipment, (5) Communication Equipment, and (6) Nursing Stations.

The Owner will award separate contracts for these program-specific activities.

Subcontract Development

The subcontract award process is as follows:

(1) Gilbane prequalifies subcontractors for predetermined bid packages
(2) Subcontractors are invited to place a bid by a predetermined time and date
(3) The lowest qualified bidder is awarded the subcontract
(4) Gilbane releases the bid results with recommendation to the Owner for selection and Owner's approval

Note: Each subcontract is a lump sum contract per the bid package's scope of work.

Once selected, the subcontractor is notified and agreement documents are procured. Ten percent of each trade contractor's payment is retained until substantial completion of scope of work. The Owner reserved the right to reduce retainage at fifty percent completion to five percent. The trade contractors are required to agree and pay for a 100% Performance and a 100% Payment bond, in addition to enrolling in Gilbane CCIP Program.

The Owner will provide Builder's Risk Insurance with a deductible of no more than $50,000. However, Gilbane Building Company is required to maintain a CCIP Insurance Program. This program requires subcontractors to complete and submit the appropriate paperwork to qualify under their insurance. In addition to this coverage, per the subcontracts, trades must carry workers compensation and employer's liability, commercial general liability, business automobile liability, an umbrella liability, professional liability insurance, and finally contractor's pollution liability.

Staffing Plan

Project Management

The project management system for the New Regional Medical Center is conducted through a full-time field staff, with supplementary support from the regional office. Gilbane Building Company's Delaware Valley Regional Office (DVRO) is overseeing the New Regional Medical Center. DVRO is based in Center City Philadelphia, Pennsylvania, and approximately 23 miles away from the project site, permitting strong support from the regional office.

As shown in **Appendix B**, the project organization chart represents the interrelationship between the Field Office and Regional Office operations. The Project Executive, Kevin Kriebel, is stationed at the job site to serve as a direct line of communication between the site activities and the Project Principle, Stephen O'Connor. Beneath Kevin is a team of six members who coordinate the various facets of the project. Their selection for their particular role is based on various measures, including previous job roles and experience in healthcare projects of this scale. Their responsibilities cover the major elements of a construction project from preconstruction through closeout, including administration, accounting, safety, quality, and engineering. As mentioned, the close proximity of the site to the regional office permits strong site support. For example, the MEP and BIM Coordinators for this project work out of the regional office; however, they host weekly on-site coordination meetings and building walkthroughs. These meetings included the modeler and/or supervisor for the following trades: (1) Sheetmetal, (2) Plumbing/HVAC Piping, (3) Fire Protection, (4) Electrical, (5) Drywall/Ceilings, and (6) Pneumatic Tube, in which constructability conflicts are resolved and work-in-place is reviewed.

Project Superintendent and Project Engineer, Brian Baird and Joseph McCammit respectively, oversee the daily site activities regarding Gilbane's project management. During the lifecycle of the construction process, slight variations of the staffing plan occurred to expedite deliverables and adapt to project conditions; however, the overall structure methodology has remained unchanged from the initial system proposed with the GMP.

Engineering Systems

Construction Means & Methods

In Montgomery County, Pennsylvania, it is typical for a hospital complex to be constructed with a steel framing system and curtain wall facade. Due to this building being the first medical center for the region in ten years, it is challenging to locate similar projects in the immediate area for a means and methods comparison. With the recent development in healthcare technology and building technology, the existing facilities in southeastern PA will not provide an efficient design and construction processes comparison.

Understanding the current state of healthcare construction, and Perkins + Will's expertise, the building methods utilized on the project reflect the current trends in construction within the Philadelphia region.

The foundation systems utilized on the New Regional Medical Center consist of foundation walls and spread footings. The work process for the foundation systems began with the north concrete spread footings and moved south. Foundation work was sequenced directly behind the excavation process, starting with the spread footings to the north, then placement of the wall footings and retaining wall, followed by the spread footings to the south.

The sequence plans (Figure 6 & Figure 7) for the structural steel of the New Regional Medical Center begins in the south-west corner of the structure and progress east, covering ground level to the second floor of the West Tower (shown in red). Once this section is complete, the remainder of the building's steel is placed to the same elevation. This phase is represented in orange. The crane returns to the south-west corner after looping the building, and continues to place the final two levels of the West Tower (shown in blue). From here, it travels along the south facade, placing the atrium and high-roof steel (shown in purple), the beginning of the East Tower (shown in green) and concludes with the remainder of the East Tower (shown in brown).

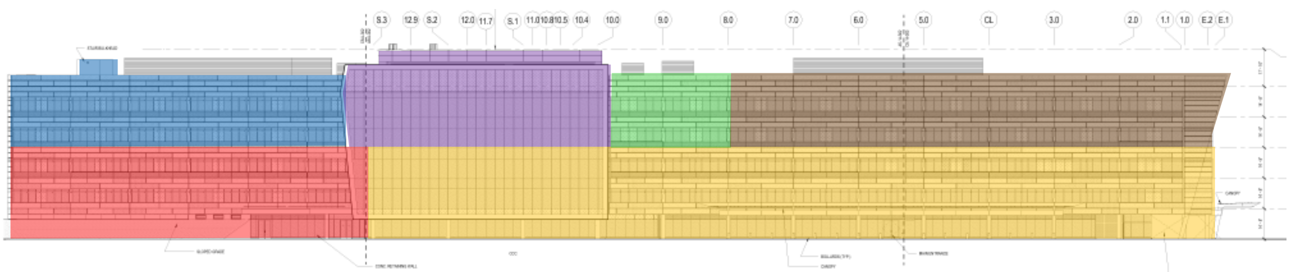


Figure 6: Structural Steel Erection South Elevation

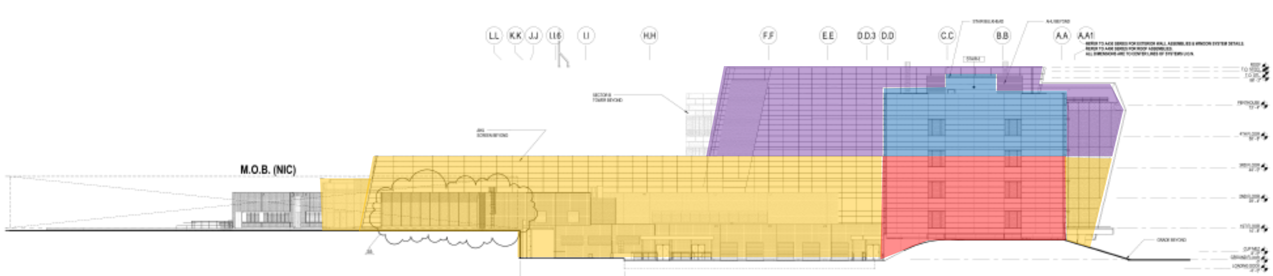


Figure 7: Structural Steel Erection West Elevation

Finish sequencing is planned for a top-down, bottom-up approach. This method permits the trades to work their way out of the building, and depart the medical center on the first floor. Doing so also permits the completed sections of the facility to be locked out and begin closeout review. The programming of the facility has placed the Emergency Department and Operating Rooms on the ground floor and first floor, respectively, of the north sector of the medical center. These two areas involve the greatest focus regarding interior systems and finishes. By working down the East and West Towers, the tower crews will complete three floors (Fourth, Third, Second); in the same amount of time scheduled for the ground crews have to complete the ground floor. The goal is for the crews to merge on the first floor and work their way north, finishing the operating room support areas and waiting area last.

Electrical System

The building will have electrical and tele-data components such as backup generators, critical circuitry to help ensure minimal power interruption, nurse call systems for effective communication and code blue systems throughout the campus. The supply power enters the site from the south-west corner, and follows the maintenance road up to the loading dock area of the medical center. This area hosts the backup generators and all utility connection for the facility. This facility has two emergency generators, with the capabilities for a third. These generators are 100KW, 1250KVA each and tie directly into the main power system.

The power enters the electrical control room through a 5000A Bus Duct that comes off of a 3750 KVA, 480/277V transformer. The medical center features a redundant supply system in parallel, permitting uninterrupted power supply. Once entering the electrical control room, the 500A, 480/277, 3 phase, 4 wire feed the building systems. The building system is also wired with for critical power, emergency power, and emergency power life safety services directly from the backup generators.

The medical center is serviced by seventy-nine 480/277V and ninety-six 120/208V panel boards which distribute power throughout the building to meet the services need of hospital equipment, staff, and patients.

Lighting System

Due to the design efforts to create an effective balance of light quality with energy efficiency, the majority of lighting fixtures in the building incorporate energy efficient compact fluorescent lights (CFL). Additionally, metal halide (MH), fluorescent (FL), light emitting diode (LED), and either electronic or magnetic low voltage (ELV or MLV). A majority of the fixtures are recessed ceiling-mounted and require 277 volts, with wattage dependent on the lighting application.

Table 1: Typical Patient Room Fixture Schedule

Fixture Location	Type	Quantity	Lamp Type	Wattage
Ceiling Mounted (Interior Side)	Recessed	2	CFL	32W/Fixture
Ceiling Mounted (Exterior Side)	Recessed	2	LED	20W/Fixture
Ceiling Mounted (Above Headwall)	Wall Wash Down	1	FL	28W/Fixture
Wall Mounted (Above Headwall)	Wall Wash Up	1	FL	14W/Linear Foot
Above Patient Bed	Recessed	1	CFL	160W/Fixture

Mechanical System

The building's mechanical systems are made up of several main components including boilers, custom air handlers, cooling towers, chillers and variable air volume boxes. The central utility plant (CUP) houses all of the major mechanical equipment that is not installed rooftop. The CUP is located at in the north-west corner of the facility and was designed at a lower elevation to permit proper pipe and utility clearances above the equipment. There are four major vertical shafts (150 - 200SF each) that service the East and West wings of the patient tower. In the central core, there are two vertical shafts for MEP distribution for the Atrium and high roof services.

The New Regional Medical Center's HVAC system is serviced by seven custom outdoor air-handling units and two indoor air handling units. The outdoor AHU's are located as rooftop units, and the two indoor units are located in the CUP. They operate as a VAV mixed air system. There are three water chillers (825Ton, 825Ton, 450Ton) which service these AHU's cooling conditions, while the building's heating system is serviced by two 500 HP boilers and one 400 HP boiler which also located in the CUP. Ductwork is utilized to transport the air to each space, and all patient rooms contain VAV boxes for individual controls. Hydronic piping transports the chilled and hot water to each AHU. The Operating Rooms have a dedicated AHU system that features a blow-through arrangement and requires a minimum of 50,300 CFM of outside air in comparison to its 45,000 CFM supply air.

Structural System

The New Regional Medical Center features a structural steel frame, which is arranged on a grid pattern of 30 feet by 30 feet. The column system includes splices that are placed four feet about first floor, and four feet above the third floor. This permits ease of connection and assembly. The columns are comprised of W12 and W14, which range from 49 lbs/lf to 170 lbs/lf. The maximum load for the interior columns of the building are estimated to be 800 kips, and the maximum load for the exterior columns of the building are estimated to be 605 kips. This project features eight different braced frame configurations, which are oriented perpendicular to the south facade in the East and West Towers. The framing plan is generally comprised of W24 girders with W14 beams. All girders have flexible moment connections designed for lateral loads on the structure.

The slab configurations various throughout the structure, and utilize different assembly configurations. All slabs are comprised of composite metal decking, shear studs, and welded-wire-fabric.

Engineering Support Systems

Fire Protection

The fire suppression system within the medical center includes a Double Interlocked Deluge Preaction Sprinkler System. This system corresponds to the facility usage since accidental discharge would be damaging to medical equipment and finishes. Water pressure is supplied by a 1000-gpm, 100-psi boot, diesel engine fire pump and networked though a combined wet standpipe and automatic wet pipe. The passive suppression system description is withheld at request.

Transportation & Conveyance

The New Regional Medical Center contains three stair towers, in addition to a monument staircase within the atrium, servicing the ground to first floors. All three of the major stair towers service the four medical floors, with the west conveyance servicing the high roof, and the central conveyance servicing the low roof. These shafts meet U.L. Design No. U467, and contain a two hour fire-rating shaft wall, in addition to two finished sides. The stair construction consists of shop fabricated steel sections. With two stringer beams, and a welded sheet metal tread pans, site filled with concrete. Due to high traffic during construction, tread pans were filled with wood blocking initially.

The elevator systems present in the medical system consist of four trauma (patient) elevators, in addition to three public service elevators. The elevator core is located at the rear of the atrium and provides a centralized vertical service to the facility. All elevator shafts are designed to the same life-safety standards as the previously mentioned for the stair shafts. The New Regional Medical Center contains three-machine room-less elevators for public service, which service 58'-8" of travel at 200 FPM for a 3000lb capacity. The four trauma elevators are a traction system that also covers 58'-8" of travel, but performs at 100 FPM for a 6000lb capacity.

PROJECT COST EVALUATION

BUILDING CONSTRUCTION COST

Building Construction Cost: **$127,653,895.80**

Total Area: 366,780 SF

Building Construction Square Foot Cost: **$348.00/SF**

TOTAL PROJECT COST

Total Cost: **$146,741,834.00**

Square Foot Cost: **$400.10/SF**

General Conditions Summary

The general conditions (GC) estimate for this project is based off of the 33 month construction schedule. It is comprised of personnel costs, construction management reimbursements and facility, temporary utilities, and miscellaneous costs, including bonding and insurances. Excluded items from Gilbane's general condition costs are also included in this section; however, they are also excluded from the table below. Table 2 and Figure 8 include summary information regarding the major components of general condition costs. This estimate was developed by using data provided by Gilbane Building Company, with supplement from RSMeans.

The New Regional Medical Center's general conditions estimate is $18,222,285, with a monthly cost of $560,094. Notable factors in the estimate are the personnel costs, in addition to the miscellaneous, bonds, and insurances on the project. Personnel costs account for 45.5% of the total GC cost, and miscellaneous, bonds, and insurances account for 52%.

Cost concerns for the general condition revolve around scheduling and billing overruns since any minor delay on the project schedule risks extending the large expense of personnel in addition to miscellaneous, bonding, and insurance beyond the scope of the GMP. In order to mitigate this, close monitoring must be made regarding construction progress, and personnel billing. The project team must monitor the construction schedule daily, and ensure their personnel costs are within the budget. Although miscellaneous, bonds, and insurances costs constitute the highest percentage of the New Regional Medical Center's general conditions, the project team can control few of these internally.

Table 2: General Condition Summary

GENERAL CONDITIONS SUMMARY			
	Cost/Unit	**Units**	**Total Cost**
Personnel	$251,661	Month	$8,304,803
CM Reimbursable	$11,102	Month	$336,375
		Single Expense	$369,175
Temporary Utilities	$10,087	Month	$332,874
Misc., Bonds, Insurance	$287,244	Month	$9,479,058
Monthly Total:	***$560,094***	**Project Total:**	***$18,222,285***

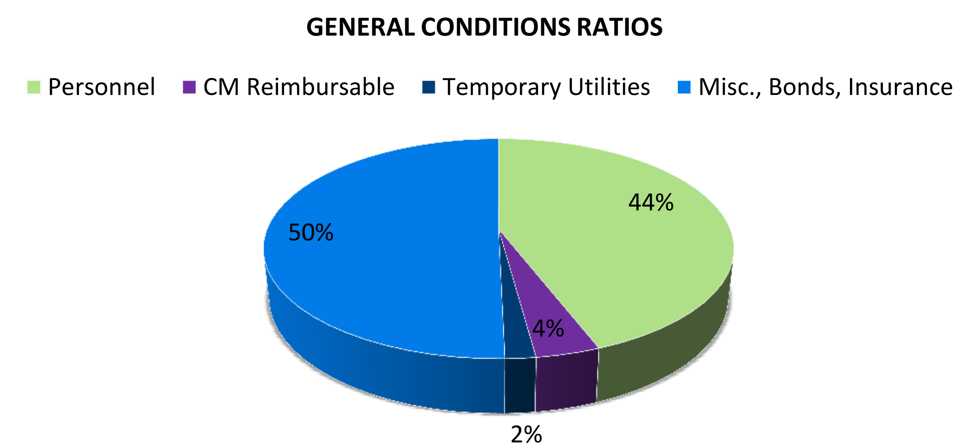


Figure 8: General Condition Ratios

SITE PLANS

EXISTING CONDITIONS PLAN

The site is located at the former location of *Wood's Golf Center* at 559 West Germantown Pike, in East Norriton Township. The site comprises 89 acres, and is bordered to the south by West Germantown Pike, and commercial and residential properties border the remaining sides. The terrain and topography of the site is typical of a standard golf course, and the site features multiple existing buildings and structures associated with the facility.

See **Appendix C** for the existing conditions plan for the New Regional Medical Center.

STRUCTURE & ENCLOSURE PLAN

This phase begins with the move of the field staff out to their project trailers. In addition to this, this phase includes the availability of onsite parking for all project workers. The tool trailers are added as more trades begin arriving to the site, and a secondary site entrance is established for emergency or after-hours use only. With the additional space in the newly built parking fields to the north, material storage for long lead items and recent project deliveries is available. The crane path is established along the south elevation of the medical center. Through the logistical planning and sequencing, this project can be completed per the schedule with one 300 Ton Manitowoc crane.

See **Appendix D** for the Steel Structure & Enclosure Phase Plan for the New Regional Medical Center.

Detailed Project Schedule

Primavera Schedule

The project detailed schedule includes approximately 270 activities and milestones associated within the phases of (1) design and preconstruction services, (2) construction activities, and (3) final closeout. The level of detail distinguishes sequencing, rough-in, finishes, and commissioning for trade activity. In addition to this, major phasing activities have been grouped in order to develop summary information concerning this work. Table 3 includes the major components of the Primavera schedule, and provides a summary of the phasing relations.

See **Appendix E** for the New Regional Medical Center's project schedule.

Table 3: Detailed Schedule Phase Summary

Primavera Schedule			
Phase	**Start**	**Finish**	**Duration (days)**
Design & Preconstruction	01-Oct-07	11-May-10	681
Construction	01-Jul-10	31-Aug-12	553
Structure	*29-Nov-10*	*18-Apr-11*	*99*
Enclosure	*22-Mar-11*	*01-Sep-11*	*116*
Ground Level	*11-Mar-11*	*25-May-12*	*310*
Level 1	*08-Apr-11*	*28-Feb-12*	*227*
Level 2	*22-Apr-11*	*28-Feb-12*	*217*
Level 3	*04-May-11*	*28-Feb-12*	*209*
Level 4	*11-May-11*	*28-Feb-12*	*204*
Project Closeout	09-Apr-12	15-Oct-12	133

Design & Preconstruction

The design and preconstruction phase consists of 681 days and includes activities from preliminary site investigation / geotechnical testing through the Owner awarding the project to the construction management team. In review of the design and preconstruction sequencing, there are two major activity lapses on the project schedule between the (1) Preliminary Geotechnical Investigation and Supplemental Geotechnical Investigation, and (2) Supplemental Geotechnical Investigation and Civil Design. These lapses occurred due to timely decisions regarding finding a suitable site, and subgrade environment for the intended medical program. Additional influences on this gap can be attributed to coordination of the land purchase and development of project funding. However, once design began on the project, this phase progressed under suitable timing.

Construction

Construction of the New Regional Medical Center consists of 553 days from Notice to Proceed (NTP) to Substantial Completion. This phase includes all major construction activities (outlined in Table 3), in addition to site clearing, driveway and parking lot establishment, and landscape installation around the facility. The construction phase is identified through 10 internal sequences that are additionally detailed within the schedule provided in **Appendix E**.

Structure

The structural phase of the construction schedule includes a combination of steel erection, and slab on deck placement. This process is dictated by an overall sequence layout, staged by bays. The sequence essentially flows from A to D to C & B as noted in Figure 9. In addition to this typical sequence, concrete work for the footings and retaining wall, and the slab-on-grade (SOG) are also included. Items that are not included due to level-of-detail constraints include activities such as in-slab electrical and plumbing rough-in, in addition to steel staging and delivery milestones.

The layout sequences were identified in such a way to permit concurrent activities between steel erection and slab-on-deck (SOD) preparation and placement. Typically each sequence requires 10 – 18 days of work, while each SOD needs 5 – 10 days for placement. In order to efficiently plan work through these spaces, the SOD began construction approximately three sequences behind, permitting a safe working area for the concrete and decking crews, while also keeping an accelerated structural schedule. A key item to note is that the SOG is held until approximately 50% of the structure is in place, in addition to a portion of the slab on deck underway. This strategy is required in order to permit the appropriate electrical and plumbing services within the slab to be roughed-in prior to pouring. Due to the location of the cafeteria on ground level in Section A, this sequencing was essential to keeping this area of the facility on schedule.

Enclosure

Building enclosure for the medical center is scheduled over 116 days, and includes major activities regarding façade and roof enclosure. Due to the various exterior materials on this project, and the internal phasing required to meet the constructability requirements of the curtain wall, this phase includes major activities surrounding the exterior walls, curtain wall pre-cast, and atrium curtain wall.

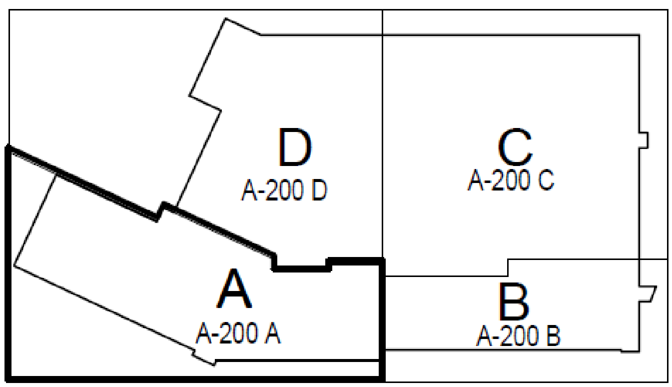


Figure 9: Building Quadrants | Sheet A-200A | Perkins & Will

The exterior walls are located surrounding the ground level at the emergency room entrance (Section C), and the loading dock area (Section D). This activity was sequenced first due to the longer duration of 95 days to complete. Following this, the curtain wall assembly was developed through the building sector layout. In this work flow, the medical center consists of 4 quadrants in which the trades are sequenced, as shown in Figure 9. Similarly, the roofs are phased by the quadrant method, in addition to designation of “low” or “high”.

Enclosure begins with curtain wall pre-cast placement in section C and D, and progresses into section A and B. The building roof system is phased in a similar pattern, approximately one section behind the curtain wall. In order to minimize crane and worker overlap, the metal panel installation travels in the same sequence overlapping roof activities. They begin to the north, over sections D and C, and continue counterclockwise into the west façade. Due to constraints along the south façade (activity: curtain wall atrium), the metal panel work flow passes by the frontage of A and B, and continues work on the east façade before returning to fill-in around the atrium curtain wall. The curtain wall atrium activity is the most critical of the enclosure sequencing due to its large size, challenging construction method, and its reliance on progress in both section A and B for tolerance controls.

Ground Level Through level 4

Construction on the ground level through level 4 consists of a systematic workflow that is repeating at each level. The only major difference between these five sequences is the overall duration. The ground level consists of 310 working days, while level 4 consists of only 204 days. The floors between these two decrease in duration with the rise in level. The range in variation is due to the overlying fact that the ground floor and level 1 are the two largest floors with the core medical systems, while level 2, 3, and 4 consist of the patient tower with repetitive elements, and a more efficient work flow.

The sequencing on this aspect of the New Regional Medical Center consists of approximately 32 activities that include the major MEP and finishes trades. It details aspects regarding rough-in, distribution, and finishes, in addition to detailing the scheduling differences regarding overhead and in-wall activities. Specialty systems of the medical center, such as the medical gas system and the pneumatic tube system, are also included in the detailed schedule. It is recognized that duration increases with floor size and system complexity. In addition to this, activity items also increase in detail; however, these additional items were excluded from the detailed estimate due to detail constraints.

The following sequence reflects the flow of work through the New Regional Medical Center:

Finish sequencing is planned for a top-down approach. This method permits the trades to work their way out of the building, and depart the medical center on the first floor. Doing so also permits the completed sections of the facility to be locked out and begin closeout review. However, the programming of the facility, places the Emergency Department and Operating Rooms on the ground floor and first floor, respectively, of the north sector of the medical center. These two areas involve the greatest focus regarding interior systems and finishes; therefore, a second crew will be dedicated to this space. By working down the East and West Towers, the crews will complete three floors (Fourth, Third, Second); in the same amount of time scheduled for the second crew to complete the ground floor. The goal is for the crews to merge on the first floor and work their way north, finishing the operating room support areas and waiting area last *(Packer, Field Engineering | Gilbane Building Co., 2011)*.

Note however, that the activities in the schedule do not convey the same message. Within **Appendix E**, and detailed in Table 3, work began on the ground level first, and additional levels were added approximately every two weeks, working up the structure. All floors are schedule to conclude on February 28th, except for the ground level which will not be completed for another 3 months. This discrepancy is due to a reevaluation of the MEP coordination and workflow process through the building. The included detail schedule reflects initial plans of the trade sequence. After discussion with the subcontractors, and revision of coordination model sequencing, it was recognized that this process is most efficient and meets the schedule and workflow progression outlined in the initial GMP.

Project Closeout

The project closeout has been included in the detailed project schedule located in **Appendix E**. Project closeout takes 133 days for the New Regional Medical Center and includes activities such as Owner move-in, Department of Health (DOH) inspections, and Owner training. Workflow for move-in, inspections, and punch list items, will be conducted from the top down – following the trades out of each area, permitting each area to be signed-off and delivered in time for Owner and medical staff training.

Analysis Weight Matrix

A weight matrix, shown in Table 4, was developed in order to appropriately allocate effort between the four core areas of investigation. The percentages within the matrix signify the actual level of time and effort dedicated to each of the four analysis areas, including the two breadths associated with the Atrium Enclosure Analysis and Pour Stop Analysis.

Table 4: Weight Matrix of Distribution in Investigation Areas

Analysis Description	Industry Research	Value Engineering	Constructability Review	Schedule Reduction/Acceleration	Total
BIM in Preconstruction	5%	5%	10%	10%	**30%**
Atrium Enclosure & Breadth	-	-	15%	-	**15%**
Pour Stop Analysis & Breadth	-	15%	10%	-	**25%**
Document Management	25%	-	5%	-	**30%**
Total	**30%**	**20%**	**40%**	**10%**	**100%**

Analysis 1 | BIM in Preconstruction

Part A: BIM for Quantity Takeoff & Estimating

Problem Identification

Gilbane utilized various processes and software platforms to quantify and estimate the New Regional Medical Center at various levels of design development. Additionally, they utilized on-screen takeoff to finalize their estimate for their bid proposal. Their process consisted of the traditional methods of plan-document review and cross reference to a cost database of past projects with similar components. Although utilizing a technology platform to develop the QTO, all quantities had to be manually counted and measured within each PDF sheet. Once completed, this data was exported into excel, and cost information was embedded per line item to reach their cost estimate. Although logical and accurate, this process can be refined by taking advantage of the capabilities of the 3D models built to produce the 2D plan construction drawings.

The Building Information Modeling (BIM) implementation on the pre-construction and construction of this project was minimal; however, the model created by the design teams was sufficient for various uses during structural estimating. This analysis will study the usability in the level of detail (LOD) and information embedment within the components modeled in the structural design. A 3D QTO and database-referenced estimate will be performed, and the results of material costs and time duration to perform the analysis will be recorded. These results will be compared with Gilbane's process, and the schedule of values recorded to construct the system. Additionally, a comparison will be made to previous thesis investigations on BIM estimating to reflect any industry growth or process development over the past four years.

Background Information

In 2009, construction management student Ralph Kreider proposed the concept of BIM in Estimating during his final report. The analysis within this report focused on the comparison of three methods of construction estimating for an interior wall assembly: (1) Manual/Traditional Methods, (2) Revit-Based Methods, and (3) Autodesk Quantity Takeoff. The results provided recommendation that the Revit-Based Method for material scheduling and quantity takeoff is the most efficient, reducing the duration to perform the exercise by 20 percent, and resulting within 1.5 percent of quantities and cost from the actual manual takeoff methods. Outcomes resulted in the directive that "construction firm[s] should begin to invest time and money into the gained efficiency of automated takeoff" (Kreider, 2009).

Later that month, Engineering News-Record released an article regarding the transformation of BIM Pilot programs during the preceding 4 years. The goal of these programs were to "improve multidisciplinary drawing coordination, [and] streamline estimating," in addition to others processes. A discussion point of the article address the concern impacting the estimating workflow, with the contractors estimating the work, disjointed from outlining the level of detail necessary in the model components to accurately estimate the work (Post, 2009).

In 2010, construction management student Ronza Abousaid also implemented the concept of Revit-Based estimating within his final report. The analysis within this report focused on both industry insight and the comparison of two methods of construction estimating for an exterior curtain wall assembly: (1) Manual/Traditional Methods, and (2) Revit-Based Methods. The results of the research also recommend that Revit-Based Methods eliminate calculation errors during quantification of areas and lengths. Although computer software such as Autodesk Quantity Takeoff or Acrobat Professional can scale drawing and make measurement, Revit-Based Methods also reduce counting errors. Implementation concluded that Revit-Based Methods reduced the duration to perform the exercise by 89 percent; however, the results produced a cost, which was below the manual takeoff by 24 percent. Outcomes resulted in the directive to continue to pursue the development and understanding of the capabilities and limitations of 5D modeling. The analysis concluded with a caveat, stating "to benefit from the time savings of model-based cost estimating, it is important for an Owner to clearly state the intent of releasing the 3D modeling [as the basis for estimating] in a contractual format with the designers" (Abousaid, 2010).

The 20th Annual PACE Roundtable took place on November 9, 2011, and brought students and industry members to discuss this year's theme of "Building Innovation into Practice: Keeping what Works." Using student-based research goals after a recap of implementation of BIM tools and technology over the past year, the following was determined a key takeaway from the program.

- Continue to compare the use of BIM tools (or technology) to traditional methods of project estimate development. Focus on concepts such as: system appropriateness, process execution, time savings, and cost accuracy, relative to traditional methods.
- Study the positive and negative effects of implementation and the added (or lost) value of its use.

On March 12, 2012, *Engineering News-Record* released industry responses to a survey they developed regarding the current state and outlook of technology implementations. The second most common statement focused on data integration with BIM, notably regarding estimating and schedule from the model. This response trailed the number one response, shortfalls in current software products. Notable concepts in which it beat out revolved around collaboration (3rd), cloud storage (5th), tablet PCs (10th), and BIM training (13th).

> "THE CONSTRUCTION INDUSTRY SHOULD FOCUS LESS ON PERCEIVED NEEDS FOR NEW TECHNOLOGY AND MORE ON HOW TO WORK WITH WHAT IT HAS." *RAY CHEN, FAITH TECHNOLOGIES*

ANALYSIS INFLUENCES

- Development of details and parameters included in modeled components.
- The accuracy of the cost database referenced.
- Ability to interpret modeled data and adjust for gaps of inadequate information.

Methodology

(1) Open structural model in Revit and view the model in a 3D template.

(2) Create a material takeoff using the “Schedules & Quantities” feature.

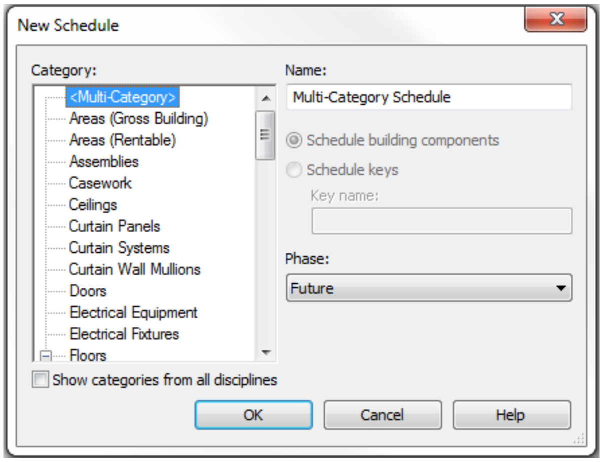


Figure 10: Step 2 – Select Category <Multi-Category>

(3) Apply the appropriate fields to the data.

Note: *Ensure the cost database pricing relation is compatible with the requested data from the element.*

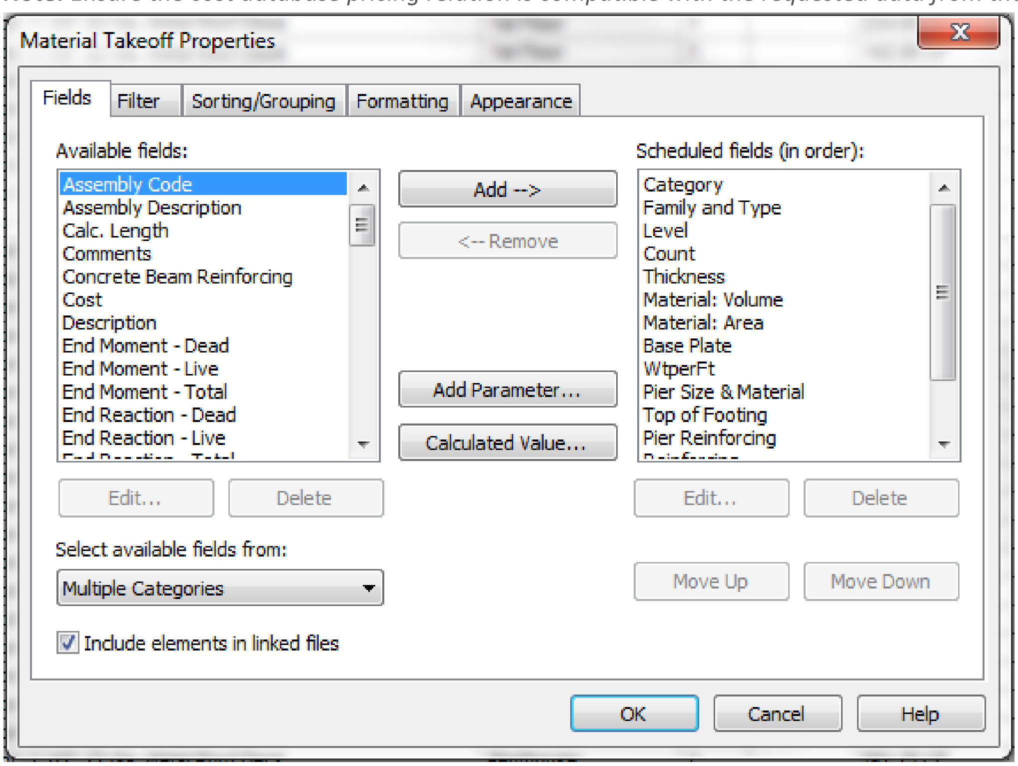


Figure 11: Select Necessary Field References Per Modeled Component

(4) Apply the appropriate grouping elements to the data.

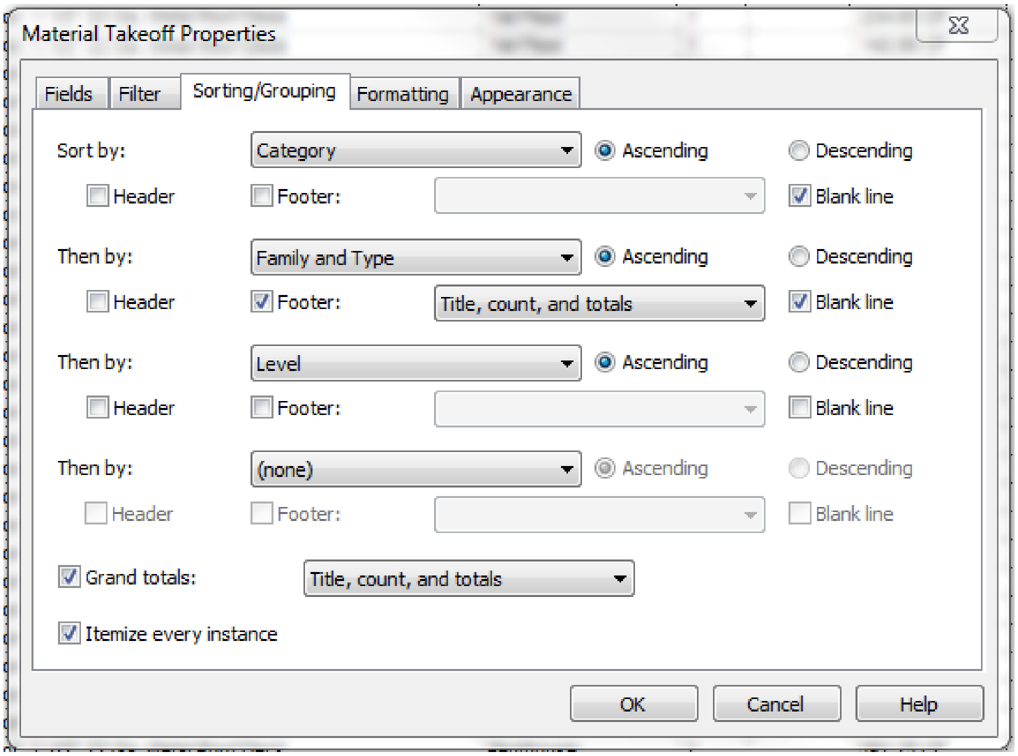
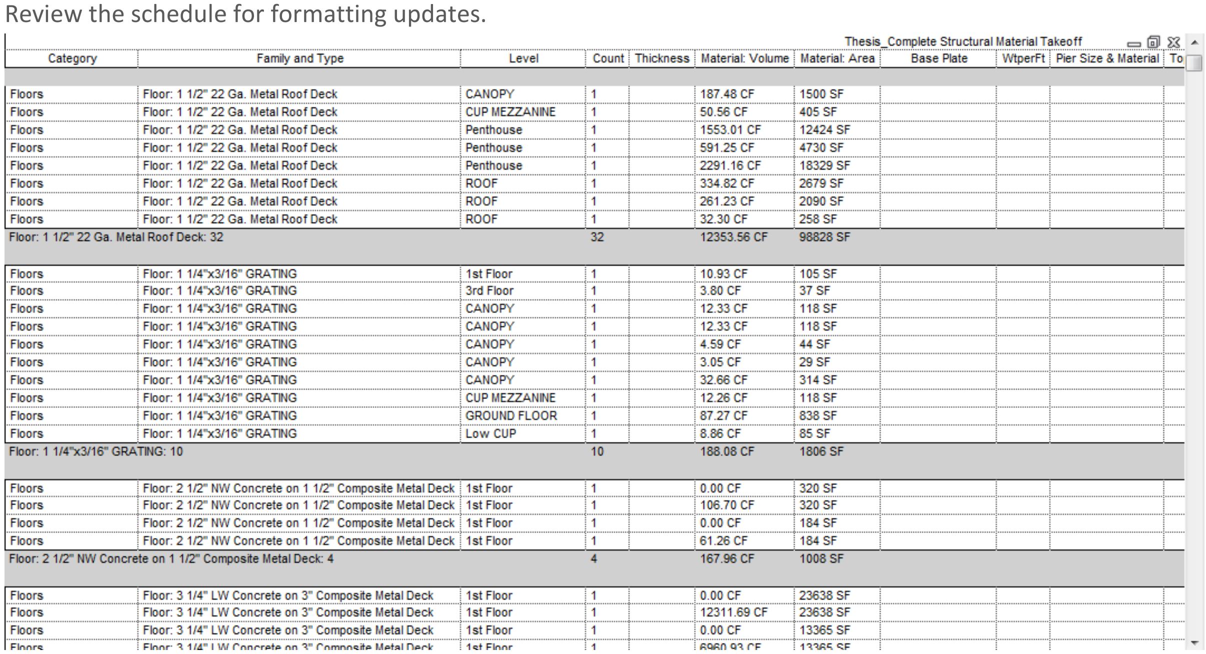


FIGURE 12: STEP 4 - SELECT NECESSARY GROUPING STRATEGIES

(5) Review the schedule for formatting updates.



Thesis_Complete Structural Material Takeoff

Category	Family and Type	Level	Count	Thickness	Material: Volume	Material: Area	Base Plate	WtperFt	Pier Size & Material	To
Floors	Floor: 1 1/2" 22 Ga. Metal Roof Deck	CANOPY	1		187.48 CF	1500 SF				
Floors	Floor: 1 1/2" 22 Ga. Metal Roof Deck	CUP MEZZANINE	1		50.56 CF	405 SF				
Floors	Floor: 1 1/2" 22 Ga. Metal Roof Deck	Penthouse	1		1553.01 CF	12424 SF				
Floors	Floor: 1 1/2" 22 Ga. Metal Roof Deck	Penthouse	1		591.25 CF	4730 SF				
Floors	Floor: 1 1/2" 22 Ga. Metal Roof Deck	Penthouse	1		2291.16 CF	18329 SF				
Floors	Floor: 1 1/2" 22 Ga. Metal Roof Deck	ROOF	1		334.82 CF	2679 SF				
Floors	Floor: 1 1/2" 22 Ga. Metal Roof Deck	ROOF	1		261.23 CF	2090 SF				
Floors	Floor: 1 1/2" 22 Ga. Metal Roof Deck	ROOF	1		32.30 CF	258 SF				
Floor: 1 1/2" 22 Ga. Metal Roof Deck: 32			32		12353.56 CF	98828 SF				
Floors	Floor: 1 1/4"x3/16" GRATING	1st Floor	1		10.93 CF	105 SF				
Floors	Floor: 1 1/4"x3/16" GRATING	3rd Floor	1		3.80 CF	37 SF				
Floors	Floor: 1 1/4"x3/16" GRATING	CANOPY	1		12.33 CF	118 SF				
Floors	Floor: 1 1/4"x3/16" GRATING	CANOPY	1		12.33 CF	118 SF				
Floors	Floor: 1 1/4"x3/16" GRATING	CANOPY	1		4.59 CF	44 SF				
Floors	Floor: 1 1/4"x3/16" GRATING	CANOPY	1		3.05 CF	29 SF				
Floors	Floor: 1 1/4"x3/16" GRATING	CANOPY	1		32.66 CF	314 SF				
Floors	Floor: 1 1/4"x3/16" GRATING	CUP MEZZANINE	1		12.26 CF	118 SF				
Floors	Floor: 1 1/4"x3/16" GRATING	GROUND FLOOR	1		87.27 CF	838 SF				
Floors	Floor: 1 1/4"x3/16" GRATING	Low CUP	1		8.86 CF	85 SF				
Floor: 1 1/4"x3/16" GRATING: 10			10		188.08 CF	1806 SF				
Floors	Floor: 2 1/2" NW Concrete on 1 1/2" Composite Metal Deck	1st Floor	1		0.00 CF	320 SF				
Floors	Floor: 2 1/2" NW Concrete on 1 1/2" Composite Metal Deck	1st Floor	1		106.70 CF	320 SF				
Floors	Floor: 2 1/2" NW Concrete on 1 1/2" Composite Metal Deck	1st Floor	1		0.00 CF	184 SF				
Floors	Floor: 2 1/2" NW Concrete on 1 1/2" Composite Metal Deck	1st Floor	1		61.26 CF	184 SF				
Floor: 2 1/2" NW Concrete on 1 1/2" Composite Metal Deck: 4			4		167.96 CF	1008 SF				
Floors	Floor: 3 1/4" LW Concrete on 3" Composite Metal Deck	1st Floor	1		0.00 CF	23638 SF				
Floors	Floor: 3 1/4" LW Concrete on 3" Composite Metal Deck	1st Floor	1		12311.69 CF	23638 SF				
Floors	Floor: 3 1/4" LW Concrete on 3" Composite Metal Deck	1st Floor	1		0.00 CF	13365 SF				
Floors	Floor: 3 1/4" LW Concrete on 3" Composite Metal Deck	1st Floor	1		6960.93 CF	13365 SF				

FIGURE 13: STEP 5 - SCHEDULE REVIEW

(6) Export Schedule in Delimited Text (*.txt) format.

(7) Open File via Microsoft Excel.

(8) Format the appearance & break apart the schedule as desired. [Family, Discipline, etc.]

(9) Simplify & Summarize groupings and families as desired.
Note: *Formatting of the table must be considered before and after export. It is best practice to use decimals and remove units within all number-based parameters in order to simplify calculation processes within Excel.*

(10) Create Columns for Material, Labor, Equipment, and Total equivalent costs.

CSI Number	Family : Quantity	Measured Units	Total Units	Weight (Tons)	Material	Labor	Equipment	Total	Material Cost	Labor Cost	Equipment Cost	Total Cost
05 12 23.40	***Lightweight Framing***											
	C10x25: 64	**837'- 4 9/16"**	**20925**	**10.46727**								
600	Channel framing, 8" and larger	25 lb/lf	LBS		0.68	2.36	0.22	3.26	$ 14,229.00	$ 49,383.00	$ 4,603.50	$ 68,215.50
	C12x30: 6	**76' 7 11/16"**	**2299.172**	**1.149586**								
600	Channel framing, 8" and larger	30 lb/lf	LBS		0.68	2.36	0.22	3.26	$ 1,563.44	$ 5,426.05	$ 505.82	$ 7,495.30
	ž3x3x3/8: 29	**131'-0 15/16"**	**131**	**0.471885**								
476	Angle 3"x3"x3/8"		LF		4.86	20.5	1.91	27.27	$ 636.66	$ 2,685.50	$ 250.21	$ 3,572.37
	ž3x3x5/16: 2	**7'-0 7/8"**	**7**	**0.021213**								
476	Angle 3"x3"x3/8"		LF		4.86	20.5	1.91	27.27	$ 34.02	$ 143.50	$ 13.37	$ 190.89
	ž4x4x3/8: 21	**188'- 6 9/16"**	**1828.888**	**0.914444**								
400	Angle Framing, 4" and larger	9.7 lbs/lf	LBS		0.65	2.69	0.25	3.59	$ 1,188.78	$ 4,919.71	$ 457.22	$ 6,565.71
	ž6x4x5/16: 2	**8' - 9 1/2"**	**90.538**	**0.045269**								
400	Angle Framing, 4" and larger	10.3 lbs/lf	LBS		0.65	2.69	0.25	3.59	$ 58.85	$ 243.55	$ 22.63	$ 325.03
	MC12x31: 10	**249' - 1 7/8"**	**7722**	**3.861886**								
600	Channel framing, 8" and larger	31 lb/lf	LBS		0.68	2.36	0.22	3.26	$ 5,250.96	$ 18,223.92	$ 1,698.84	$ 25,173.72
05 12 23.40	*Lightweight Framing*								*$ 22,961.70*	*$ 81,025.22*	*$ 7,551.59*	***$ 111,538.52***
03 31 05.70	***Placing Concrete***											
	GB 30"x32": 1	**4.16 CY**	**4.16**	**NA**								
150	3000 psi		CY		99			99	$ 411.84	$ -	$ -	$ 411.84
3200	Grade Beam, direct chute		CY			11.45	0.31	11.76	$ -	$ 47.63	$ 1.29	$ 48.92
03 31 05.70	*Placing Concrete*								*$ 411.84*	*$ 47.63*	*$ 1.29*	***$ 460.76***
03 21 10.70	***Glass Fiber Reinforced Polymer Bars***											
	Round Bar 1": 53	**1531'-9 9/16"**	**1532**	**0**								

FIGURE 14: ESTIMATING SPREADSHEET

(11) Total by Family, CSI Family, and report findings for comparison.

See **Appendix F** for a process map for the execution of 5D Estimating in this analysis.

OUTCOME

Using the BIM model developed through the design, fabrication, and installation of the structural system in the medical center, an accurate structural estimate was procured for the entire structure. With a single pass through the model, multiple material schedules were developed and exported into Excel for data management and cost incorporation from *RSMeans Facility Construction Cost Data 2011*.

According to discussion with Gilbane's estimating team, the structural system estimate on the New Regional Medical Center took a team of four members approximately 20 hours each, to complete the estimate. The acquired estimate value by Gilbane totaled to $19,890,000. Once construction was completed on the structure, the schedule of values resulted in a cost of $5,642,000 for the concrete system, and $7,672,000 for the metals system, totaling to $13,314,000

The original detailed estimate, through the utilization of modeled components, resulted in a cost of $9,155,687. Once the location factor[1] was applied, a more appropriate estimate of $10,190,280 was achieved.

[1] Location factor #194 is applied to the RSMeans data in order to produce a more accurate estimate to the geographic location of the project. Within the appendix of the RSMean catalog, location factors by city and state are listed. The value

This value is 23.46 percent short of the actual project cost, as identified through the schedule of values released for the work. This process took 10 hours to complete, including the formatting, research, and input of the RSMeans data into the quantity takeoff tables which consisted of over 5,000 components.

Reflecting on the results of the current state of the analysis, a 23.46 percent short is unacceptable to suggest further research and development of this BIM tool. After reviewing scheduled quantities, and RSMeans data for accuracy, it was confirmed that a "blind" release of modeled component into a cost database matrix to gather an estimate is impractical. With further investigation and application of the information gathered from (1) the original estimating process, (2) bid packages development, and (3) the components included and excluded from the related scopes of work, a hybrid estimating process was implemented.

Considerations for Reevaluation

In light of inaccuracies in comparison to the original estimate values and the schedule of values produced during construction for the New Regional Medical Center, modifications to the derived values are outlined in the following section. The bases for modifications include elements which were not included in the model, or are unable to be attributed or entered as a modeled parameter. These values were derived off of the schedule of values in order to accurately incorporate the material, equipment, labor costs into the bid package's scope of work, permitting compatible comparisons. It is recognized below that implementation of a hybrid estimating program which incorporates both model-based data and on-screen (or by-hand) takeoffs still produces variable results, depending on the building system.

Table 5 includes the breakdown of the outcomes of this analysis. Note that due to the adjustments made within the hybrid estimate concept, (1) means and methods, (2) non-modeled elements, (3) inaccurate modeled elements, (4) overhead and services, and (5) design-alternate can be incorporated into the final number, producing a much more accurate and usable result.

Concrete Hybrid Estimate

Original: CIP Concrete [$2,466,807]

Adjust 5D estimate to reflect the following additions/subtractions as noted:

- Stone Sub Base for SOG: +$109,559
- Vapor Barrier: +$25,851
- Concrete Curbs: +$37,538
- Concrete In-Fill Stairs: +$12,000
- Site Retaining Walls: +$634,998
- Concrete Sealer: +$5,460
- Housekeeping Pads: +$112,500
- Surveying/Layout: +$200,000
- General/Daily Cleanup: +$142,000
- Reinforcing Steel: +$523,998

obtain for Norristown, PA is 111.3, and is the multiplier for the total cost and cost per square foot. This value is then divided by 100 per RSMeans directions in order to adjust the costs back to the baseline factor of 100/100.

Original Values: Concrete [$2,466,807], Metals [$6,688,880].

Modified: CIP Concrete [$4,270,711]
Location Factor: [$4,270,711] * [111.3/100] = $4,753,301
Sales Tax: 6% = $285,198

TOTAL: CIP Concrete [$5,038,499]

Steel Hybrid Estimate

Original: Structural Steel [$6,688,880]
Adjust 5D estimate to reflect the following additions/subtractions as noted:

- Mobilize: +$60,000
- Scaffold Stair System: +$72,500
- Reinforcing Steel: -$523,998
- Precast Connections: +$164,000
- Surveying/Layout: +$25,000
- General/Daily Cleanup: +$49,000

Modified: Structural Steel [$6,535,393]
Location Factor: [$6,535,393] * [111.3/100] = $7,273,892
Sales Tax: 6% = $436,434

TOTAL: Structural Steel [$7,710,326]

Table 5: 5D Estimating Comparisons

Comparison Table | 5D Estimating

Bid Package	Component	Cost	Cost/SF	Difference from SOV
System Estimate Costs (Provided by Gilbane)				
03A	CIP Concrete	$5,959,569	$16.25	+5.63%
05A	Structural System	$8,345,697	$22.75	+8.78%
		$14,305,266	**$39.00**	**+7.45%**
Modified Estimate from 5D Process				
03A	CIP Concrete	$5,038,499	$13.74	-10.70%
05A	Structural System	$7,710,326	$21.02	+0.50%
		$12,748,825	**$34.76**	**-4.25%**
Schedule of Values (Provided by Gilbane)				
03A	CIP Concrete	$5,642,000	$15.38	
05A	Structural System	$7,672,000	$20.92	
		$13,314,000	**$36.30**	

See **Appendix G** for the summation of each modeled element family associated with the structural estimate.

Concrete Model-Based Discrepancies

Reinforcement Quantification

Concrete reinforcement metadata within the modeled concrete elements do not output a quantity into the material schedule created through the 3D export process. The output of this information is merely the tag embedded as a parameter depending on how the element was created during design. The resulting data only forecasts bar quantities and sizes, and does not include relevant lengths. Due to this, most of the resulted data concerning reinforcing is handled exactly the same as if it is performed as a traditional-estimate takeoff. In lieu of this, the accuracy of reliance on the model to produce quantities becomes invalid.

Gilbane's Estimate for Reinforcing Steel: $523,998
5D Estimate for Reinforcing Steel: $354,956

Discrepancy: $169,042 [-32.26%]

The reinforcing component estimated values have been supplemented with information provided by Gilbane, due to significant discrepancy and inconsistencies in model output. At this time, there is not a process to extract accurate reinforcing elements based off of the methods the information was embedded within the structural model for the New Regional Medical Center.

Volumetric Calculations

Concrete volumes and square footages did no calculate on some components. Although located and reviewed within the model, it is unknown why the information did not translate. The instances did transfer into the quantity schedule. Recognition of this permitted the errors to be quantified through the traditional method; however, these values remain excluded from the model-specific estimate to validate 3D Estimate capabilities.

Due to this occurrence, these components are not included in the model-specific estimate, and have been omitted from the estimate tables and QTOs included within this report.

Formwork Square Footage Calculations

Concrete formwork and square footage values are not associated within the parameter values of the modeled elements; therefore, an estimate for these components is excluded from the concrete CIP total. It is unknown if it is possible to attribute related formwork systems into different component types through parametric properties with Revit.

Due to this occurrence, these components are not included in the model-specific estimate, and have been omitted from the estimate tables and QTOs included within this report. It is believed that exclusion accounts for a majority of the 10.70% discrepancy.

Potential for Personnel Cost Savings

It is recognized that a 3D QTO process, with cross reference to a database for the estimating process has the potential to create more efficient QTO's for counted or calculated elements. Concurrently, this efficiency can be applied against personnel rates to demonstrate cost savings against the pre-construction budget for Gilbane.

Estimating Personnel: $127 / HR
Estimating Team: 4 members
Traditional Estimating Timeframe: 4 team member, 20 Hours each [$10,160]
5D Estimating Timeframe: 1 team member, 16 Hours [$2,032]

Potential Cost Savings: $8,128 [64 Hours]
Potential Cost Savings per 10,000 Square Feet: $2.21 [0.17 Hours]

This savings can directly be applied to reduce the budget for the pre-construction activities, or application towards time and estimating efforts for more complex and detailed systems within the facility.

Reflection

It is believed that this analysis will expose new opportunities for model information usage for the structural system of the New Regional Medical Center and upcoming projects for Gilbane and other firms. This analysis identifies the current state, growth, and continued potential of leveraging BIM within preconstruction and construction estimating.

Although there is deviation from the actual value, the amount of time saved in utilizing a model for takeoffs permits a greater level of attention to the details and the constructability of the project. In addition to this, cost savings due to a more efficient estimate process can assist in development of cost estimation modeling training, or funding of Autodesk program licenses to access and perform the task. Through performance of traditional method estimating, while concurrently producing a 5D estimate on available model components, a comparison log permits a stronger understanding of the correlation of model detail and component parameters, with an accurate estimate. Additionally, a firm can also develop cross-referencing strategies to supplement traditional method estimating for systems that are more complicated.

Moving forward, this analysis, along with previously developed reports, continues to demonstrate the capabilities and risks of 5D modeling. Additionally, they feature both the shortcomings and growth of the process since its initiation, as shown in Figure 15. It is recommend that firms begin using 5D estimating for the basis of structural steel bid packages (Nahas, 2012) and interior partition bid packages (Kreider, 2009), and supplement this process, with traditional methods in order to align modeled components with the scope of work, or account for details not included with the model. Additionally, it is recommended that companies continue internal research in Revit-Based Methods concurrent to traditional estimating practices on more complicated modeled systems, such as concrete (Nahas, 2012), and curtain wall systems (Abousaid, 2010). Through implementation and continued development, construction firms can provide input and monitor design firms' evolution towards transferrable parameters and modeled features into an estimating matrix.

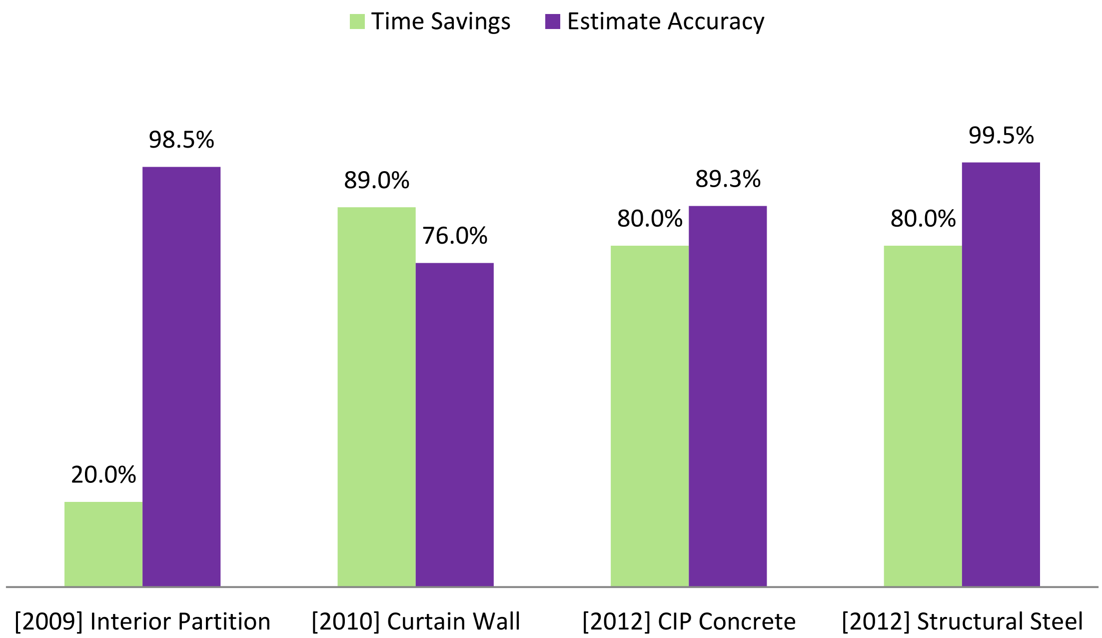


Figure 15: Research Result Trend vs. System in 5D Estimating

Part B: Crane Planning & Logistics

Problem Identification

Gilbane utilized a traditional process and minimal software platforms to identify and select the appropriate steel erection logic for the New Regional Medical. Their process consisted of the review of the structural engineer's plan-documents and cross reference to a database of past projects. Although utilizing of the traditional method produces an accurate crane size, and correctly locates crane pick logistics, there is no basis to identify any trending data for the location and frequency of the critical picks for the structural steel frame. It has been recognized that for the duration of the project, the crane on site was oversized; however, due to the erection sequence determined for the project, there was no ability to downsize the crane for cost savings.

This analysis will investigate the usability in the information embedded within the components modeled in the structural design to visualize erection workflow options. A structural steel erection workflow analysis will be performed, and the results of the recommended workflows relative to crane size optimization will be recorded. These results will be compared with Gilbane's process, and the crane rental expenses of the processes. Additionally, an overview of different program approaches and limitations will be developed, reflecting industry challenges and barriers to this investigation.

Background Information

This analysis will research and develop the process to retrieve embedded information to develop a structural steel estimate, identify the location of critical-pick steel members, and develop a logistics plan for the structural steel erection phase of construction at the New Regional Medical Center.

The second technology break-out session of *The 20th Annual Pace Roundtable,* titled "Strategies and Opportunities for Taking BIM into the Field" focused on the benefits of BIM in the field and developing field logistics. Overall, comments reflected on technology training and generation gaps typically found within the industry, and the challenges to overcome 2D versus 3D communication. Although many industry member comments were in full support of implementation strategies, risks associated with legal concerns, file exchanges, and document standards on BIM models were voiced. Notable issues arose with discussion around model Ownership and model sharing. Sharing models and information tools have developed to permit levels of access from owning, editing, viewing, to excluding. With hopes to mitigate and manage document controls, a higher level of confidence is instilled.

At the conclusion of the session, multiple recommendations were made by industry professional concerning potential research ideas. 3D and 4D crane logistics workflows were proposed during the break-out session, and developed through discussion after the conclusion of the PACE Roundtable. The following section outline the methodology designed though research and industry discussion.

Analysis Influences

- Locating details and parameters included in modeled components.
- The interoperability of project data into various software platforms.
- Ability to interpret modeled data within the software and create a visual representation.

- Alternative methods to visualize outcomes if document data exchange method is not supported.

Methodology

Accessing Embedded Steel Parameters

(1) Create Structural Column Schedule
    a. Fields Required: Family, Type, Column Location Mark, Top Level, Wt/ft, Length
(2) Access Schedule Properties
    a. Add Calculated Value (weight-Tons), Formula: WtperFt*Length/1'/2000, add to Fields
    b. Select the Sorting/Grouping Tab, and sort by weight (tons) descending.
(3) Repeat Step 1 & 2 for Structural Framing Schedule

Updating the 3D Model to Render Colors Relative to Steel Member's Total Weight

(4) Open the {3D} View
    a. Highlight all, Override graphics in view to White, Solid.
    b. Leave non-structural elements in the model.
        i. These elements are boundaries to crane placement, however, hide the floors.
(5) Open One of the newly created schedules
    a. Locate Structural members over 10 Tons,
        i. Highlight rows in Schedule, and click "Highlight in Model".
        ii. Once in Model, right click and select override graphics in view by element
            1. change surface pattern:
                a. Over 10 Tons to RED, Solid.
                b. 5 - 10 Tons to ORANGE, Solid.
                c. 3 - 5 Tons to YELLOW, Solid.
                d. 1 -3 Tons to CYAN, Solid.
                e. 0.5 – 1 Ton to GREEN, Solid.
                f. Below 0.5 Tons, Ignore and leave as white elements.
    b. Repeat Step 10a for the other schedule.

Exporting the View

(6) Duplicate 3D View with Detailing
    a. Open {3D} Highlight All, Override Graphics, NONE
    b. Rename Copy of {3D} to "Structural Member Weight (Ton) Analysis.
(7) Export to SKP
    a. Revit Export>Options>Setups DWG/DFX
        i. Layers (Export all BYLAYER, and create new override)
        ii. Colors (Index Color)
        iii. Solids (ACIS Solids)
    b. Export.CAD Formats>DWG, Next... Save.

Note: *at this point in the methodology, Sketchup, nor other software platforms, were not able to load the overridden colors applied to the view in Step 5. The only export file which was readable with the overridden* *colors was (.DWF). Unfortunately, this file format prevents the elements from being edited or manipulated in any other way, and is considered a "Read-Only" format. Figure 16 is a visual demonstrating the export format.*

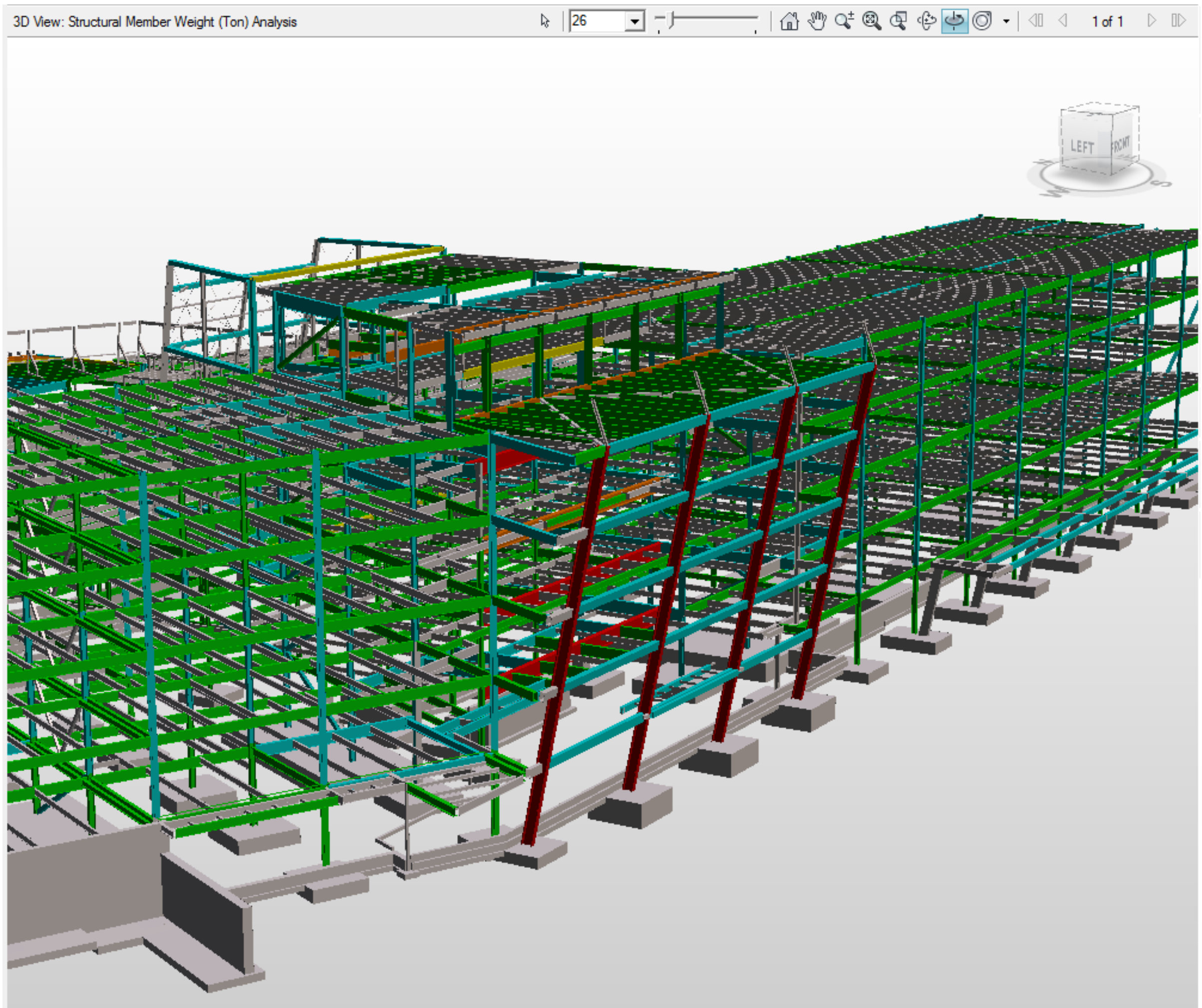


FIGURE 16: DWF MODEL OF CRANE ANALYSIS COLOR ATTRIBUTING

IMPORTING INTO SKETCH UP

(8) Sketchup Pro>Import>Select File...

(9) Group modeled components per the Erection Plan Phases

  a. Assign each group to a Layer, identifying phase sequence within the name

(10) Logically walk though each erection phase by turning on each layer

  a. Within each phase, recognize the heaviest member based on the color scale.
  b. Locate possible crane placement paths, and measure linear distance between
  c. Identify shortest logical location & make mark
  d. From radius (linear distance), sketch necessary lines to identify crane sizing parameters
  e. Reference crane load chart and select crane size

(11) Repeat for each progressive phase

a. Note that it is appropriate to assume the same crane size as a starting point in identifying location of crane; however, keep in mind, a smaller crane option may be available for the phase at hand.

(12) Review crane selection outcomes and optimize logistics to meet safety, financial, and schedule requirements of the project. Insert appropriate crane model if utilizing 4D model.

(13) Export out of Sketchup via IFC File type, if utilizing 4D model.

IMPORTING INTO SYNCHRO

(1) Import the IFC File into Synchro
(2) Sequence the model to the schedule via the provided erection zones, or appropriate subsets.
(3) Have active timeline color remain in the gradient color scheme, and override old phases to be shown as grey elements.

-Alternate process if 4D model already exists-

(4) Load process or Crane Models from Sketch Up into existing 4D model to verify workflow logic with rest of site activities.

INTEROPERABILITY ISSUES

In the March 2012 issues of Modern Steel Construction, an in-depth review covered the steel industry's migration to IFC file structure. The goal of this conversion is to increase interoperability of steel models as open-source files which permits translations across multiple software platforms used within the industry.

> "SIMPLISTICALLY THE IDEA WAS THAT IF TWO SOFTWARE PRODUCTS FULLY ADOPTED THE SCHEMA, THEN THE END USER COULD SIMPLY PRESS A BUTTON TO EXCHANGE DATA AND IT WOULD BE 100% CORRECT." *CHRIS MOOR, AISC DIRECTOR OF INDUSTRY INITIATIVES*

The article, titled "Interoperability for Construction" proceeds to talk about the limitations and barriers to open standards and proprietary data within software vendors. It has been recognized that due to need to maintain a competitive edge in the market, the software will never exchange data as easily as the users would prefer. However, it was noted that as long as limitations and the elements of propriety data are known, solutions can be found.

> "AT EACH EXCHANGE POINT A THOROUGH UNDERSTANDING IS NEEDED OF WHO IS INVOLVED, WHAT SOFTWARE IS INVOLVED, AND WHAT DATA NEEDS TO BE EXCHANGED (OR CAN BE EXCHANGED) AND WHAT THE DATA WILL BE USED FOR." *LUKE FAULKNER, AISC DIRECTOR OF INFORMATION TECHNOLOGY INITIATIVES*

Currently, new workflows and processes need to be recognized, along with the shortfall of information exchange, in order to appropriately realign modeling and software standards and interoperability. This analysis is a perfect example which details "the reality [...] that the broader construction industry has become

BIM-hungry and as its capacity to utilize BIM has grown, so too have the expectations of what data it expects to be able to access" (Moor & Faulkner, March 2012).

> "IN THE END, OUR GOAL IS TO PROVIDE A SERVICE TO THE INDUSTRY SUCH THAT USERS CAN ENTER A FEW PIECES OF INFORMATION ABOUT THEIR ROLE, SOFTWARE AND THE DATA THEY WISH TO EXCHANGE AND IN RESPONSE WILL OBTAIN A RECOMMENDATION FOR HOW BEST TO ACHIEVE THE EXCHANGE." *AISC INITIATIVES*

In light of growing interoperability concerns identified by software providers and end users, an Open BIM Program has been developed as of March, 13, 2012. This program was established through a joint effort of leading software vendors in order to launch a "global program to help promote Open BIM collaboration workflows throughout the AEC industry" (buildingSMART International Ltd., 2012).

> "OPEN BIM PROGRAMME IS A MARKETING CAMPAIGN INITIATED BY GRAPHISOFT®, TEKLA® AND OTHER MEMBERS OF BUILDINGSMART® TO URGE AND FACILITATE GLOBALLY COORDINATED PROMOTION OF THE OPEN BIM CONCEPT THROUGHOUT THE AEC INDUSTRY, WITH ALIGNED COMMUNICATION AND COMMON BRANDING AVAILABLE TO PROGRAMME PARTICIPANTS." *BUILDINGSMART*

Although in its inception, this concept further presses the importance of identifying intended workflows, BIM processes, and the expectations of data exchange through software platforms. Although this analysis has identified limitations in software exchange, it has assisted in bringing to light the current state of the industry's efforts of create solutions and developing more efficient processes. In response to buildingSMART press release, Michal Wojtak, Integrated Construction Manager at Mortenson Construction agreed, stating "I believe this is one of the most important standards to tackle, considering how many challenges we currently encounter in data exchange just between the Autodesk products." He continued, "Unfortunately, the original partnership of Open BIM does not include Autodesk, but hopefully this strategy creates competitions to make the products and processes better, and not continue to isolate data exchanges processes by software providers" (Wojtak, Integrated Construction Manager | Mortenson Construction, 2012).

Alternate Process

In lieu of the current state of the document exchange regarding the efforts of this analysis, an alternative method of structural steel workflow planning for the New Regional Medical Center's site logistics and crane selection process has been developed. This alternative process takes advantage of readily available and exportable data from the 3D structural BIM model, and organizes the information is a way for visual analysis and interpretation of construction workflow based off of trends in structural steel tonnage by member.

Methodology

Accessing Embedded Steel Parameters

(1) Create Structural Column Schedule
   a. Fields Required: Family, Type, Column Location Mark, Top Level, Wt/ft, Length
(2) Access Schedule Properties
   a. Add Calculated Value (weight-Tons), Formula: WtperFt*Length/1'/2000, add to Fields
   b. Select the Sorting/Grouping Tab, and sort by weight (tons) descending.
(3) Repeat Step 1 & 2 for Structural Framing Schedule

Embedding Steel Location and Project Sector

(1) Open one of the 3D Model views
   a. Duplicate with detailing and update the Visual Graphics to only display Structural Steel members (including Beam and Columns).
(2) Change the view point to a plan view of the 3D Model, utilizing the ViewCube
(3) Highlight the elements based off of the building Key (or Sector) Map provided with the drawings.
   a. In the properties window, select one of the element categories.
      i. In the "Comment" field, enter the Sector number or letter.
      ii. Repeat for other element categories which were highlighted.
   b. Repeat this process for all of the building sectors.

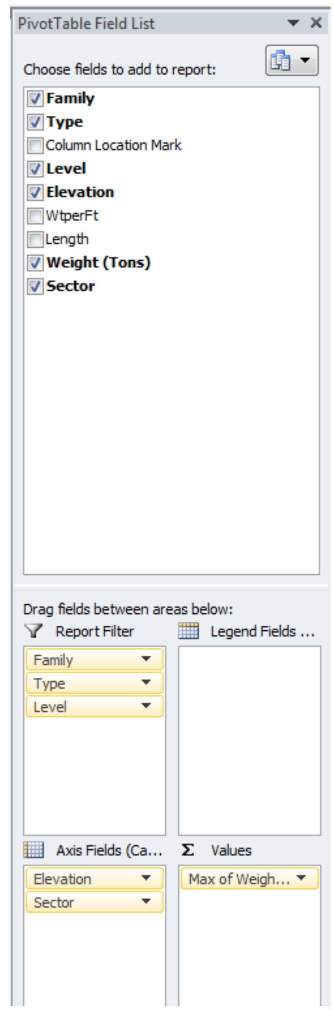


Figure 17: PivotTable Field Configuration

Developing the Material Takeoff Schedule

(1) Follow the guidelines provided in Analysis 1: Part A Methodology to create the schedule for all of the structural steel components within the model.
(2) In addition to the fields provided, also include the "Comments" field, as this will provide directive for the sector or region the member is located within.
(3) Export the Schedule.

Developing the Pivot Chart

(1) Import the data into Microsoft Excel, and place the related tables

within their own worksheet.

(2) Create three additional sheet, labeled “Pivot Chart,” “Pivot Table,” “Merged Data.”
    a. If the “Reference Level” line item of the exported schedule provided specific labels for “First Floor,” “Second Floor,” etc. Create a fourth sheet, permitted a VLOOKUP command, which will update the data extracted from the model and replace the values with the proper elevations. This method provides a stronger understanding of the height of steel.

(3) Update the Data for Reference
    a. In the “Merged Data” table, copy and paste the data from the exported model schedule.
    b. Add an additional column to provide the VLOOKUP function to reference elevation heights.
    c. Format the data using “Format as Table.”
    d. If interested, apply “Conditional Formatting” to particular columns of interest.

(4) Create the Pivot Chart
    a. Select a cell within the “Merged Data” table
    b. Select “Insert” – “Pivot Table” – “Pivot Chart”
        i. Place this chart within a new sheet.

(5) Apply the Filter Parameters
    a. Reference Figure 17 to identify the placement and logic of the PivotTable fields.

(6) Update the Summation Field to identify the “Maximum” steel weights per filter parameter.
    a. Right click on the Field, and select “Vale Field Settings”
    b. Change the “Summarize value field by” to “Max”

(7) Revise the graphical representation, colors, and chart setting to provide a stronger visual.

Interpreting the Pivot Chart

(1) When visualizing the initial data per the Field Table Field List provided in the previous section, the following image depicts the outcome.

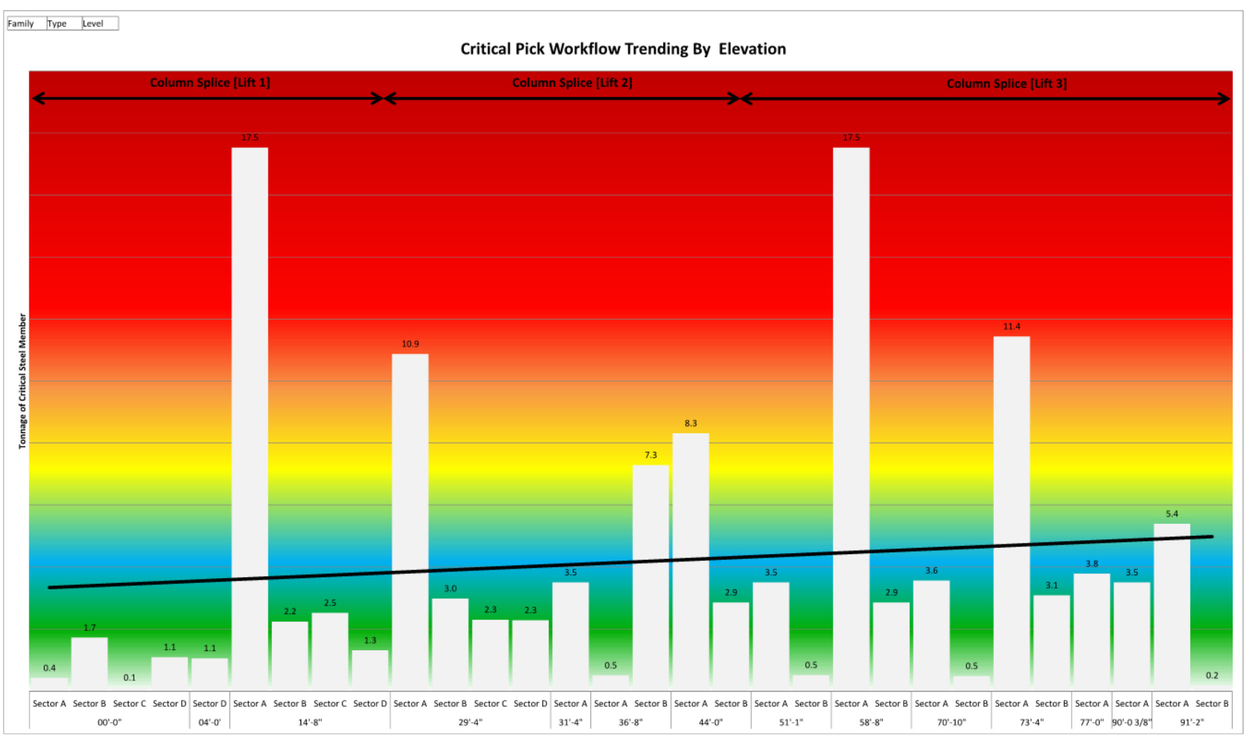


Figure 18: Critical Pick Workflow - Trending by Elevation [See Appendix H for Full Scale]

(2) Reversing the order of the "Axis Fields" within the Field Table Field List provides an alternative visual.

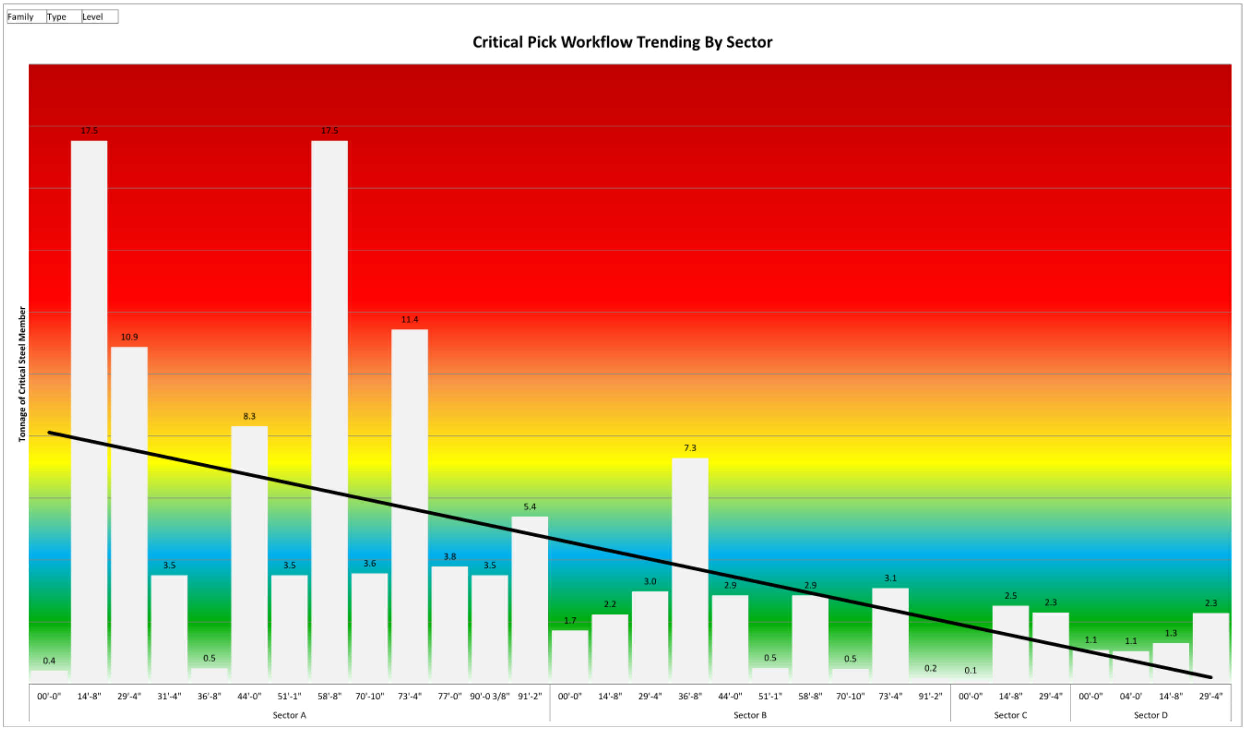


Figure 19: Critical Pick Workflow - Trending by Sector [See Appendix H for Full Scale]

Outcome

Figure 18 and Figure 19 display the two-workflow options available at the New Regional Medical Center. As this site is a greenfield project, with an open landscape surrounding the steel erection process for the facility, this interpretation process is beneficial to identify structural steel tonnage trends in order to properly sequence the erection process in order to optimize the crane capacity present on site, and minimize costs.

Figure 18 represents the workflow conducted by Gilbane at the New Regional Medical Center. This figure represents the structural steel erection workflow moving vertically, erecting the facility by sector, but only up until the column splice. Once each column splice was reach, the remaining sectors were also built to that elevation. This figure represents the requirement to keep a larger crane on site, as multiple lifts consists of steel over 17.5 tons at both the first floor and the third floor, which occur in different column lift sequences. Figure 18 highlights the efficiency of having a single crane on site, through analysis of a horizontal trend line. This efficiency focuses on having a single high-tonnage rig on site during the entire erection program minimizing the overhead costs of setup and breakdown, in addition to the delivery of multiple crane systems. However, this chart also displays the fact that there were only 7 instances out of 30 where a non-typical lift occurred, and the crane was sized to these cases. Due to this, the crane was oversize 77% of the project, and applying much higher rental expenses into the project's budget.

Figure 19 represents an alternative workflow for the project. This chart represents the structural steel erection workflow moving by sector, and completing the entire elevation's structural frame, moving onto the next sector. This figure represents the requirement to keep a larger crane on site, as multiple lifts consists of steel over 17.5 tons at both the first floor and the third floor, which occur in different column lift sequences. Figure 19 highlights the efficiency of having cranes sized to a particular erection sequence, however with a nonhorizontal trend line; it also identifies the risks of having additional expenses for each crane's setup and mobilization. This efficiency focuses on having the highest-tonnage rig on site during only the erection program it is required. With 6 out of 7 non-typical lifts occurring within Sector A, it is sensible to bring in a specific crane for this instance, and remove it from the site after the members are erected. This workflow permits a more cost-effective strategy in the erection process.

Cost Savings

Construction by Elevation (Level)

A 300 ton 2250 Manitowoc crane will be placing the critical structural steel members. This truck crane travels around the perimeter of the building per the sequencing narration and the site logistics plans. The complete crane arrived on site via approximately 15 trucks, and is schedule to perform all major lifts for the duration of the project. This 2250 model features a 500 HP engine, a 140 foot boom (6 inserts), and a 60 foot fixed jib attached.

Mobilization & Demobilization Costs: $9,000 x 2 = $18,000
Rental Costs: $20,000 x 18 weeks = $360,000
TOTAL: $378,000

Concurrently, a 300 ton 2250 Manitowoc crawler will be placing the balance of the structure in addition to the precast facade. This model included a 140 foot boom in addition to a 110 foot luffing jib. As this crane would be present in both workflow cases for a common duration, it has been assumed that any cost savings with a redistribution of the critical pick workflow would be negligible.

Construction by Sector (Bay)

The same crane configuration for the 300 ton 2250 Manitowoc truck crane would be utilized. However, the crane would be required on site for a shorter duration, only required for Sector A and Sector C, and a smaller capacity crane, sized below, will replace it for Sector B and D.

Crane Selection[2]

The crane selection process consists of two main determinants. These focus on the required lifting capacity of the crane for the heaviest pick at a particular distance and height. Once the crane type and configuration conditions are identified, reference is made to a load chart for the particular model to identify capabilities and final selection. Additional influences to consider include the workflow, base configuration of the crane, the quadrant the lift is occurring within, and the site conditions and necessary preparations for the crane to operate.

Selection for the size-reduced crane will parallel many of the parameters in which the crane selected by Gilbane comparing the alternative workflow derived through this analysis.

[2] Lecture *Crane Selection* in AE475 [Building Construction Engineering I] on October 7, 2010

(1) Determinants
  a. Workflow: Sector A & B (300 ton), Sector C & D (TBD)
  b. Critical Lifting Weight: 2.3 tons at 29’-4” or 2.5 tons at 14’-8” Elevation
  c. Critical Lifting Reach: 140’ Radius in Sector D
  d. Base Configuration: Outriggers of a Mobile Truck Crane
  e. Boom Configuration: Boom and Extension
  f. Quadrant: 360 degrees
(2) Sizing
  a. Crane Selection: Grove TMS9000E
  b. Boom Selection: 110 Feet + 33 Feet Extension with 40’ Insert
  c. Crane Specifications: See **Appendix I**
(3) Outcome
  a. 140’ Radius: 5620 tons (less 2 x 1609 lbs for block and tackle) = 2402 lbs
  b. Require a 142.3 foot boom with 33 foot luffing jib at 5-20 degrees offset

Resultant Costs

Mobilization & Demobilization Costs: $9,000 x 2 + $3,400 x 2 = $24,800
Rental Costs: $20,000 x 15 weeks + $5,840 x 3 weeks = $317,520
TOTAL: $342,320

Workflow Requirements

- It is essential to erect the Central Utility Plant first (Located in Sector D)
- Sector A must begin next, as this is the largest quadrant and includes the Atrium

Taking advantage of the greenfield site, a revision to the crane workflow was possible, as there were limited site constraints, in addition to the ability to meet the workflow requirements outlined above. With the ability to visualize structural steel trends, the PivotChart provided an opportunity to develop a more efficient erection program for the New Regional Medical Center. If this site was more restricted, the PivotChart could still be utilized, however the results would have to be evaluated in order to reflect the workflow requirements and limitation of the site.

Potential for Schedule Acceleration

In addition to cost savings associated with reducing the crane size, there is potential to sequence the crane logistics and erection schedule to reduce time for erection using two cranes instead of one crane. Figure 20 includes an overview of the two-crane workflow process in correspondence to the updated workflow developed earlier in this analysis.

Table 6: Proposed Schedule with Two Cranes (Values provided through Gilbane Scheduling)

Sector A	Sector B	Sector C	Sector D
2250 Manitowoc	2250 Manitowoc	Grove TMS9000E	Grove TMS9000E
38 Days	34 Day	6 Days	7 Days
15 Weeks		**3 Weeks**	

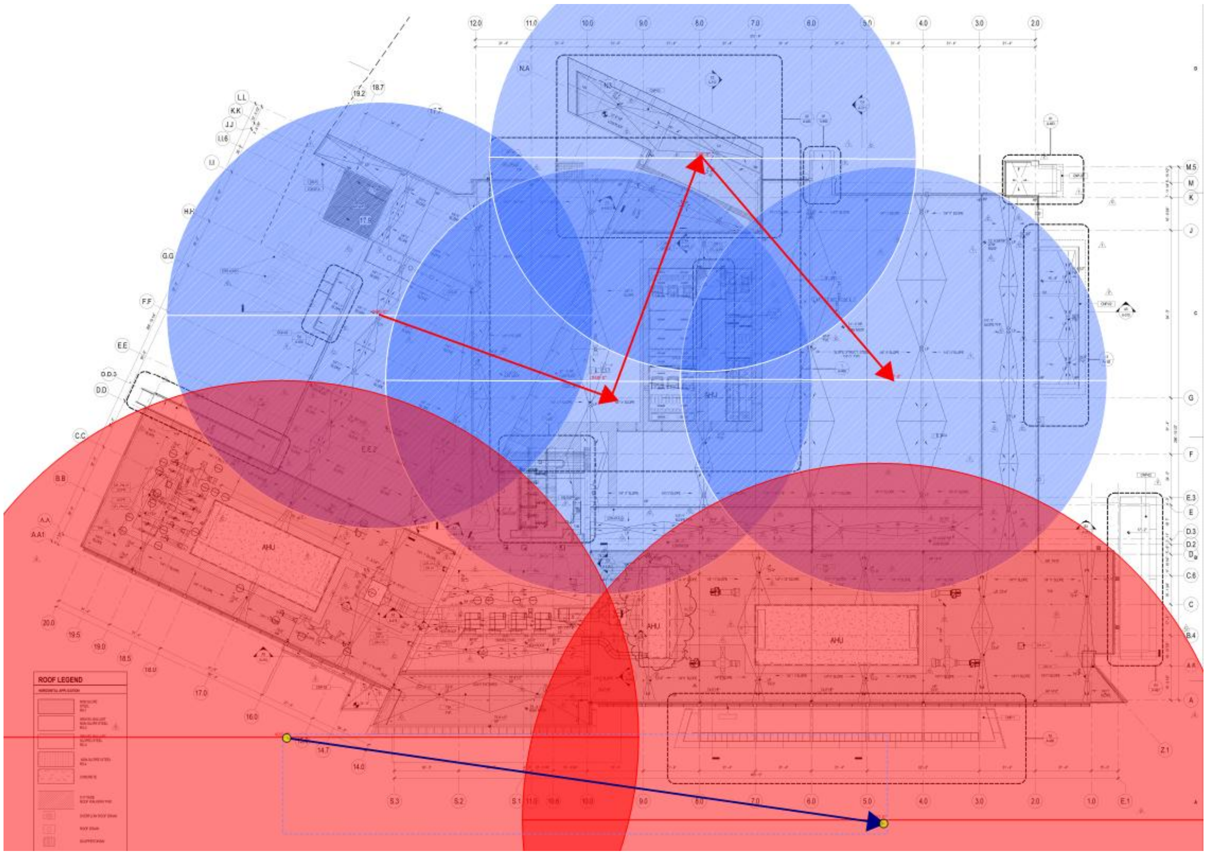


FIGURE 20: CRANE LOGISTICS – BLUE: GROVE TMS9000E, RED: 2250 MANITOWOC

Following the proposed erection schedule, the governing duration is 15 weeks, which accounts for the combined durations for Sector A and Sector B. The original project schedule following the elevation, lift-based erection plan results in duration of 85 days, or 17 weeks. This revised approach reduces the erection schedule and the total project schedule by 2 weeks, as structural steel erection resides on the critical path of the construction schedule. This results in a cost savings of $280,047 based on the month general conditions cost outlined previously in this report.

REFLECTION

Due to limitations in software interoperability and data exchange, the key component to identify steel size does not transfer out of Autodesk Revit. At this time, this method is not feasible for crane site logistics as view filters are not transferrable between Autodesk-based formats, nor are they compatible with open source formats. With further development and insight into similar industry initiatives, workflows can be evaluated and revised to meet the developing standards of data exchange between software products.

In lieu of the current state of the document exchange regarding the efforts of the original analysis, the alternative method still provided a strong visualization of the location, height, and weight of the critical picks. Additionally, through the development of this process, trending information that would have been overlooked in the 3D modeled approach were readily present and provided suggesting and inquiries towards optimization of the erection workflow. It was recognized that the workflow process of the structural erection of the New Regional Medical Center contained an oversize crane for 77% of the duration. Through a visual analysis of the data stored within the structural model, a more comprehensive understanding in addition to alternative workflows are presented, optimizing the logistics, and expenses of cranes during the structural steel erection process. Additionally, a schedule acceleration opportunity was recognized and provided additional costs savings of $280,047 in general condition costs, in addition to a savings of $35,680 on crane rental. In total, this analysis identified a new VDC method in order to highlight trending data within a structural steel model, and resulted in a savings of two weeks on the construction schedule, in addition to $315,727 of the project cost.

Analysis 2 | Redesign of Atrium Enclosure Process

Problem Identification

The atrium glazing enclosure is an extremely challenging scope of work at the New Regional Medical Center, as the assembly is entirely stick-built in situ. Additionally, the interior finishes of the atrium are located on the critical path of the project. If any delay were to occur during the assembly of this curtain wall system, potential impacts to temporary heating, interior finishes, and the status of the remaining schedule items would be affected. Due to the potential for delay during the construction process of this system, an alternative system will be designed, permitting prefabrication of the atrium's enclosure components, and a more efficient construction process for the New Regional Medical Center.

Breadth

This analysis will constitute the architectural breadth component of this report, and will involve redesigning the New Regional Medical Center to include elements to improve the constructability of the atrium's curtain wall glazing system, in addition to the inclusion of public space, which looks out onto the surrounding property and into the neighboring Norristown Farm Park. Associated with this architectural redesign, the unitization of the curtain wall glazing components will be addressed. These efforts will include the modularization and prefabrication of the glazing units in order to reduce costs and project schedule. Additionally, the goal of the breadth is verify the benefits of the redesign in comparison to the existing design of this space regarding quality, safety, and construction logistics.

Background Information

The New Regional Medical Center's critical path consists of 83 activities over 500 working days and began on October 29, 2010, and concludes per the schedule on October 15, 2012. This path revolves primarily around non-accessible drywall finishes in the patient tower, in addition to heavy rough-in in the operating and surgical cores of the medical center, primarily in sector 1C. However, the critical path concludes with the finish elements of the atrium of the facility. This area is the key focus for the final 7 months of the project, as Owner furnished equipment begins to be installed in other areas of the hospital.

See **Appendix H** for the New Regional Medical Center's critical path schedule.

Focused items on the critical path include the sequence: (1) Frame Non-Accessible Walls, (2) Drywall Non-Accessible Walls, and (3) Sheet Metal Overhead Rough-In. This sequence occurs in 11 phases and walks from the 4^{th} floor down to 2^{nd} floor, moving from sector A into B (as shown in Figure 9, Page 26). Once sector 2B is completed, these trades skip over the 1^{st} floor and proceed to the ground level. Ground level critical path activities only include sector A and C. Sector A includes the medical center's cafeteria and kitchen, and sector C includes elements of the emergency room.

Once these three activities are completed on the ground level, they return to the 1^{st} floor and work from A to B to C, and tie into completed areas of D, in addition to future critical path items associated with the operating and surgical rooms. Critical activities in this sector include overhead and in-wall rough-in for plumbing, electrical, medical gas, security, and pneumatic tubing. This area is finalized with partition and ceiling drywalls. Due to drywall's placement on the critical path of sector C, the atrium progress is also added to the critical path of the hospital.

With the large size of the atrium, scaffolding is required in order to install and finish many of the features located within the ceilings and high walls of this space. All finish elements of the atrium, from scaffolding installation to removal, is a critical activity.

Finally, in order to deliver a completed project, final walk thru, sign-offs, and inspections conclude the critical path for the New Regional Medical Center.

Risks to Completion Date

The largest risk to completion date is missing the enclosure deadline of September 1, 2011. If missed, the critical path described above is impacted beginning with 1st floor sector C activities, resulting in delay of the atrium, and potentially substantial and final completion. Additionally, depending on the delay, other activities such as pouring the concrete pour stops in each wing of the facility may be held due to cold weather conditions within the building, as delay will progress into the winter season. Failure to pour these slab sections on time will create delays on interior flooring of the patient towers, and potentially impact finishes and equipment installation in these areas.

Based off the project schedule included in **Appendix E**, with comparison to the critical path schedule included in **Appendix J**, the atrium enclosure assembly is to be completed on August 1, 2011, which permits a float of one month before the enclosure deadline, permitting additional time to complete the complex assembly if required.

Existing Parameters

Cost Information

The atrium's curtain wall system was part of Bid Package # 8.C – Curtain Wall & Aluminum Windows, and was awarded to R.A. Kennedy & Sons Inc.

The bid constituted a lump sum of $5,571,410 and included 17,664 hours of labor for the following systems:

(1) Glazed Curtain Wall System
(2) Aluminum Windows
(3) Automatic Entrances
(4) ICU/CCU Entrances
(5) Interior Glazing
(6) Glass Handrail
(7) Glass Partitions
(8) Aluminum Storefront
(9) System Caulking & Sealants
(10) Reveal Break Metals

Focusing into the Glazed Curtain Wall System components alone, Table 7 details the cost breakdown per the award bid amount provided by R.A. Kennedy & Sons Inc.

Table 7: Curtain Wall Cost Summary

Glazed Curtain Wall System Breakdown	
Quantity	41,000 SF
Man-hours	10,173 Hours
Crew Size	23
Material	$2,132,000
Installation	$1,023,342
Caulking & Sealants	$100,000
Cleanup	$35,328
System Total	**$3,326,670**

Schedule Information

Proposed Schedule

The proposed schedule accounted for 8 weeks for the system to be completed, with an approximate schedule of 2 weeks to construction the framing system, 4 weeks to insert the gaskets and glazing panes, and finally another 2 weeks to caulk and seal the system.

Table 8: Proposed Schedule for Atrium Enclosure Activities

Activity	Start Date	End Date	Duration
Curtain Wall Atrium	June 6, 2011	August 1, 2011	40
Overall Enclosure Schedule	***March 22, 2011***	***September 1, 2011***	***116***

Due to challenges and complexities in constructing this system, it was recognized that the scope of the curtain wall system would take longer than the 8 weeks initially planned. An updated activity status placed the completion at the middle of October, with an ultimate delay to the enclosure schedule of approximately one and a half months, or 32 working days.

Actual Schedule

The frame and glass was installed beginning on August 1st and concluding on October 15th, and required an extra six weeks for the silicone seals and trim to be completed. This process began construction already delayed from the original baseline schedule, and continued to be affected by an aggressive assembly timeline. The system took three additional weeks to assemble over the original estimate. R.A. Kennedy & Sons utilized a crew of 23 members to install the curtain wall system. Due to the challenges of the leaning wall configuration, the installation required a larger crew size and additional equipment when compared to a traditional system.

Table 9: Updated Schedule for Atrium Enclosure Activities

Activity	Start Date	End Date	Duration
Curtain Wall Atrium	August 1, 2011	October 15, 2011	54
Overall Enclosure Schedule	***March 22, 2011***	***October 15, 2011***	***148***

Construction Process

The curtain wall construction consists of a stick built process, which involved the complete assembly of the system on site and in place on the exterior of the structural framing.

Due to the restrictions of height and site logistics, the workflow could not be overlapped or sequenced due to safety concerns, and accessibility of the working surface. The work path consisted of working by level up the face, then proceeding to the next assembly to the west (left), and finally concluding the enclosure at roof level, as shown in Figure 21.

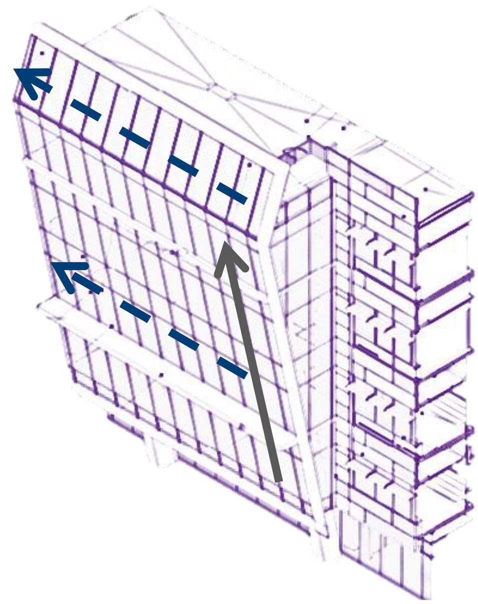


Figure 21: Curtain Wall Glazing Workflow

The entire system was assembled using multiple pieces of equipment, which were orchestrated to provide a safe working platform and material delivery to the work surface. The aluminum framing was set using a crane for lifting the frames, and a hi-reach lift for guiding the frame into place, due the inverted application. The glass was set using a crane with a power cup attachment, for lifting the glass, and two hi-reach lifts, one to guide the top of the glass and the other the bottom. Additionally, since the parapet of the atrium curtain wall is inverted in the opposite direction, it required two HEK towers so the very top of the reverse lean could be installed. A photo of the system during the construction process can be seen, in Figure 22.

Analysis Influences

Subcontractor Interview[3]

On March 22, 2012, an interview was conducted with Al Batten, who is Project Manager for R.S. Kennedy & Sons, Inc., and is overseeing the design, construction, and operations of Bid Package # 8.C – Curtain Wall & Aluminum Windows at the New Regional Medical Center.

System Challenges

The inverted application caused some challenges during construction. One item that required much focus was the perimeter panels and the panel steel support structure. These components are often overlooked during the design process, as typically they do not appear to be difficult. Unfortunately, R.A. Kennedy & Sons were not provided any structure to attach the perimeter panels; therefore, they have to fabricate support steel to attach to the structural columns, in order to affix the panels. They were only provided the steel column layout for the atrium, and there was no thought on how to support the curtain wall by the design team. This fell onto the subcontractor and required them to design and build out steel structure to support the curtain wall designed by Perkins & Will.

[3] Al Batten – Project Manager, R.A. Kennedy & Sons, Inc.

A second challenge regarded the steel reinforcing which was required within the frame. This specification, along with a temperature-based expansion/contraction for a plus or minus temperature range of 180 degrees made the construction especially complex. It required the subcontractor to design the system "horizontally," allowing the bottom of each frame to "float," with only the top of each frame anchored to the structure. The design team outlined these specifications in order to minimize the number of custom extrusion needed for the system.

System Recommendations

Due to the bidding process and the outlined construction schedule, R.A. Kennedy & Sons, Inc. was not permitted to provide any recommendations, alterations, or options for the system design. They were only provided with a structural steel grid in which they had to design how to attach their own system.

It is recommended that prefabrication of unitized panels for the atrium's curtain wall system would have been a better alternative. However, more time would need to be allocated to the design and system constraints, in addition to a final design decision occurring sooner. During R.A. Kennedy & Son's shop drawing submittal process, crucial design items were still being determined. Additionally, interior working platforms or decking would make construction easier, permitting a team to align and affix the base of the panel from the interior.

Prefabrication (unitizing) closes a building in quickly, but all of the design work needs to be done well in advance. Stick building, which was the process for this assembly, allows for time in the schedule to work out sizes and design issues in the field. Additionally, if a unitized system were to be used, all new extrusions would have to have been used and there was not enough time. In this facility, R.A. Kennedy & Sons prefabricated every other glazing system, except for the atrium's enclosure. Looking back onto how this system played out, they would have preferred to have this system unitized, with prefabricated frames, and preinstalled glazing units. With this option, the field assembly would have been more efficient, cost-effective, and safer.

Figure 22: Curtain Wall Construction [Taken on 10/4/2011 by Al Batten, R.A. Kennedy & Sons Inc.]

Methodology

The redesign of this system will be performed through the reference of "The International Building Code 2006" prepared by the International Code Council, with additional compliance coordination from "ADA Accessibility Guidelines for Buildings and Facilities" prepared by the U.S. Architectural and Transportation Barriers Compliance Board. In order to aesthetically transition the additions into to the space, a majority of the interior finishes will remain typical of the space, and refer to existing components of the facility. The goal of the analysis is to design a permanent working platform at the first and third floor to assist in construction logistics of the inverted curtain wall system. Additionally, this platform will be finished as public space and designated as a public lounge area for patients and visitors. Finally, this area will provide additional workspace necessary for maintenance and cleaning of the glazing system.

Existing Parameters & Guidelines

The following factors will be examined and taken into account during this analysis:

(1) Dimensions and configurations of the building
(2) Aesthetic finishes of the atrium space
(3) Provision for constructability and usable finished space
(4) Adherence to relevant life safety codes
(5) Adherence to relevant building codes, such as ADA compliance

The following assumptions will form the basis of this analysis, unless otherwise noted:

(1) Member layout to remain typical to the existing design
(2) Joist type and spacing to remain typical to the existing design
(3) LRFD design analysis process will be utilized
(4) The expansion joints will be located in the same place as the concrete pour strips, if applicable.

The following notes from LS-001 Code Compliance Data are of particular importance to this analysis:

(1) International Building Code (IBC) Section 308: Occupancy Classification: Assembly [Group A-2]
(2) IBC Section 404: Atriums
    a. Automatic Fire Protection and Smoke Control
    b. Interior Finishes shall be a minimum of Class B without reduction for automatic sprinklers
        i. Flame Spread Index: 26 - 75
        ii. Smoke Developed Index: 0 - 450
    c. Travel distance to means of egress shall not exceed 200 feet
(3) IBC Section 602.2: Type 1 Construction
(4) Egress Requirements
    a. Capacity of Egress: 15 net Square feet per Occupant – Assembly Unconcentrated
    b. Egress Width: 0.15 inches per occupant
    c. Travel distance from exit of egress travel shall not exceed 250 feet

The following notes regarding ADA accessibility are of particular importance to this analysis:

(1) 4.2 Space Allowance and Reach Ranges
    a. 60 inches minimum for wheelchair passing width and turning space
    b. Handrails must be continuous in the space and terminate parallel to the floor level if angled

The following notes from S-001 Schedule & General Notes are of particular importance to this analysis:

(1) Floors have been designed as composite beam and composite deck.
(2) All concrete shall be ready-mix and have a minimum compressive strength at 28 days of:
    a. Concrete Slab on Metal Deck: 3,500 SPI
(3) All concrete shall have a minimum of 500 lbs of cement per cubic yard.
(4) All structural steel shall be fabricated and erected in accordance with the latest AISC Code. All connections, including at HSS sections, shall be designed and detailed in accordance with the latest AISC Code. All wide flange shapes shall be ASTM A992.
(5) Design Load Requirements
    a. Typical Floor: Dead Load–65 pounds per square feet, Live Load–100 pounds per square feet
    b. Atrium Roof: Dead Load–75 pounds per square feet, Live Load–100 pounds per square feet
(6) Utilize a 3 ¼” Lightweight Concrete on 3” Metal Deck

Architectural Analysis Process

Architectural redesign will take place using Autodesk Revit Architecture and Structure in order to modify and add to the existing model furnished by Perkins & Will. The redesign will include the development of two working interior platforms, which are to be utilized by the trades for construction of the curtain wall-glazing units, in addition to the interior finishes. These working platforms will be designed in order to meet building codes applicable to the space, and permit them to double as and interior corridor and lounge that will be cantilevered off the structural steel at the face of the curtain wall-glazing units.

The concept will create a lounge that will be accessible from both the east and west patient towers at level one and level three. This space will include furnishing and side tables to provide a comfortable and flexible environment for the patients and their visitors. This space will overlook the front façade of the medical center and provide a panorama view of the Norristown Farm Park.

The existing parameters and guidelines referenced above have been taken into account, and the following renderings highlight the redesign space.

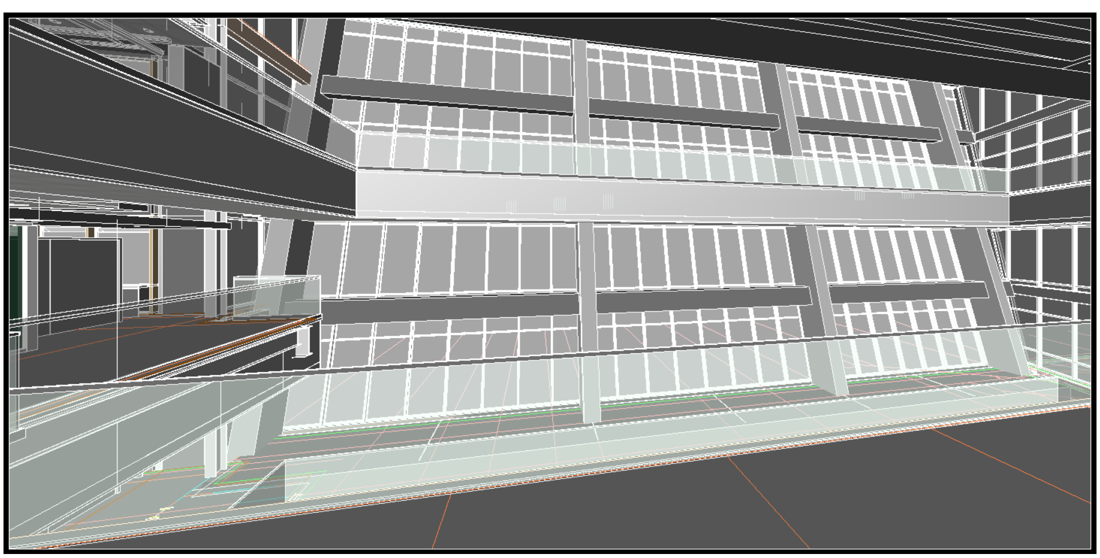


Figure 23: Interior Model Image at 2nd Floor Atrium

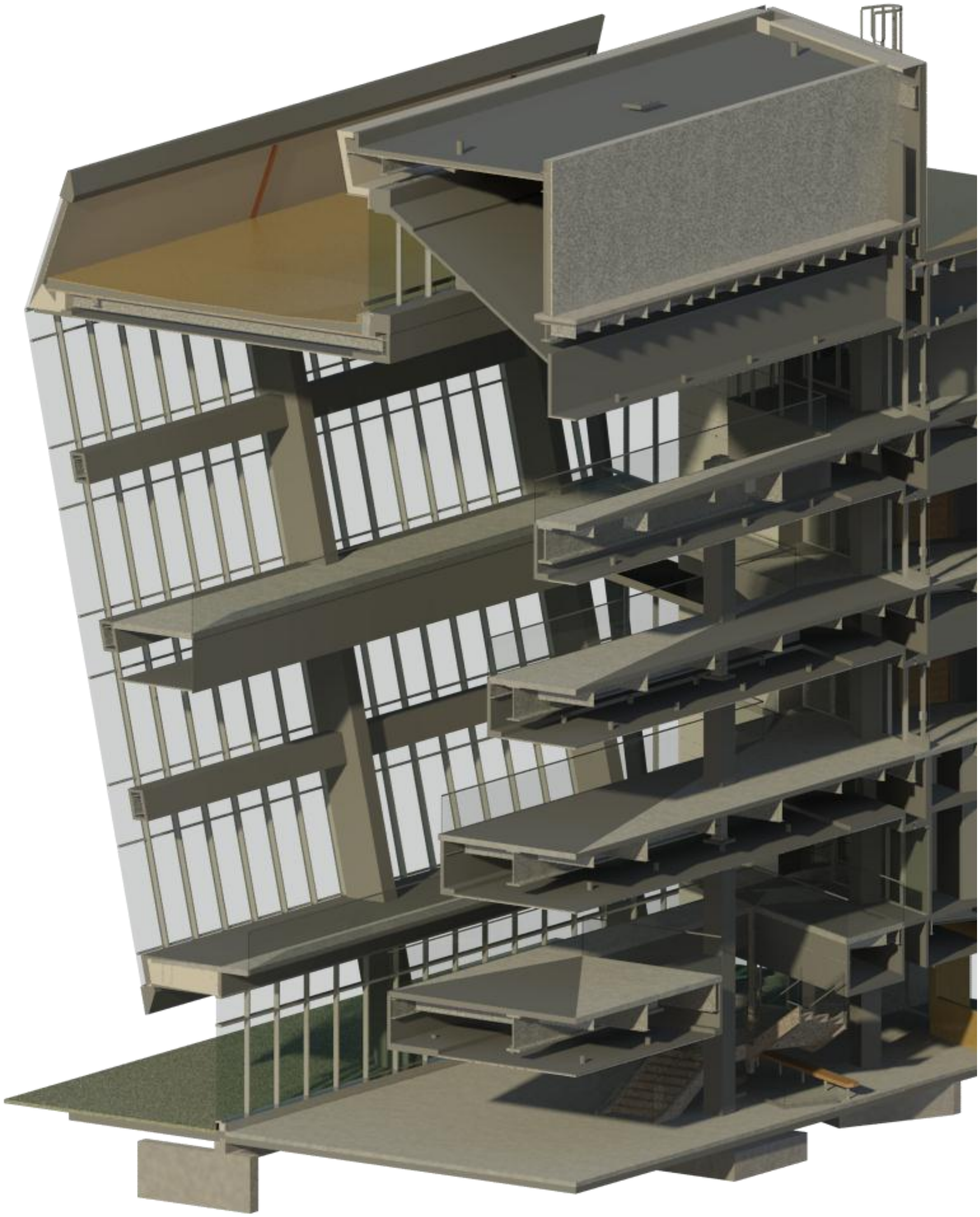


FIGURE 24: RENDERED 3D INTERIOR SECTION AT ATRIUM

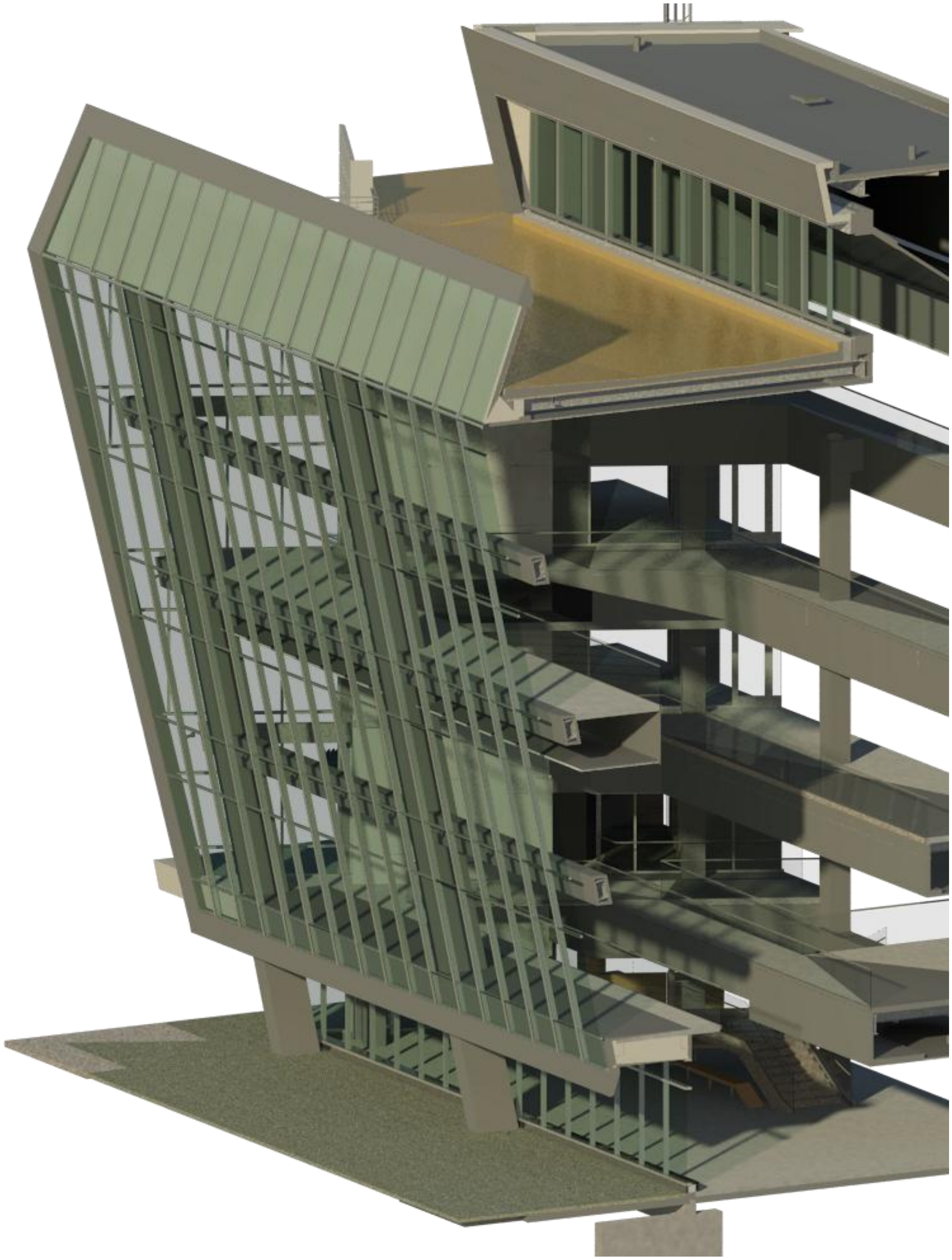


FIGURE 25: RENDERED 3D EXTERIOR SECTION AT ATRIUM

Unitized Curtain Wall System

Analysis is to be performed to calculate the optimum assembly dimensions for the unitized system. The new assembly will consist of panels in which span each floor level. Additionally, due to delivery restrictions, the overall dimension of the length will be limited to what R.A. Kennedy & Son's is capable of hauling. Figure 26 and Figure 27 display the delivery sequence and truckload distribution for the curtain wall units. Additionally, due to height restrictions on delivery, the front façade panels require a field assembly to stack two panels to reach the full height, corresponding with the work platforms, allowing a safe working plane to affix the panels to the structural system, as shown in Figure 28.

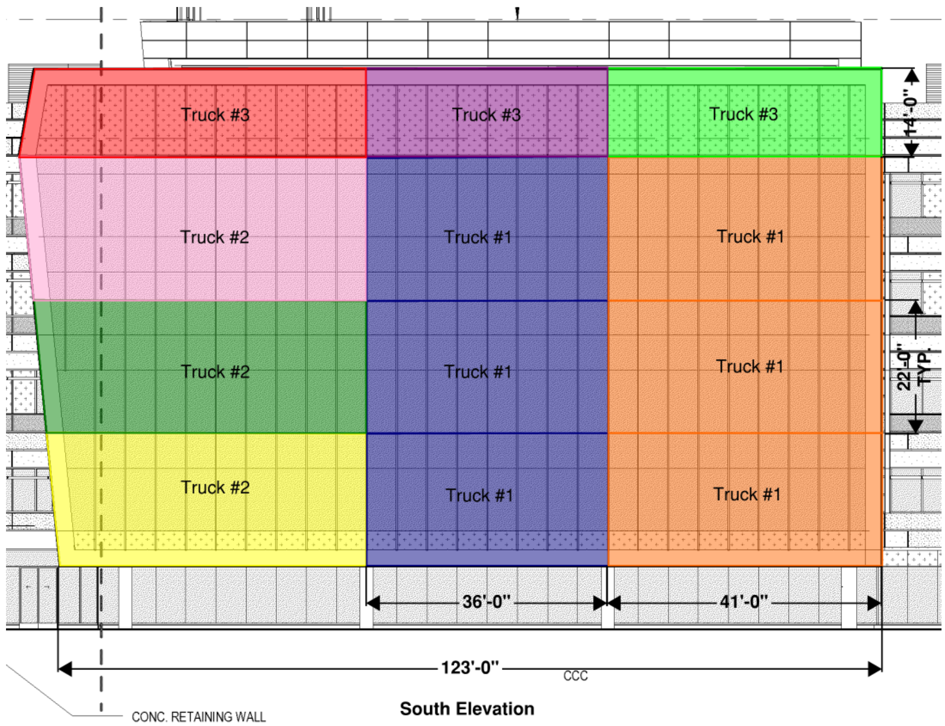


Figure 26: South Facade Delivery Sequence

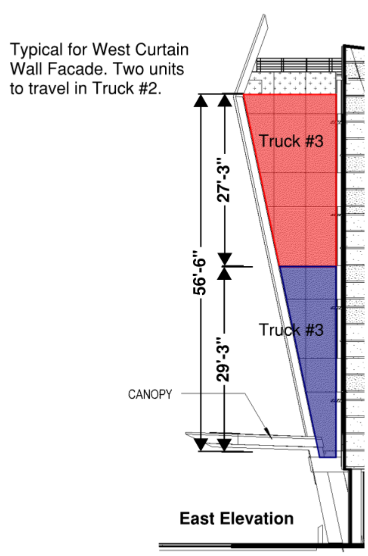


Figure 27: East Elevation Delivery Sequence

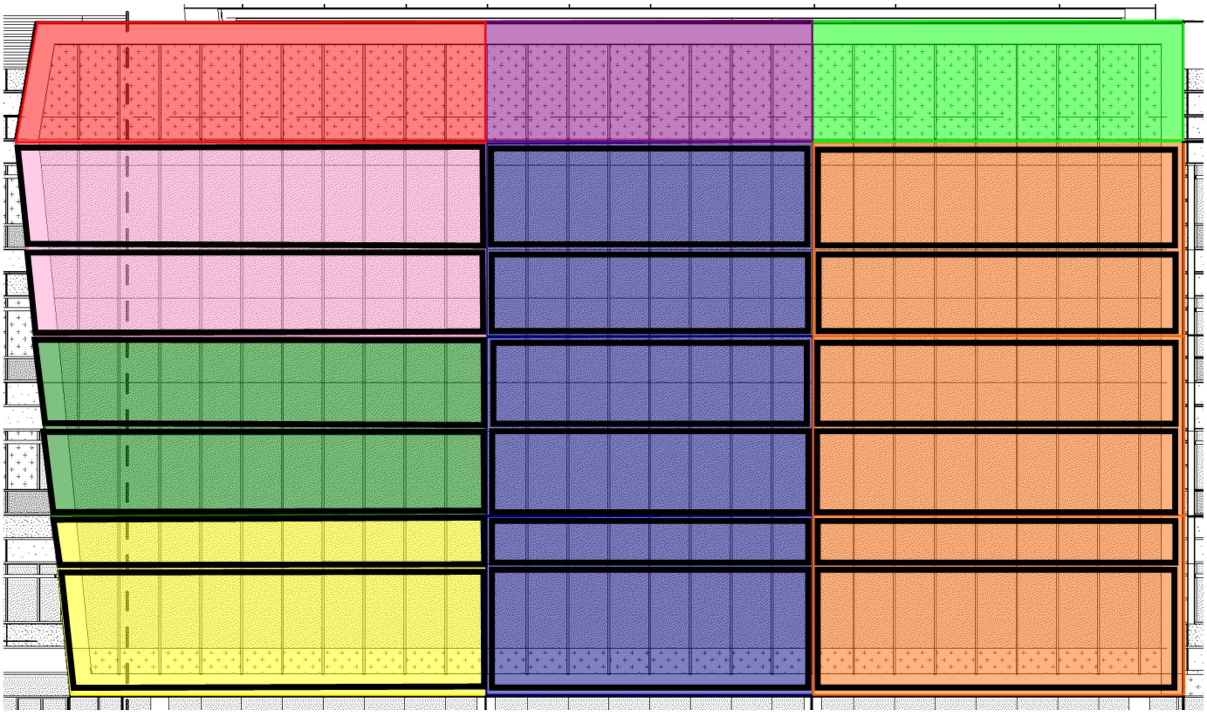


FIGURE 28: FIELD JOINTED UNITS [SHOWN IN BLACK OUTLINE]

In order to coordinate the lifts with the inverted façade, a crane will pick the assembled 22’-0” tall unit towards the building, and hang the unit from the engineered support structure. Once hanging in place, a crew standing on the new working levels inside of the structural frame will pull the bottom edge back to the face of the steel and affix the base of the unit, as shown in Figure 29.

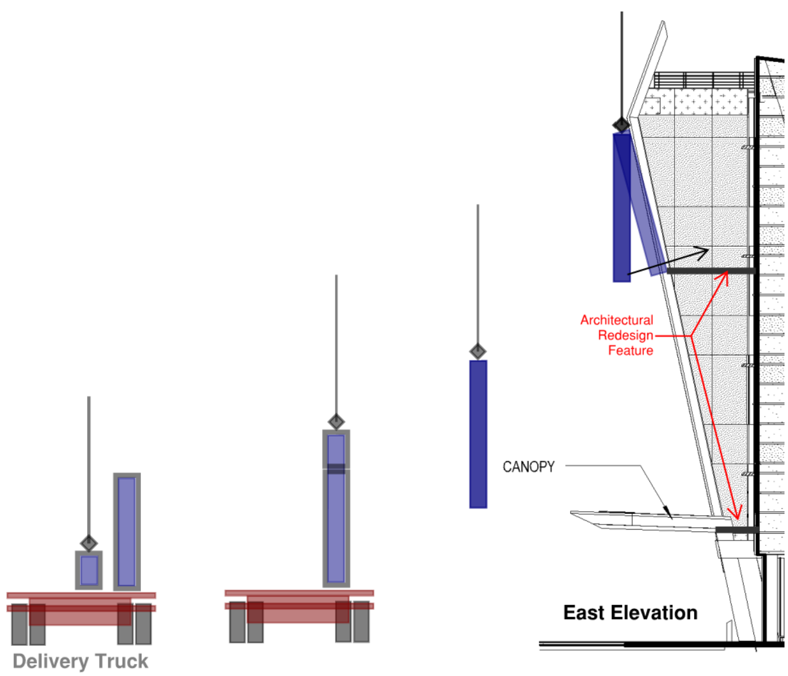


FIGURE 29: SCHEMATIC LIFT SEQUENCE

Outcome

Architectural Redesign Cost

Square foot estimate costs are applied against the additional architectural and structural elements required to include this redesign into the project costs. Below is a table of the additional costs and outcome.

Table 10: Architectural Redesign Costs

System	Cost
Floor System	$8,450
Structural Steel	$24,338
GWB	$3,280
Finishes	$87,387
Redesign Total	**$123,455**

Redesign costs for the unitization of the curtain wall assembly is comparable in costs to a stick built system. The major changes with the costs are that the in-filed construction costs for equipment and labor are reduced, while the fabrication and assembly costs are increased, in addition to transportation costs. In talking with R.A. Kennedy & Son, they justified that there would be very little cost differential in the two system approaches. In this case, a lead-time of 20 weeks would be required to allow for procurement of materials and fabrication. The major benefit of the unitized system would permit a quicker building enclosure and a reduction in high-risk construction activities on site. Overall, unitization for this project would not create a schedule acceleration situation. Due to the lead-time relative to when R.A. Kennedy & Sons were brought into the project, the unitized system would arrive on site in just enough time to complete the enclosure on schedule. Unitization would only prevent the delay in which occurred with the original stick-built system.

Constructability Savings

Due to the architectural configuration of the existing system, notably the incline and reverse incline of the atrium's glazing curtain wall, great efforts, financially, were made in order to engineer a safe manner to construct the original design. In addition to the need of multiple cranes and lifts, a crew double in size to typical installations, was required to complete this façade. With the implementation of a unitized system, the need for multiple cranes, lifts, and an oversized crew is eliminated. If planned properly, the entire system can be constructed with a typical crew size and only one crane in operation. This will reduce substantial equipment and labor expenses for the system, in addition to reducing the level of risk for the workers. With the inclusion of the architectural redesign, the workers are placed at a safe working height and can maneuver the flying panels into place with more control. Additionally, future trades who are responsible for encasing the steel columns in gypsum wall board and painting, will have a safer working platform, eliminating the need to cantilever scaffolding out to the inside of the enclosure.

Aesthetics, Space, and Usability

In development of the architectural redesign, the goal was to provide a more efficient construction process, while in turn, developing a permanent space for facility use. It has been recognized through analysis that multiple public space features were removed from the original design due to cost overruns. Keeping this in mind, an aesthetically pleasing space was designed in order to improve constructability and eliminate a high-risk construction process on the site, while also providing a space for patient and visitors to enjoy the greenfield landscape surrounding the hospital. Additionally, a more accessible access point is created for interior glazing cleaning. Overall, this redesign and unitization process meets the Owner's expectations by providing high construction quality in a safe environment, while enhancing the patient's experience.

Reflection

It is believed that this analysis confirms that stronger focus should have been provided during design development of the atrium's curtain wall enclosure. With this component being one of the most time critical events during construction, a stronger outline and interface with a glazing subcontractor should have been performed. Doing so would have permitted constructability input, design development, and transparency behind achieving the design intent in the most economical process. Although early subcontractor involvement would have resulted in the unitization and design reviews of the atrium enclosure, the delivery method for this project created a barrier for input. The New Regional Medical Center would have benefitted from a modular system, in addition to an architectural revision to include catwalk lounges along the atrium exterior wall.

From this analysis it is recommended that design teams review their curtain wall systems with a stronger focus. Additionally, obtaining a glazing subcontractor for consultation would also assist in design development in order to ensure that the expected product meets the schedule, cost, and quality level that the owner and construction team expects to produce. With the assistance of a prefabricated glazing system, the construction site requires fewer trades working in high-risk locations, in addition to less equipment on site. Finally, the key to this system being implemented is open communications and consultation during design development and design revisions.

Analysis 3 | Redesign of Structural Pour Strip

Problem Identification

The New Regional Medical Center was faced with constructability issues surrounding the schedule and access to the pour strip regions of the facility. Due to the reliance of an on-time completion of the pour strip, in order to continue to install the interior components on schedule, the design decisions of this element will be analyzed. A design alternative would include a traditional building expansion joint. Typically, expansion joints create ease in construction methods and do not rely on the building enclosure activities. With the risk of an enclosure delay on this project, this analysis will analyze the project costs, schedule, and aesthetics of an expansion joint, identifying if this would have been a better option given the complexities in the atrium enclosure activities and the uncertainty of its schedule.

Breadth

This analysis will constitute the structural breadth component of this report, and will include redesigning the concrete pour stop as a typical building expansion. Structural calculations will be performed to compare this system to a building expansion joint system. Additional costs, schedule impacts, and constructability reviews will be considered as a substantial part of the redesign, notably focusing on foundation changes, and steel frame revisions. With review, acknowledgement of which system would have performed best in this case and in combination with the schedule derived from Architectural Breadth previously discussed. Reflection on the outcomes will discuss design decision logic from a construction point of view.

Background Information

The New Regional Medical Center is roughly 556 feet in length and has two concrete pour stops, per floor, located within each patient tower, which are each offset 125 feet from the east and west exterior walls (Figure 30). Although the main structure is steel with metal decking, the structural design detailed pour stops in lieu of building expansion joints. This connection detail requires the entire building to be enclosed and climate controlled prior to pouring the final connection. Once the structural steel and concrete decking reach typical interior temperature conditions, and transition through temperature expansion and contraction, this strip will be in-filled (Figure 31). This concept creates a rigid frame for the facility, providing both a structurally sound facility in addition to an architecturally pleasing interior without visible joints.

Unfortunately, per Analysis 2, the building enclosure date was missed on the project, which induced schedule

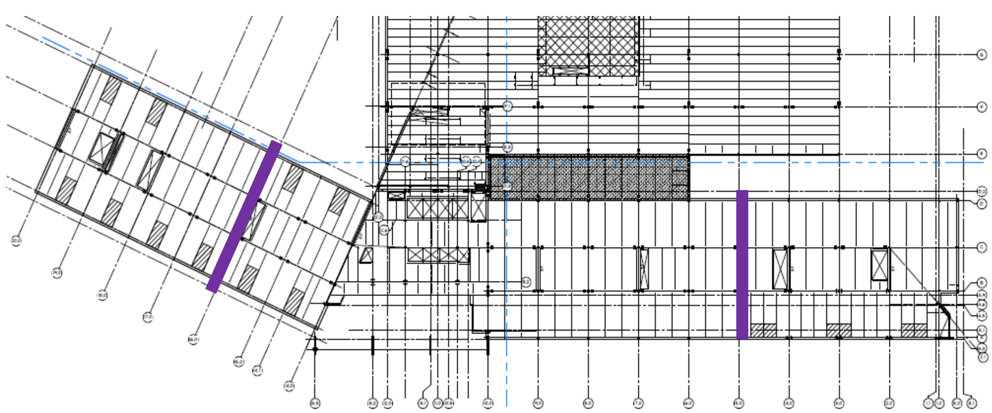


Figure 30: Second Floor Overall Framing Plan [Sheet S-120 | Perkins & Will]

delays for a conditioned facility. Without a neutralized temperature in the space, and adequate time for the materials to expand and contract, the pour strip could not be placed. Ultimately, this delay affects interior finishes, such as flooring, as the pour strip areas still contain exposed metal decking and reinforcing for the floor slab.

In order to overcome this issue, and return the project back to the intended schedule, temporary enclosures were made at the connection of the patient tower and the atrium, as the atrium glazing was still being installed. Once temporary enclosure was complete, the towers were conditioned to the heat requirements for the pour strips.

In lieu of these challenges, this analysis will compare the existing pour strip system to an expansion joint system, and identify the more applicable design to this case. It will address if the pour stop was the best choice, in addition to review cost, schedule, and aesthetics concerning structural joints and pour strips.

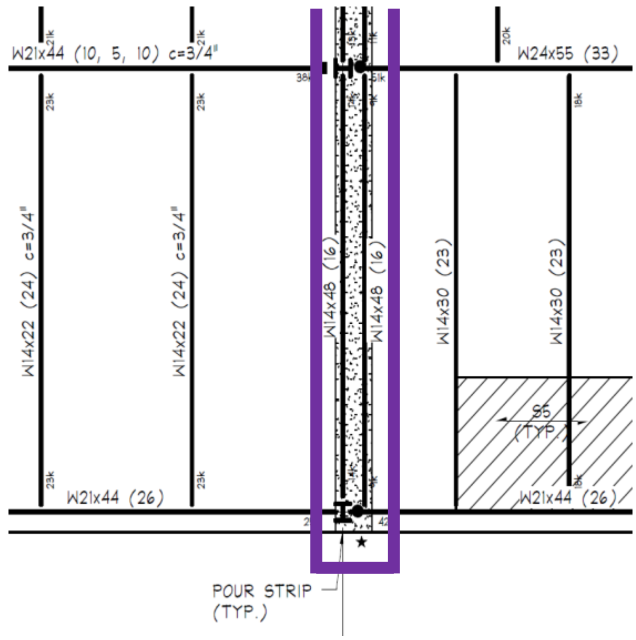


Figure 31: Enlarged Pour Strip [S-220B | Perkins & Will]

Existing Parameters

Cost Information

Due to the complexities of the components associated with the pour strip being located within multiple Bid Packages, the cost information provided will be derived through quantity takeoff and *RS Means* cost information.

The estimate constituted a sum of $239,772. Table 11 details the cost breakdown per the calculated values. **Appendix K** includes resultant values per detailed quantity takeoff.

Table 11: Pour Strip Cost Summary

Pour Strip Assembly	
Foundation System	$59,512
Structural Columns	$61,217
Structural Beams	$101,826
Slab on Grade	$684
Slab on Metal Deck	$9,230
Reinforcing	$7,303
Total:	**$239,772**

Schedule Information

Although discussion in the previous section detailed the delay of building enclosure, and the impact it created on conditioning the space and properly placing the building's pour strip system, the winter weather in which this system was being completed within was extremely mild. Due to this, the project did not have any long-term schedule impacts, and the initial delay recovered within reasonable time.

Although this is fortunate for the construction schedule and process needed for the pour strips, it must be recognized that grave delay entering the winter months, could have negatively affected the outcome of the project. Identifying this system as a critical assembly within the building, these circumstances and constructability requirements must be reviewed during the design process. Alternative designs should not only be considered for cost savings, constructability, or aesthetic purposes, they should also be reviewed against ability to recover from unforeseen delay.

Construction Process

The entire system was assembled during the steel erection process, and did not require extra effort to arrange the component per the design details. This assembly required that a 2'-6" gap be left within the slab on metal deck. Once the building was conditioned, this gap was in-filled with concrete via a wheelbarrow, and the welded-wire fabric within the gap was overlapped from the bordering slab edges. The critical construction influence this system has is the fact that there is a 2'-6" break in the slab on deck, with two instances on every floor above grade. This can be seen below, in Figure 32. With not only the development of a tripping hazard, coordination of the interior finishes must be orchestrated properly to ensure that this system is completed, and the temporary floor plate cover is removed, before the floor systems and wall board are installed.

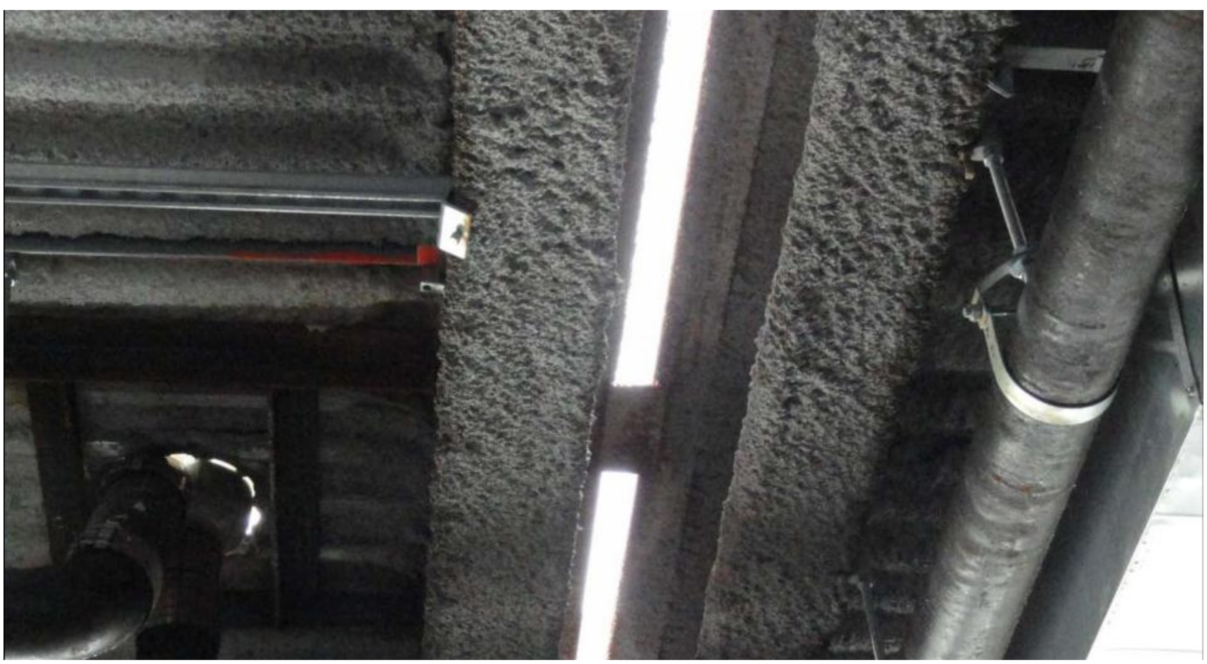


Figure 32: Sector B Roof Pour Strip [Taken on 6/13/2011 by Gilbane Building Co.]

Influences

Owner Interview[4]

In order to properly understand the design decision of selecting a pour strip system over a typical building expansion joint, an interview with Richard Montalbano, who is the Vice President and Project Executive for Albert Einstein Healthcare Network, was conducted on January 31, 2012. Below are the results of the discussion.

Q: Why was the pour strip system selected for the New Regional Medical Center?
A: The New Regional Medical Center has an elegant, sleek, architectural aesthetic on both the interior and exterior of the facility. Although the expansion joint could be hidden behind the precast enclosure panels, the interior finishes would not support the look of an expansion joint cover.

Q: Does the Albert Einstein Healthcare Network have negative experience with expansion joints?
A: Yes, we have a number of facilities that contain expansion joints, and this system creates a maintenance nightmare. It may be specific to healthcare and hospitals, but our expansion joints see extensive wear and tear due to the loading crossing the threshold. This is mainly due to the hospital beds and other equipment movement.

Q: How has maintenance affected your design decision?
A: Maintenance is the critical reasoning why the expansion joint system was not utilized on this facility. Although there may be new products on the market, the direction of interior finishes selected for the hallways do no support a gap within the building. Typically, the expansion joint cover plates are carpeted-over in our other facilities. However, we cannot utilize carpet within the hallways of this hospital. If vinyl tile were placed over the gap, the tiles would warp and crack. Unless a product is available in which the floor finish can be in-laid in the system, an expansion joint is not practical.

Q: It is recognized that the construction process for a pour strip becomes much more complicated, especially as the finishing requires building enclosure. How do you feel if this system creates a delay on the project?
A: Many of the design decision made within this facility revolved around building comfort, aesthetics, and the lifecycle of the facility. It is understood that this design decision may create construction issues, and areas for delay. Although this decision does not simplify the AEC's project approach, it eases the maintenance and lifecycle control of the space. If I can make maintenance that much easier for my facilities, the decision is justified.

Q: If a product is located which is capable of embedding the architectural finishes within the joint cover, in addition to providing structural support, would you consider the system as a feasible design alternate?
A: Yes, I think this would be a reasonable design alternate to consider. I would be most concerned with the cost difference. It is understood that the construction team would be able to perform either system without considerable schedule alterations. Focus on costs and aesthetics.

---

[4] Richard Montalbano - Vice President & Project Executive, Albert Einstein Healthcare Network

Methodology

The redesign of this system will be performed through the reference of "Expansion Joints in Buildings – Technical Report No. 65" prepared by the Standing Committee on Structural Engineering of the Federal Construction Council. Additional references will include material used in AE 404 and AE 308, notably "Fundamentals of Structural Analysis, Third Edition" by Kenneth M. Leet. Finally, structural calculation for foundation redesign will follow the guidelines presented in CE 397A, and "Principles of Foundation Engineering" by Braja Das.

Existing Parameters & Guidelines

The following factors will be examined and taken into account during this analysis:

(6) Dimensions and configurations of the building
(7) Design temperature change
(8) Provision for temperature control
(9) Type of frame, connection to the foundation, and symmetry of stiffness against lateral displacement
(10) Material of construction

The following assumptions will form the basis of this analysis, unless otherwise noted in calculations:

(5) Floor construction assemblies to remain typical to the existing design
(6) Member layout to remain typical to the existing design
(7) Joist type and spacing to remain typical to the existing design
(8) LRFD design analysis process will be utilized
(9) The expansion joints will be located in the same place as the concrete pour strips, if applicable.

The following notes from S-001 Schedule & General Notes are of particular importance to this analysis:

(7) Floors have been designed as composite beam and composite deck. Beam/deck shoring is not required unless noted otherwise on drawings.
(8) Bottom of footings shall bear on undisturbed virgin soil capable of safely supporting 4,000 PSF.
(9) Reinforcing steel shall have a minimum clear cover as follows:
  a. Concrete poured against earth: 3"
(10) All concrete shall be ready-mix and have a minimum compressive strength at 28 days of:
  a. Spread footings: 4,000 PSI
  b. Slab-on-Grade: 3,500 PSI
  c. Concrete Slab on Metal Deck: 3,500 SPI
(11) All concrete shall have a minimum of 500 lbs of cement per cubic yard.
(12) All structural steel shall be fabricated and erected in accordance with the latest AISC Code. All connections, including at HSS sections, shall be designed and detailed in accordance with the latest AISC Code. All wide flange shapes shall be ASTM A992.

The following tables from S-001 Schedule & General Notes are of particular importance to this analysis:

TABLE 12: DESIGN LOAD SCHEDULE [S-001 PERKINS & WILL]

DESIGN LOAD SCHEDULE
(ALL LOADS SHOWN ARE IN POUNDS PER SQ. FT.)

COMPONENT \ AREA	4" SLAB ON GRADE	6" SLAB ON GRADE	8" SLAB ON GRADE	TYPICAL FLOOR	SURGERY FLOOR	BED TOWER PATIENT BATHROOMS	MECHANICAL PENTHOUSE	ROOF w/ CONCRETE	MECHANICAL PENTHOUSE ROOF	TYPICAL ROOF	3rd FLOOR LOW ROOF	ATRIUM
CONCRETE SLAB	50	75	100									
3 1/4" L.W. CONC. ON 3" DECK				48								
3 1/4" N.W. CONC. ON 3" DECK												58
5" N.W. CONC. ON 3" DECK					81		81					
3 1/4" L.W. CONC. ON 2" DECK						43						
ROOF & INSULATION									8	8	8	
STEEL				8	10	8	10	10	10	7	7	8
CEILING				2	2	2	2	2		2	2	2
M.E.P.				4	4	4	4	4	15	4	4	4
COLLATERAL				3	3	3	3	4	12	4	4	3
CONCRETE OVERPOUR						10						
BALLAST											10	
8" CONCRETE PAD								100				
TOTAL DEAD LOAD	50	75	100	65	100	70	100	120	45	25	35	75
TOTAL LIVE LOAD	100	200	250	100	100	100	150	100	30	30	30	100
TOTAL LOAD	150	275	350	165	200	170	250	220	75	55	65	175

TABLE 13: SNOW DESIGN LOAD SCHEDULE [S-001 PERKINS & WILL]

SNOW DESIGN LOAD SCHEDULE
INTERNATIONAL BUILDING CODE 2006/ASCE 7-05

ITEM	SYMBOL	VALUE	REFERENCE
GROUND SNOW LOAD	P_g	30 psf	FIGURE 1608.2
SNOW EXPOSURE FACTOR	C_e	1.0	TABLE 7-2
SNOW LOAD IMPORTANCE FACTOR	I_s	1.2	TABLE 7-4
THERMAL FACTOR	C_t	1.0	TABLE 7-3
FLAT-ROOF SNOW LOAD	P_f	26 psf	SECTION 7.3

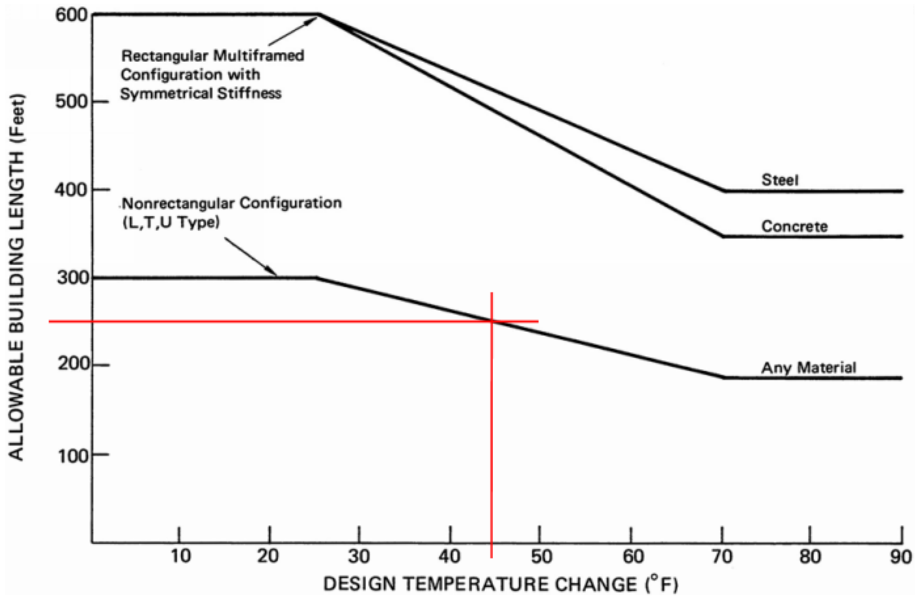


Figure 33: Allowable Building Length Per Calculated Design Temperature

Structural Analysis Process

(1) Analysis is to be performed to calculate the necessary gap required for the building expansion joint.[5]

- a. Calculate design temperature
- b. Identify allowable building length
- c. Calculate upper bound for joint closure
- d. Apply construction tolerances
- e. Select gap dimension & appropriate cover products

(2) Analysis is to be performed to design each column, and is to result with an economically designed column per gird intersections (4 per wing) from the foundation to the roof. Splices will occur at elevations previously present in the building's structural design.[6]

- a. Tributary Areas Calculations
- b. Live Load Reductions (as needed)
- c. Locate Splices
- d. Design Column

(3) Analysis is to be performed to design the necessary footing per column system case.[7]

- a. Calculate design temperature
- b. Identify allowable building length
- c. Calculate upper bound for joint closure

[5] Analysis process formed on standards included within (Standing Committee on Structural Engineering of the Federal Construction Council, 1974) with reference to (Stein, Reynolds, Grondzik, & Kwok, 2006).
[6] Analysis process formed based on AE 404 and AE 308 with reference to (Leet, Uang, & Gilbert, 2008).
[7] Analysis process formed based on CE 397A with reference to (Das, 2011).

d. Apply construction tolerances
e. Select gap dimension & appropriate cover products

See **Appendix L** for the calculations for the expansion joint system for the New Regional Medical Center.

Structural Analysis Outcome

In order to provide a comparable result, the cost information provided to quantify the value of the building expansion joint system will also be derived through quantity takeoff and *RS Means* cost information. Through modeling an alternative system within the structural Revit model, BIM and virtual construction is leveraged to quickly review and quantify the system changes.

The estimate constituted a sum of $297,570. Table 14 details the cost breakdown per the calculated values. **Appendix M** includes resultant values per detailed quantity takeoff.

Table 14: Expansion Joint Cost Summary

Expansion Joint Assembly	
Foundation System	$32,758
Structural Columns	$60,671
Structural Beams	$101,826
Slab on Grade	$684
Slab on Metal Deck	$8,552
Reinforcing	$8,613
Expansion Joint Covers	$40,289
Misc. Steel Angle	$44,177
Total:	**$297,570**

The selected interior finish of the expansion joint includes Nystrom expansion cover system that permits the inclusion of the finished floor and wall materials. The components include the following components:

EJ-TMM-200-W
EJ-TMM-200w-W
EJ-RJS-200

Appendix N includes the Nystrom product guide for the selected components of the system.

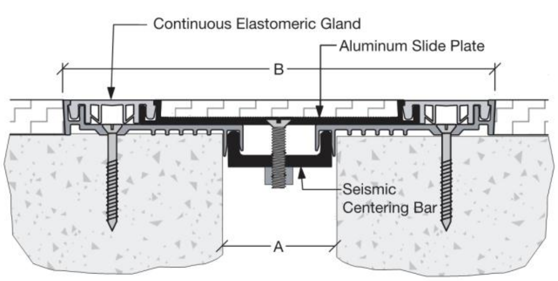


Figure 35: Joint Detail

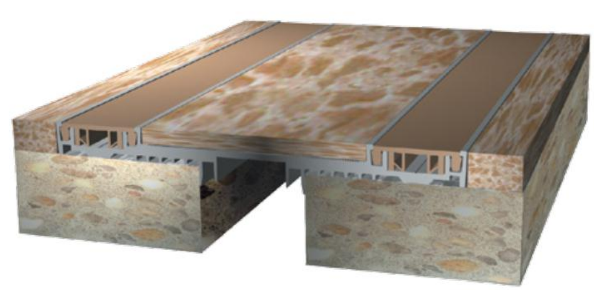


Figure 34: Joint Rendering

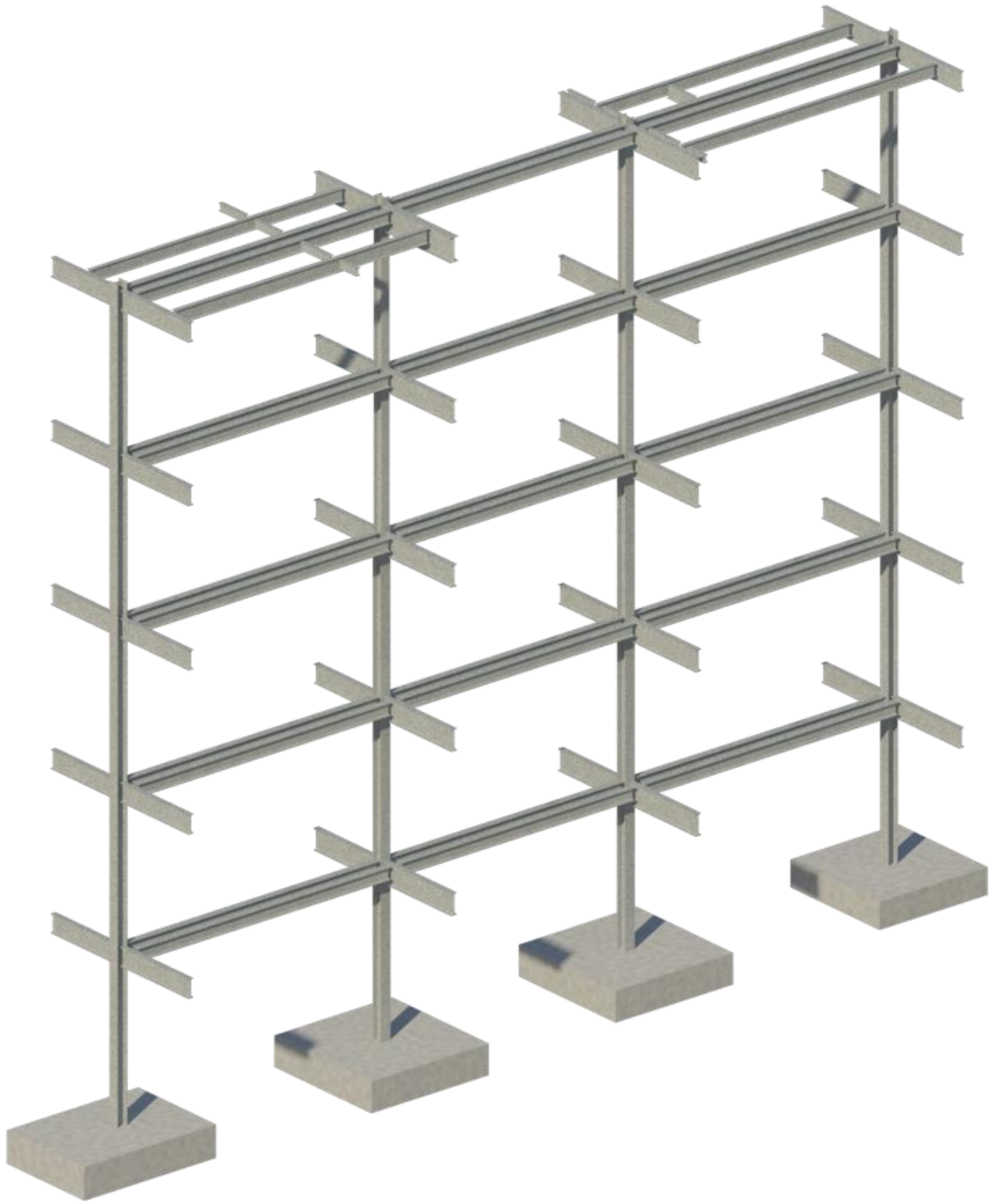


FIGURE 36: POUR STRIP STRUCTURAL FRAME SYSTEM

FIGURE 37: EXPANSION JOINT STRUCTURAL FRAME SYSTEM

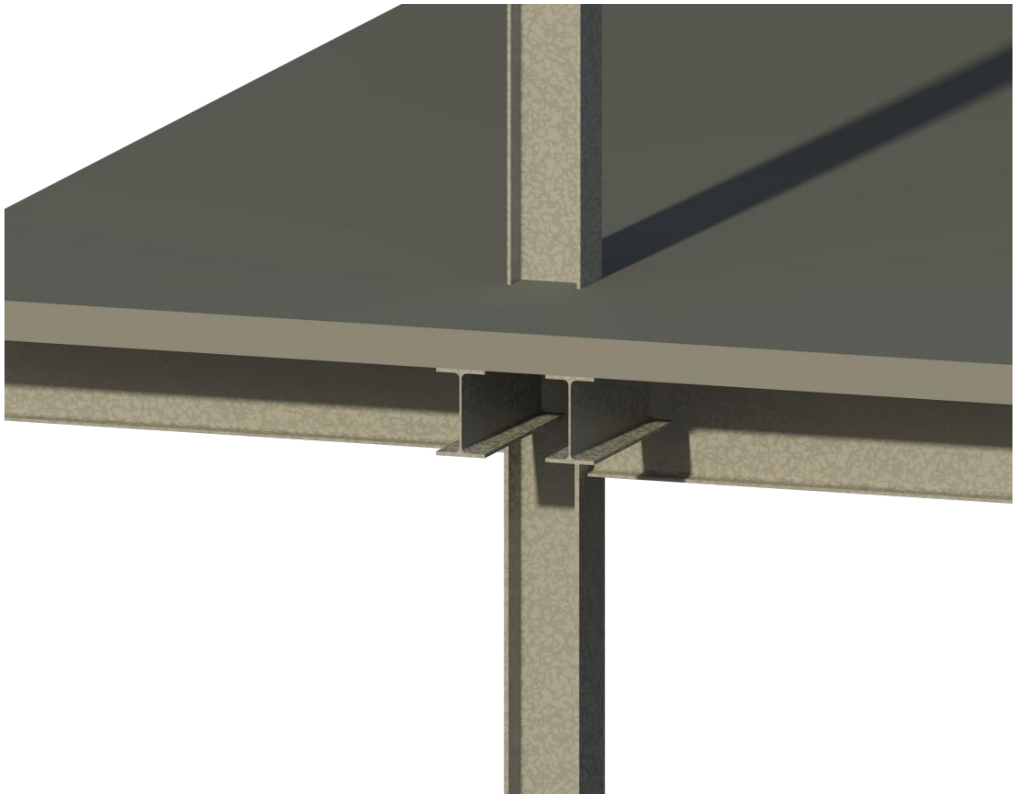


Figure 38: Close-Up Pour Strip Slab & Structure Configuration

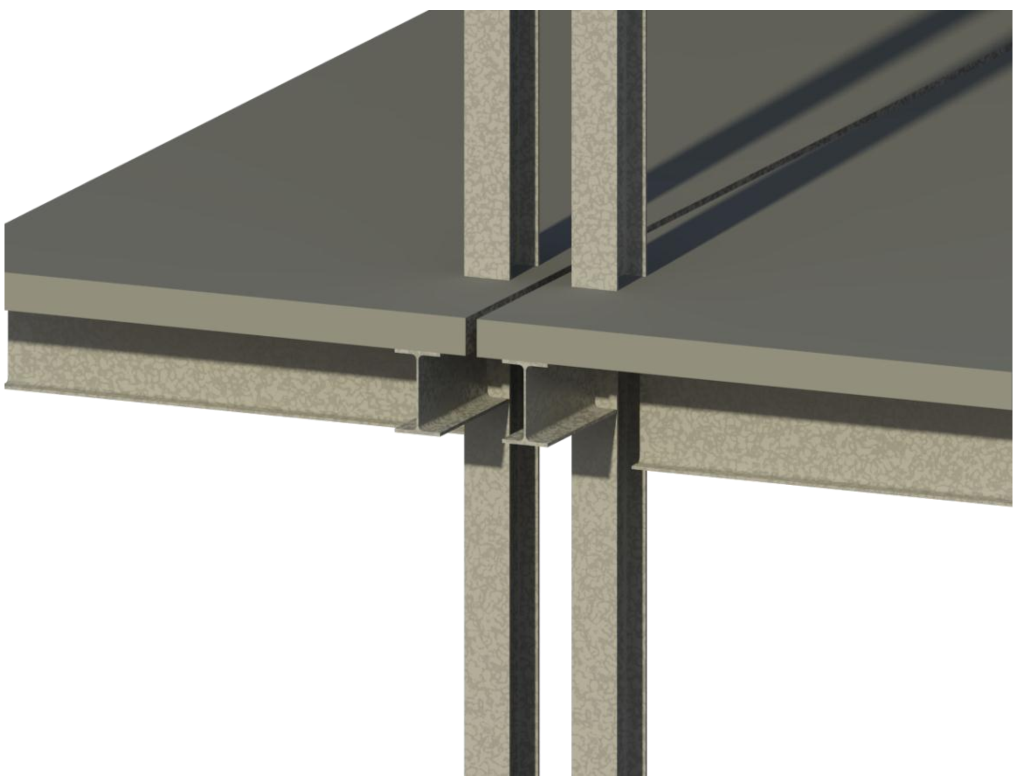


Figure 39: Close-Up Expansion Joint Slab & Structure Configuration

Outcome

Structural Assembly Cost Comparison

This analysis identified that the building's pour strip system is a more cost effective design decision. The choice to utilize the pour strips over expansion joints saved the project approximately $57,800. Although the expansion joint system permitted a decrease in the size of the foundation system, and slight decrease in the concrete slab and metal deck, these reductions did not offset the increase in other system costs. The expansion joint system requires an added cost for the miscellaneous steel angles for the slab edge at the joint, in addition to the finishing cover strips for the floors, walls, and roof.

Table 15: Cost Comparison

Pour Strip vs. Expansion Joint Assembly	% Change
Foundation System	-44.95%
Structural Columns	-0.89%
Structural Beams	0%
Slab on Grade	0%
Slab on Metal Deck	-7.35%
Reinforcing	+17.94%
Expansion Joint Covers	+100%
Misc. Steel Angle	+100%
Total:	**+24.11%**

Aesthetics' System Comparison

This analysis clarified that the building's pour strip system is a more aesthetically pleasing system and is preferred by the Owner. Although consideration were made to locate and include a system which met the maintenance and aesthetic interior requirements of the Owner, it is understood that the more cost effective system also included the least disturbance to the finishes and aesthetics of the space.

Reflection

It is believed that this analysis confirmed the design decision made in correspondence with the Owner and the design team. Although it is believe that an expansion joint system creates efficiency and cost savings in construction, it is clear that in the application at the New Regional Medical Center this is not the case. Due to the high expectations of the Owner regarding patient experience, finish quality, and maintenance.

From this analysis, it is recommended that other design teams and Owners investigate the implications of a pour strip within their facility in lieu of an expansion joint. Although the expansion joint provides a simpler construction method, the aesthetic results and additional costs may not be worthwhile. It has become commonplace that an expansion joint is more efficient; however, it is recommended that the design team or construction management firm use the design alternate process within Autodesk Revit to quickly analyze the cost benefits of a building pour strip, and cross-reference these outcomes with the intentions and goals of the Owner and facility user group.

Analysis 4 | Document Management for the Owner

Problem Identification

As discussed earlier in 'Analysis 1 | BIM in Preconstruction,' this project underutilized recent industry growth and implementation of Building Information Modeling. Although not requested by the Owner, recent developments in collaborative tools and data integration, has created interest in research into development of a facility management document dashboard for the New Regional Medical Center. As the first building for this new medical campus, this facility is the perfect opportunity to develop and test out a new technology platform, and demonstrate the capabilities of new collaboration methods and information management, which have been of growing interest over the past two years.

State of the Industry

The 20th Annual PACE Roundtable took place on November 9, 2011, and brought students and industry members to discuss this year's theme of "Building Innovation into Practice: Keeping what Works." The breakout session titled "BIM Services for the Owner", focused on many of the difficulties and challenges of conveying BIM services through the life cycle of a project, and into a usable form for the Owner's facility management staff. It was understood that many Owners are confused on BIM requirements and interfacing elements necessary to capture usable information. It was also recognized that different types of Owners dictate different level of BIM services within project development. The two main distinctions were between an Owner and a developer. As an Owner, BIM services are more influential because they retain the facility for operation. However, focusing on developers and their consistent building turnover, BIM services were less likely to be requested from the Owner, as the resale value of BIM models and facility databases are not readily defined to date.

Consensus was reach that the BIM for Owners drivers revolve around cost reduction, notably through change order reduction and a more transparent construction information exchange process. However, risk was acknowledged that BIM should be developed through particular metrics that are focused on the delivery process outlined by the Owner. Due to legal constraints, information exchange and collaboration should be highly detailed and compliant with various BIM contracts, such as AIA E202, AGC Census Documents, and BIM Addendum.

It was recognized that additional drivers of information exchange has to come from the fabrication facilities, and not necessarily the Owner. Software developments must be made in order to take usable data from a designer's model into fabrication facilities, and back out to an Owner. Although the Owner's facility management staff may require a system restructuring or redevelopment of their asset databases, it is understood that this direction is easier to perform over retooling fabrication facilities.

The construction industry was identified as a difficult industry to develop design and component standards, in order to minimize new, unique details within each project. Although project uniqueness creates great strides in technology and progresses typical means-and-methods, unique and specialty construction on every new project, creates high risks for both the designer and the contractor. BIM level of detail is being challenged consistently with document quality falling due to insurance risks, high profile projects, and complex details.

With current developments of Owner resources and reflections on BIM strategies, hopes are high for a stronger, more developed, Owner understanding on BIM services in the future.

At the conclusion of the session, multiple recommendations were made by industry professional concerning potential research ideas. The key point agreed upon by the industry professional present was to utilize the technology and software platforms available on the market. The importance was stressed to take advantage of the skills and training the current workforce already has, and to make information access easier and more streamlined.

Finally, it was acknowledged that with the upcoming *BIM Planning Education Session* workshop on April 17, 2012, much of the workflows, interfacing, and development of a facility management database should be focused on the understanding and integration of medium developed through the construction process, and not redefining the BIM process. Additionally, the upcoming release of "Owner Execution Planning" by the Computer Integrated Construction Research Program, at Penn State University's Department of Architectural Engineering (see Research & Collaboration), will ground may of the recent efforts.

Related Articles

As companies begin to complete their BIM pilot projects, much recognition was made to the need to reevaluate and change their workflows and company organization. This influenced the design team the most, changing from design assignment "sheet-type based" workflow, into a "model-element" process, as the sheets automatically update when components are added and modified. In addition to this, many companies began to reach the limits of their hardware, regularly having system crash, or freeze. Moving forward, firms recognized their limits, and began modifying their capabilities in order to continue to press BIM's development. At this point, "progress became decentralized and organic;" however, "BIM is not a silver bullet and is not going to resolve issues on its own, though it may help clarify […] choices that may not have been previously evident" (Post, 2009). Reflecting back on the progression of BIM and restructuring of organizations, rarely do firms address the need to update documentation organization. For the most part, document structure has been overlooked in the transition of BIM enabled project. As facility-management databases are developed out of construction BIM, there is a risk that a format will not be developed until the project is underway, forcing a divided workflow.

> "A divided workflow […] meant project knowledge was being deposited in two separate databases, defeating one of the potential efficiencies of BIM. Each database needed constant manual updating to stay coordinated and useful." *Nadine Post, Engineering News-Record*

Over the past few years, as BIM has developed into a tangible benefit for Owners and the building's user groups, additional interest and collaboration has produce solutions and recognizable benefits of the value in capturing information. The driver behind this effort includes efficiency, accessibility, and differentiation in the industry. It has been recognized that many of the existing methods of a facility management document transitions includes a data handoff that includes the file structure relevant to construction. As projects convert into a digital environment, much of the data is being embedded into the models, and organizational methods are adapting to "construction-to-FM model handover standards and systems". This process requires the project team to gather and store equipment and material information in a logical way as the project proceeds, and eliminates the inefficiencies of manually collecting and organizing handover data at the end of the project. The key to delivering data from construction into the life-cycle operation includes the "introduction of relatively easy-to-use tools and process adjustments" which not only produces a better product for the Owner, but has also improved construction awareness (Sawyer, Data for the Life Cycle, 2011).

"THE OWNERS ALL ARE AFTER THE SAME THING: TO IMPROVE THE QUALITY OF CONSTRUCTION AND MAKE THE DATA HANDED OVER TO FACILITIES TRULY USEFUL, RATHER THAN BEING EITHER A PAPER OR DIGITAL LANDFILL AS IN THE PAST" *TOM SAWYER, ENGINEERING NEWS-RECORD*

As companies begin differentiating themselves through a long-list of client deliverables, it is common for an Owner or a construction firm to 'add-on' new items during the construction process, namely those focused on BIM and Facility Management turnovers. Although challenging to upgrade an active project or modify documents on a completed project, it has been recognized that simple processes can replace the need to start BIM modeling process from the beginning. Facility users do not necessarily need an intelligent model to perform their job, or make their tasks more efficient. What they do need is an intelligent system that assists in accessing the original documents, and allows them to utilize BIM on newer facilities. With the ability to utilize simple document exchanges, "information [can] be loaded into the system from scratch." Seeing the advantages of incorporating "intelligent" document control for existing facilities, with "intelligent" model development permits a single source deliverable that can be tailored to the situation (Ross, 2011).

"YOU DON'T HAVE TO DESIGN THE STRUCTURE IN THE FIRST PLACE USING BIM SOFTWARE, ALTHOUGH THAT WOULD BE NICE. AND YOUR CLIENTS DOES NOT NEED SUPER-SOPHISTICATED SOFTWARE TO TAKE ADVANTAGE OF THE DELIVERABLE." *STEVEN ROSS, ENGINEERING NEWS-RECORD*

Based out of Vancouver, British Columbia, a company called *Multivista* produces project photography using high-end cameras and wide-angle lenses to document construction conditions and as-built components of a facility. Founded through a former electrical subcontractor, it was recognized that accurate images conveyed the conditions of his firm's work before it was covered up. Having digital photos integrated into construction documents minimized and properly designed liability if questions arouse. Although designers and builders utilize "as-built" drawings in their facility documentation turnover, it is recognized by most of the industry that inaccuracies are likely to occur within these documents, as not all elements corrected or adjusted in the field, make it back to the design team to update the document. *Multivista* has developed into a franchise, and they now become involved in the project during the preconstruction stage, and integrate their services alongside the rest of the team. By identifying "hotspots" of the facility with the Owner, the photographers coordinate their database to align with the Owner's needs and the construction schedule. At the conclusion of the project, the Owner has a database of photographs, which have been indexed within the construction documents, and can be referenced as desired (Judy, 2011).

"The images are then indexed to plans and uploaded to a secure internet-based system for project team access." *Scott Judy, Engineering News-Record*

As the construction industry begins to transform into an information-technology based industry, it is important to identify the characteristics of the digital intuitive generation. As companies seek differentiation in a network that is becoming ever connected, the following five observations have been made:

(1) Digital natives live publically online
(2) They share knowledge
(3) They believe transparency yields trust
(4) They are timely, but not time-managed
(5) They believe in interactions, not transactions.

As the construction industry continues to transition into the digital generation, it must also recognize the capabilities, training, and personalities of Owners, partners and consultants in which they interact with. It must be recognized that as new collaborative, digital, environments become the hub of company interface; the development must be catered to new innovations which make work more efficient, but also permit earlier generations to seek the added-value (Manafy, 2011).

"Companies that praise collaboration, learning and socialization will look more attractive than those that focus solely on structured timeliness and productivity."
Michelle Manafy, Engineering News-Record

Industry Research

On March 12, 2012, *Engineering News-Record* released the results of a survey performed with the *ENR Future Tech* reader group to assist in identifying the current state of technology use and wishes for future development. The article, titled "Hot Tech Topics" includes the summary of 445 responses received in late February and includes feedback from a variety of firms as shown in Figure 40.

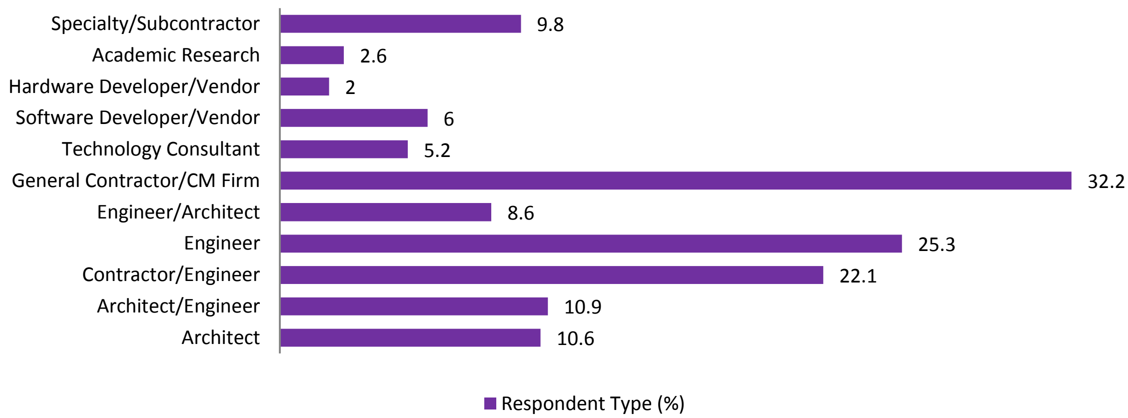


Figure 40: Survey Respondent Firm Types[8]

The survey was prepared to allow the respondents answer open-ended questions, permitted a wider range of results to eliminate any suggestion towards a particular tool or product. The results were gathered by category, and ranked by frequency into two series of results:

Table 16: What Readers Like About Their Information Technology Today[9]

01 | BIM	**02 |** iPads	**03 |** Collaboration Environment
04 | Online Project Documents	**05 |** 3D CAD	**06 |** Mobile Tools & Devices
07 | iPhones	**08 |** Smart Phones	**09 |** Tablets
10 | The Cloud	**11 |** VELA	**12 |** GIS/GPS/Mapping
13 | Enterprise Systems	**14 |** Laser Scans and LIDAR	**15 |** Digital Photos, Job Cams
16 | Videoconferencing	**17 |** PDF Distribution and Markups	**18 |** Other Responses

Table 17: What Readers Say About Their Future Information Technology Needs[10]

01 | Cheaper, Better Software	**02 |** Data Integrations (BIM)	**03 |** Online Collaboration
04 | Mobile Hardware	**05 |** Cloud Storage & Tools	**06 |** Linked & Live Project Controls
07 | Construction-Specific Apps	**08 |** Broadband Coverage	**09 |** Standardized Data Formats
10 | Ruggedized Tablet PC	**11 |** Single-Source EPS	**12 |** Estimating/Scheduling Apps
13 | Technology Training	**14 |** GIS Utilization	**15 |** Project Marketing & Tools
16 | Online Bid Tools	**17 |** Paperless Work Flow	**18 |** Social Media Marketing

[8] (Sawyer, Hot Tech Topics, 2012, March 12) "Survey Respondent Firm Types" Page 27
[9] (Sawyer, Hot Tech Topics, 2012, March 12) "Information Technology Today" Page 28-29
[10] (Sawyer, Hot Tech Topics, 2012, March 12) "Future Information Technology Needs" Page 26-27

Major trends in results focused on BIM tools, mobility, and a collaborative project environment. Responses focused on the need for better organization, document, transitions, and an easier to build, use, and update interface to personalize the process for the parties involved. Consistently, over the past three years, the topics mentioned in the previous articles found themselves at the top of discussion boards, and the need to provide these components as a package to the Owner for facility management use became ever-more present with the results delivered in this article. The future of our industry rests in a concept which is "versatile, works flawlessly and can be tailored to specific needs" (Sawyer, Hot Tech Topics, 2012, March 12).

"THE INDUSTRY DOESN'T REALLY NEED ONE MORE NEW DEVICE. THE SYSTEMS NEED TO BE INTEGRATED BETTER." *RAY CHEN, FAITH TECHNOLOGIES*

"THE WORDS THAT CAME UP MOST OFTEN WERE 'CHEAPER,' 'SIMPLER,' STREAMLINED,' 'USER-FRIENDLY,' 'INTEROPERABLE,' AND 'INTEGRATED'." *TOM SAWYER, ENGINEERING NEWS-RECORD*

NEW REGIONAL MEDICAL CENTER TURNOVER

The turnover process for the New Regional Medical Center consists of a print set of the as-built specifications, and building plans. Additionally, all submittal information that has been logged by Gilbane Building Company will be supplied to the owner. The current document management software is Prolog Web, and this site will remain accessible for a short duration after the project for document retrieval and download.

Overall, the turnover is focused on paper documents and digital construction photography. Although digital PDFs of pertinent construction data are provided to the owner, this means is only included for a digital backup of the print items. There will be no models, drawings, or writable files delivered with the completed project.

RESEARCH & COLLABORATION

Concurrent to the discussions during the *PACE Roundtable*, Penn State's Computer Integrated Construction Research Program has been finalizing their report and guide for "Owner Execution Planning." This guide is designed to supplement their current release of "The BIM Project Execution Planning Guide and Templates Version 2.0" and focus on "a guide for Owners that provides a structured procedure to develop a strategy for integrating BIM throughout their organization including the following focus areas:

1. *Defining Standard BIM Processes and Practices […]*
2. *Designing Information Integration Strategies […]*
3. *Identifying BIM Contract Requirements […]"*

As mentioned in the State of the Industry section, there will be a one day workshop which has been designed to spark discussion within the group of industry members regarding current implementation of the "BIM Project Execution Plan" in addition to previewing the "BIM for Owners Planning Procedure." Although this workshop takes place after the conclusion of this senior thesis report, one of the key components of the industry feedback will result from the "[development of] information exchange requirements for exchanges between project participants" (The Computer Integrated Construction Research Program, 2011).

Case Study: Office of Physical Plant

On June 21 2011, the Computer Integrated Construction Research Program released the draft of their "Case Study Procedures." This document outlines the methods used to analyze an Owner's organization to understand their structure and plan for BIM implementation. At the same time, the results of the procedure, and the application of the analysis on Penn State University's Office of the Physical Plant (OPP) were released. Below is an excerpt of their findings.

> Penn State University's Office of Physical Plant (OPP) officially began their adoption of BIM in January 2010 after it was discovered that the University saved a substantial amount in the construction of a new laboratory building by using BIM. To begin the BIM integration process, the Assistant Associate Vice President provided support for the Applied Facilities Research Group (AFRG) to be formed. This group was tasked to improve the efficiency of internal and external processes primarily through the use of BIM.

> The AFRG began BIM implementation by researching the Physical Plant's organizational structure and interviewing all divisions within the organization. The intent of the interviews was to learn each division's internal processes, responsibilities, strengths, and challenges. After each of the eleven divisions within OPP were interviewed and analyzed, the Work Control Center[11] and Design & Construction[12] were identified as having the greatest potential for BIM. The team began working with the two departments developing process changes and information requirements which would allow the incorporation of BIM.

> In December 2010 the AFRG published the first version of BIM requirements for new construction. These requirements which incorporate many of the needs of both the Work Control Center and Design & Construction are the first step to full BIM integration, but there is still significant effort required to further advance BIM use within the organization

(The Computer Integrated Construction Research Program, 2011).

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[11] The Work Control Center department plans, prioritizes, and schedules maintenance, repair, and renovation work at Penn State's University Park Campus.

[12] The Design & Construction department oversees all design and construction at Penn State's University Park Campus. They are composed of five sub—divisions: Construction Services, Contract Administration, Design Services, IT Support Staff, and Project Management.

This report recognized that the Work Control Center consists of one of the most advanced asset management staffs in the country; however, it takes as much as two years to incorporate new asset data after substantial completion of the project. A reduction in the delay is possible if asset information begins incorporation during the construction processes by developing a more appropriate translation of construction to facility maintenance information. Additionally, the Design & Construction department was recognized in having no requirement for record modeling, and no process of updating "as-maintained" models. Although a more developed interface for document databases will not fix the training and competency needed to manage models, a manage file of as-built models and drawings should be provided in a way where revisions can be modeled directly into the file, and saved, without having to reattribute and save as a new file. Ideally, these updates should be tracked, with revisions of each update archived for reference if needed.

Analysis Influences

Owner Interview[13]

On January 31, 2012, a phone interview was conducted with Richard Montalbano, who is the Vice President and Project Executive for Albert Einstein Healthcare Network, and is overseeing the design, construction, and operations of the New Regional Medical Center. Using the guidance provided in the CIC Research Program's "Case Study Procedures," the interview consists of predetermined interview questions.

Below is an overview of the outcomes of the interview.

Design and Construction

Q: How are projects procured?

A: Design-Bid-Build with a CM hired for construction services. Due to funding from the state or government programs, the only way to integrate a CM for collaboration early into the process is hiring them for preconstruction services.

Q: What is the level of participation?

A: There is a project executive overseeing the project development and the construction phase. As needed, other members of the New Regional Medical Center, Inc. become involved. Although the facility management staff is not directly incorporated in the process, great efforts are provided to procure the most practical design for the patient and the facility staff.

Q: Has the Owner used BIM on prior projects?

A: BIM has not been used by the Owner on previous project. Although the project team may use BIM in the design process for internal benefits, the Owner does not request any BIM specific components.

Q: How is a facility handed over?

[13] Richard Montalbano - Vice President & Project Executive, Albert Einstein Healthcare Network

A: The facility is handed over after substantial completion, which allows the Owner to finalize outfitting the medial equipment and training staff member. A model is not provided to the Owner at turnover.

Q: How do you manage as-built & record drawings?

A: The as-built and record drawings and specifications are provided to the facility management department for archival and reference when needed. No commentary on the condition and quality of these drawings. Lack of accuracy was mentioned, which permits for debate over the need for maintenance and updates of facility information as renovations and installations occur.

Facility Management

Q: What are the Facility Management staff's primary duties?

A: The facility management staff's primary duties are to locate, interpret, and correct problems. Additionally, they manage the asset database for the healthcare network, and handle maintenance schedule for corrective, preventative, and emergency procedures.

Q: What information do they manage?

A: They manage as-built and record drawings for their facilities. This also includes the library of specifications, operations and maintenance manuals, and finish submittals. The current format that the information is stored in consists of both paper documentation and electronic formats. The team does not have 3D models of any assets or facilities.

Q: What do they use to manage this information?

A: Asset management software was not provided; however, the current task of management was considered a challenging process and involved great efforts to update the process with the incorporation of a new facility and medical campus in the coming years.

Q: Do they share/receive information from other departments?

A: Information shared and received through other departments consisted of paper copies, email, or integrated into their asset management or work order programs. Asset information is taken off of record drawings and specifications.

Q: What issues do they experience with their facilities?

A: The facilities within the healthcare network are very old, and have very old documentation which is not necessarily accurate, nor do some of the documents exist. With a variety of format, there is never an easy way to solve the issue at hand. There is currently a plan room located at the existing campus to host the documents for reference; however, organization and accessibility for off-campus facilities [the new hospital] could be a challenge.

Q: What would assist them in doing their job more efficiently?

A: The implementation of electronic documentation and databases, with minimal training, will make their workflow more efficient. Faster access to the necessary documents, and ability to view, update, and override current documents. Eliminate duplicate sources and "out-of-date" plans.

Q: Who are the best people to work with in order to gain information on day-to-day processes?
A: The facility management staff is the best people to contact for more information regarding the workflow of daily tasks. Additionally, anyone with similar healthcare FM management would be assistive. However, note that the current staff is resistant to change, notably with all data located in a model, which would be inefficient for them to access due to lack of experience. Consider giving them options for various methods of accessing information.

Additional Comments:

- *In order to incorporate BIM, the FM staff needs the hardware, software, and training capabilities.*
- *The Owner need to furnish continued training and development once BIM becomes incorporated in order to accurately take advantage of the system, unless a detached, viewer concept is developed, with certain team member with training for updating models and databases.*
- *Great deal of resistance for FM staff to use a computer keyboard, mouse, and small screen to use drawings and specifications. The staff is hands-on and prefers large work plans in order to get multiple team members involved in investigation.*
- *Tablet utilization would be helpful; however, no current system to efficiently incorporate them.*
- *Finding the room information, location on a plan, equipment in the room, etc. fast is important.*
- *The ability to review the information remotely (not in the plan room) would be helpful.*
- *Photographs of key locations, assemblies, etc. would be more helpful then plans in understanding what is in place in the facility.*
- *Want to understand how to modify, and "exchange" a new OR layout into an existing OR, utilizing BIM to minimize rework, and understand the depth of the renovated to minimize the downtime of the space.*

Concept A: FM Dashboard Development

In order to anticipate a particular portion of industry commentary at the *BIM Planning Education Session*, in addition to creating additional interest regarding research in construction and facility management document controls, a Facility Management Dashboard will be developed for the New Regional Medical Center. The basis of this dashboard is to reflect recent trends in information exchange and technology being discussed by the industry and researchers, alike. Additionally, the solutions created within the dashboard are designed in a way to reflect commentary received though industry articles, case studies, and interviews. Throughout development, consultation with user groups will be performed to enhance the analysis, and detailed as feedback. Common observations will be reflected in the final adaptation of the document dashboard, which is located within the AE Senior Thesis E-Portfolio under the FMPortal tab. *Note: a password is required for access. To request the password, consult the "Student Biography" section and make request via email.*

Dashboard Concept

During investigation and development into new options and methods of embedding pertinent information in a model, it was recognized that although logical, there is a much stronger solution, which permits a majority of the data to be developed into usable facility-management information in its original form. Although this does not precisely provide a 'BIM' deliverable which many Owners are beginning to analyze, it does answer many other concerns and questions. The development of this dashboard concept was derived through direct interview of the needs and capability of the Owner's facility management team, and the status of much of the documentation they were requesting.

The development of this interface provides many layers of solutions to resolve, expedite, and transition the New Regional Medical Center into a digital facility management interface. Figure 41 presents the key data the Owner would have requested for a digital turnover if this system was currently on the market.

The essential logic behind the system is a very simple file structure, which hosts all of the necessary digital files, as explained later in Figure 45. As the life-cycle of the facility evolves, these original files can be updated or overridden, providing the facility team to always have access to the latest files, and system information. Once these files are formatted properly and linked to each other, much of which is performed already by leading construction firms during the preconstruction or construction process, the data and exchanges between documents and into other facet of project information becomes available.

In order to develop a user-friendly system, that is accessible via any internet connection, and any style of mobile device, it was decided that an HTML format, or other web-based platform, is most appropriate. Utilizing the background file structure as the host, the data can be developed (or operated) by either a construction firm – as part of a lifecycle facility management program, or by the Owner – as their own internal system in which multiple projects can be hosted, maintained, and controlled by their own IT Department. This dashboard is configured as a database which hosts access points and document information in order to quickly access and solve typical facility management inquiries.

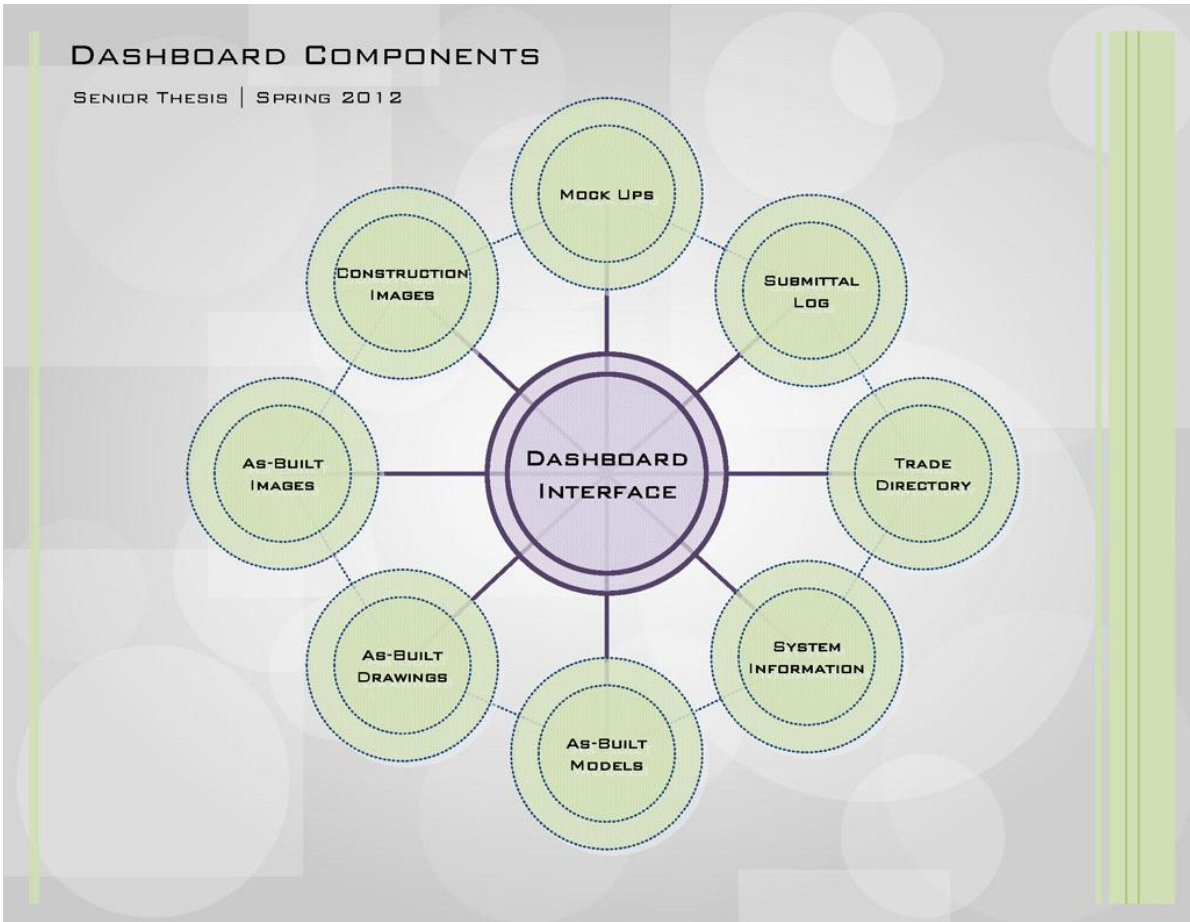

Figure 41: Dashboard Components

Due to the research goals to understand document exchanges and interactions between different project mediums, the dashboard interface was developed in dreamweaver, following simple HTML coding practice, and including some additional javascript functions to simulate organizational options and usability feedback from the associated testing groups.

One of the key concerns from the Owner's perspective was document security as all of their project documentation will be placed on a server that may be access from outside of the network. Similar to current construction document interface, such as Prolog, a username and password would be required for access. Additionally, depending on the level of development, expertise of the members coding the dashboard, in addition to the requests of the Owner, multiple security tiers could be developed and associated with each username. This would in effect, control the user's interface and dictate limitations to opening, overriding, and updating data within the interface and the project's file structure. In order to suggest this option, the document dashboard developed in tandem with this report includes a login script as shown in Figure 42.

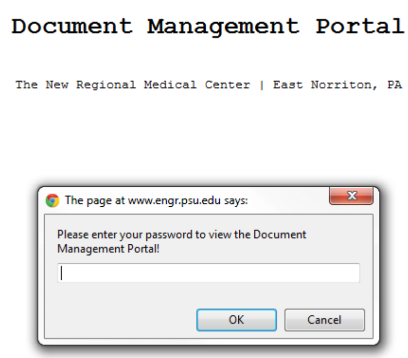

Figure 42: Web-Interface Login Script

Currently the New Regional Medical Center's campus will open with two facilities on the property. With time, additional facilities associated to the healthcare network will begin to populate much of the surrounding space available on the campus. As this occurs, the Owner will request the development of multiple Project Pages within the dashboard in order to properly organize the project and facility information as the campus grows. This would be a similar situation to a University or other large Owner-group. As an internal facility document management system to a healthcare or university provider, they will easily be able to add facility, assets, and new document exchange concepts without reliance on a particular firm to construct the entire campus, in addition to hosting all of the document management exchanges.

Figure 43: Portal Homepage

Although the documents are managed through a server and can be accessed directly, the dashboard concept provides the ability to build a digital planroom environment. This room would consist of touch screen monitors, multiple tablet PCs, in additional to the necessary desktop computer stations. The goal would be to engage the Owner in a paperless facility management system, in unison with the construction team. The project homepage, as shown in Figure 44, was develop in collaboration with the Owner, and was based on the logical workflows the facility management team experiences during their inquiry.

(1) Provided Room Name – need to access particular data concerning this space
(2) Provided Renovation Request – need to access overall plans in all disciplines to investigate
(3) Provided Design Alternative – need to access and develop alternate models of the new space
(4) Provided Work Order – need to access Equipment or Submittal data for maintenance/reordering

These inquiries outline the initial application and investigation into the facility documentation. Once inside each method of information organization, applicable components will create links and dialog with other components and make transitions into other file types seamless.

Figure 44: Project Homepage

File Structure Management

The file structure for the Document Management Portal can be seen in Figure 45. The key to file develop for this concept is to adopt a logical structure prior to development. Although much of the interface is linked via relative-links, if documents are moved or relocated, some of the pages may not work properly or locate the information as needed. Another key goal is to identify the major turnover items and create catagories for their use. Additional use of the dashboard may be considered for during the construction process, or as a combined construction – facility management information exchange program. Note that if this system is developed, the related folder file structure must be thought out to accommodate how the construction project team members utilize the structure in relation to how the facility management team and Owners organize this information .

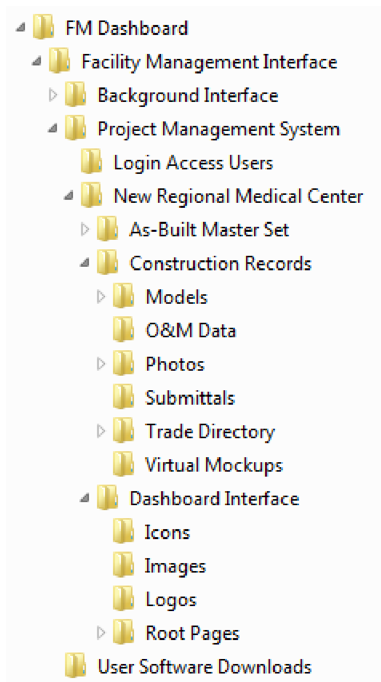

Figure 45: File Structure

Data Management Concept

Room Log Database

The room-log database section references components located in multiple folder systems within the file structure shown in Figure 45. This logic permits the files to be updated and modified as necessary within the lifecycle of the facility, and the room log automatically reference the new components. This builds on the concept of a single-source document enterprise. All of the references in the room log can be accessed through other pathways in the dashboard; however, this section is organized by room number, permitting the user to easily obtain all of the necessary documentation for reference. The intial access of the page promts the user to select the floor level in which the room is located on. Once the rooms are loaded below, a series of drop-down menus host all of the data links. Notable features include the 180 degree photography. This concept was developed off of concern that as-built drawings are not necessarily accurate to what is in place; however, with a photograph, all of the elements can be defined. The photos can be taken as a particular point in construction or at building turnover as requested by the Owner. These images contain hotspots which also link to pertinant information depending on the photo's progress.

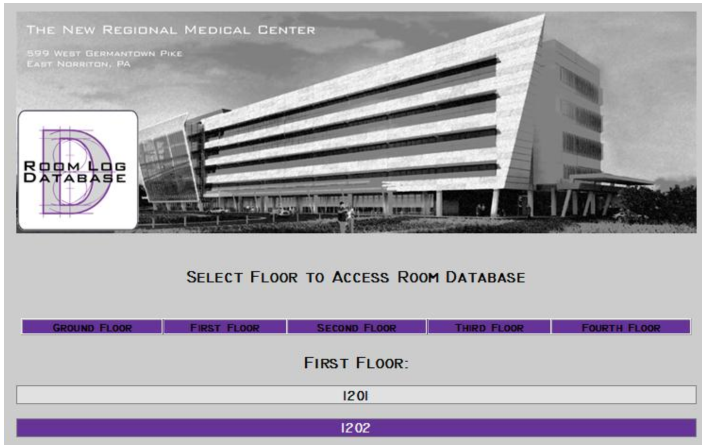

Figure 46: Room Log Database Webpage

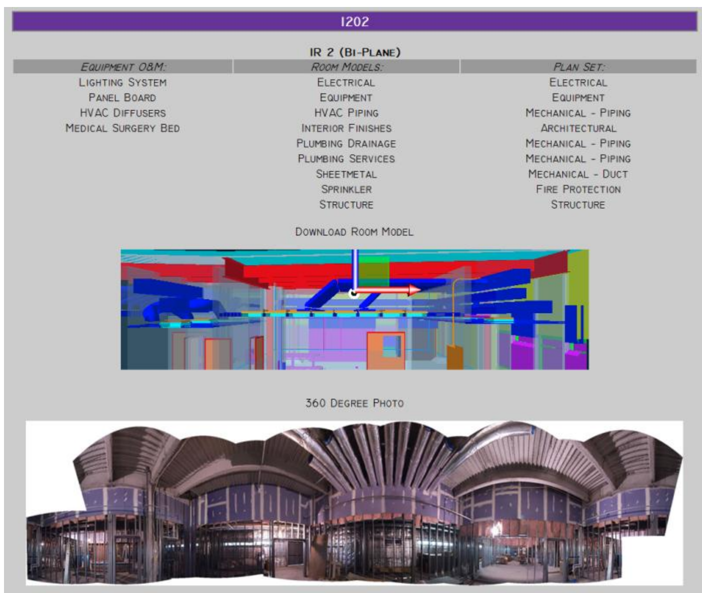

Figure 47: Room Log [Enlarged]

AS-BUILT DRAWINGS

The as-built drawing section references the ‘As-Built’ file structure and permits direct access into the drawing file of reference. These drawings contain hyperlinks on common details, such as building sections, elevations, and wall details. Utilizing the hyperlink capabilities of software such as Adobe Acrobat Professional or Bluebeam CAD Revu, links can be embedded in the construction documents, or after the construction process is completed, and saved into the documents. As long as the links are embedded as ‘relative path’ items, the file structure can be relocated without losing operability. The as-built drawing section provides an entry point into the plan set. Once a sheet is opened, users can navigate the plans utilizing the hyperlinks to access additional drawings for more details or information.

FIGURE 48: AS-BUILT DRAWINGS WEBPAGE

AS-BUILT MODELS

The O&M data section references the ‘As-Built’ file structure and permits direct access into the model files of reference. These models contain the overall geometry used in the design process, and updated to reflect the as-built conditions of the facility. The page is configured to permit two levels of document access. The ‘viewer’ option only permits viewer capabilties of the models. This file will open in the file format according the the selected type. Additionally, the ‘manage’ option will open the editable file, and will also permit the document to be saved, allowing the user group to make updates as the facility is renovated. Once updates are complete, the user may created a new ‘viewer’ file and override the old version, permitting the latest file to be referenced by others. The level of detail and the quality of information embedded in the model can be designated in the BIM execution plan for the project. Since this webpage creates an access point into the files, any style or level of detail model can be incorporated into the page.

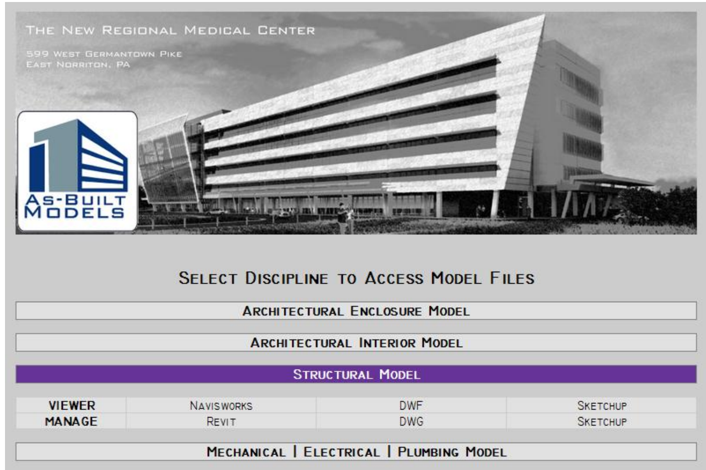

Figure 49: As-Built Models Webpage

Submittals | O&M Data

The Equipment Manual tab in the O&M data section references the 'O&M Data' file structure within the 'Construction Documents' folder, and permits direct access into a log of equipment in the facility for reference. This page has be developed under the concept that the user will know the equipment name, permitting query to open for additional equipment information and direct access into the equipment manual file. Additionally, this drop-down menu includes the room locations of the equipment, a service log or link to an asset management structure, a direct link to the manufacturer, and the contact information of the subcontractor or supplier of the equipment for servicing or replacement parts. Although similar information can be embedded into a model, this pages provides ease of access for users not familiar with model navigation.

Figure 50: O&M Data Webpage

Similar to the Equipment Manuals tab, the Submittal Database tab references the 'Submittal' file structure within the 'Construction Documents' folder, and permits direct access into a log of approved submittal processed during construction, for reference. This page has be developed under the concept that the user will know the submittal log number, or have developed a naming system to permit a search filter of the page. This section also includes a drop-down development, allowing users to easily scan the submittal log, and quickly access important information regarding the document. If necessary, a link is provided for the option to open or download the approved submittal for reference. Additionally, the drop-down menu includes the related discipline of the submittal, a direct link to the manufacturer, and the contact information for reordering replacement materials. Although similar information can be embedded into a model, this pages provides ease of access for users not familiar with model navigation.

FIGURE 51: SUBMITTAL WEBPAGE

TRADE DIRECTORY

The Trade Directory section references the 'Trade Directory' file structure within the 'Construction Documents' folder, and permits direct access into a PDF file containing the contact information in addition to scope of work to trades acciociated with construction and renovation of the facility, for reference. This page has be developed by loading a PDF file into the internet brower interface. The document contains hyperlinks to email addresses, which permits direct means of contact if the mobile device or workstation is configured with email software. Within the file structure, the original excel file can be opened and updated as needed. By resaving as a PDF document within this file structure, the webpage will automatically update to include the new information. It has been discussed that the ability to submit a new entry via the webpage may increase usability of the directory. After research in webcoding to perform this task, it was decided that the frequency of adding new contacts does not offset the additional effort to develop the javascript and it also increases the load time of the page.

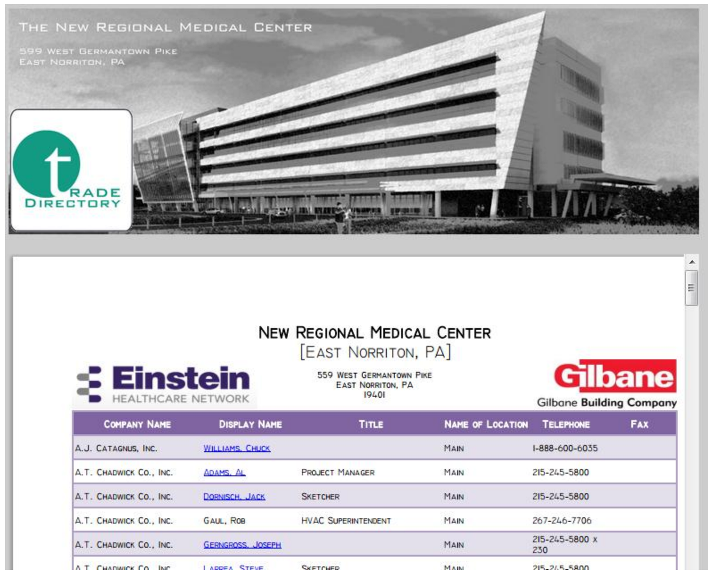

FIGURE 52: TRADE DIRECTORY WEBPAGE

FEEDBACK[14]

COMPLETED ITEMS

- Include a room log for quick access to pertinent information (Mort).
- Incorporate as-built photography to help identify in-wall or above ceiling scenarios (NRMC).
- Simplify file structure and development in construction to transfer into facility management (AE).
- Include submittal items, as not all components are represented with an O&M manual (GBCo).
- Link related sheets and details to show capabilities of interactive PDF documents (Mort).
- Include a combined model (for viewing only) which shows all modeled elements of a room (NRMC).
- Include hyperlinks to access free viewer software for various software platforms utilized (Mort).
- Password protect pages to show capabilities to create usernames and access restrictions (NRMC).
- Include links to editable files, notably for models, for “as-maintained” modeling (NRMC, Mort).
- Make As-Built Drawing Log “interactive” to simplify the page layout (Mort).
- Hotspot the image to hyperlink to related information (NRMC).
- Test the configurations on multiple browsers, tablets, smart phones, and touch screens (Mort).

ITEMS FOR FUTURE RESEARCH

- Permit the room models to show alternative design concepts (NRMC).
- Include an updatable Trade Directory via a web submission form (GBCo).
- Include RFI documents so when referenced in PDF plans, the hyperlink loads correctly (GBCo).
- Design a welcome page to show capabilities for multiple buildings (AE).
- Look into ability to make an integrated construction/facility management information system (AE).

[14] Feedback and input provided by the New Regional Medical Center, Inc. [NRMC], Gilbane Building Company [GBCo], Mortenson Construction [Mort], Penn State AE Faculty [AE], and Penn State’s Office of the Physical Plant [OPP].

Concept B: FM Interact Development

With the development of the FM Document Dashboard, further interest engaged the ability to streamline this process, and eliminate the need for custom pages, each with their own embedded links and images. With the ability to create a database with Microsoft Excel, and include various file types, metadata, and hyperlinks, a more concise and fine-tuned deliverable can be created quickly and easily.

Additionally, this method creates the ability to leverage open source programming and development tools through Microsoft Live Labs and Silverlight, creating an interactive, streamlined, and customizable document management portal, hosted via a webserver or on a local computer.

Although the FM Document Dashboard provides accessible information to an owner during the lifecycle of the facility, the setup process can be laborious depending on the format in which the document are developed during the construction process. Without a commitment to this interface at project startup, it is very challenging to integrate this system as an after though. With the FM Document Dashboard moving past a “Prolog Web” interface and into a more visual stimulating and easier to navigate interface, it still does not create an open web of document correspondence and relationships, as desired.

Through more defined exploration into html code and software development, a stronger understanding of enterprise-sized document exchanges were found, in addition to how to properly attribute and search metadata. Without the utilization of an enterprise server, such as Oracle, to host and develop the infrastructure, it is challenging to host this interface in an efficient manner.

> “A FM document interface should not consist of a series of internet pages built around a specific Attribute; it should consist of an interface which reads a database of relative information, data, and asset.” *Dr. Craig Dubler, Office of the Physical Plant [PSU]*

Through this concept, inquiry was reached though the identification of Microsoft Silverlight's PivotViewer, and the ability to transform document management from a paper based, or website page interface, into a single source viewers for document controls and facility information access.

The concept is called "FM Interact." It is hosted through a webpage, however, it features an interactive system which reads an excel database which displays inquiries -- sorting, and distributing information to identify results, trends, and an overall understanding of relations within the FM documents embedded in the database. Additionally, specific information and links can be attributed to the information, permitting accessibility and additional inquiries to drive down to the ideal document.

FM Interact becomes a visual tool, as opposed to a windows explorer file folder system. It permits stronger interactions between relevant information, it hosts all the data as single source, and it still permits a database for information updating, addition, and deletion as the life-cycle of the facility progresses.

Interact Database Concept

The driving force behind the investigation of an FM Interact concept, through the utilization of Microsoft Silverlight and Pivot Viewer, is to create a more efficient and accessible format to access construction photos during the life cycle of the building. Additionally, lifecycle photos can be added to the interface, permitting a photo log of searchable, and relatable images. Through additional investigation, other document formats can be included as hyperlinks within this interface, permitting the viewer to sort the data as necessary, while also allowing accessibility into the original file when needed.

Current PivotViewer applications include interfaces developed by companies such as Netflix, as shown in Figure 53. PivotViewer allows visitors to search large amounts of data easily and effectively. Additional sort critera can be applied in order to narrow in on related documents, as shown in Figure 54. Through the utilization of the open source programming, the host only has to identify which data collection to reference, and the user interface allows them to apply controls and access search and sort criteria of the information, as shown in Figure 55. Finally, once an element is selected, specific data regarding the document which has been included in the database is shown in Figure 56. This information can include descriptions, metadata, hyperlinks to external sources, and are completely customizable

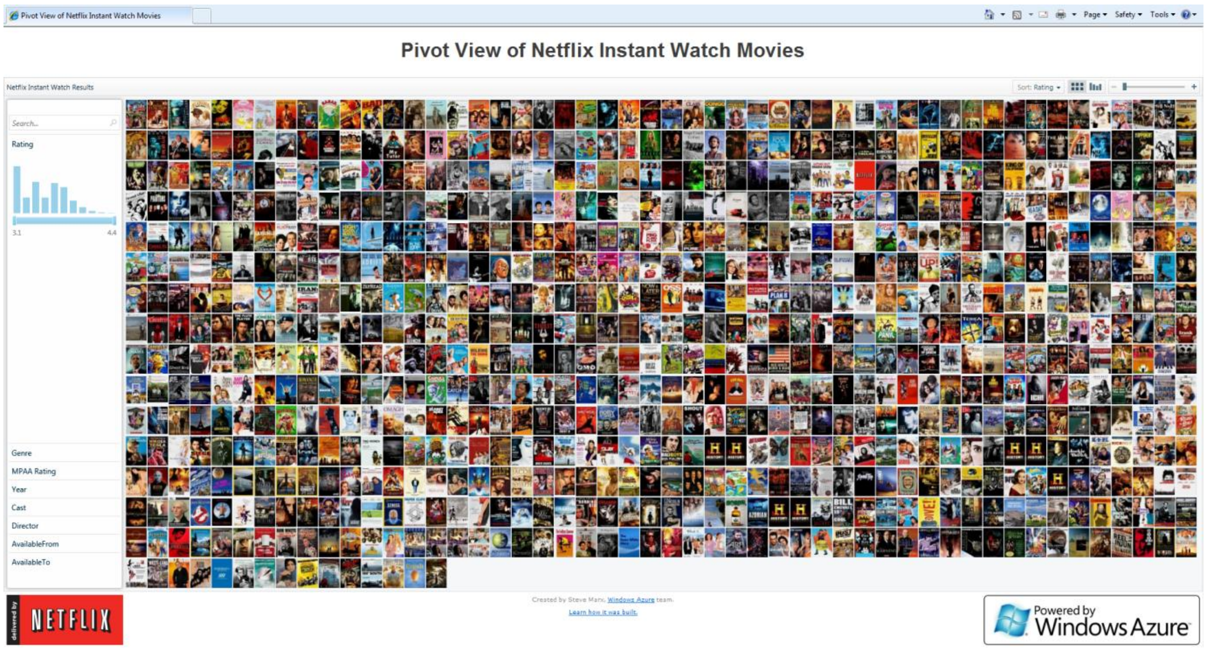

FIGURE 53: PIVOTVIEWER NETFLIX APPLICATION

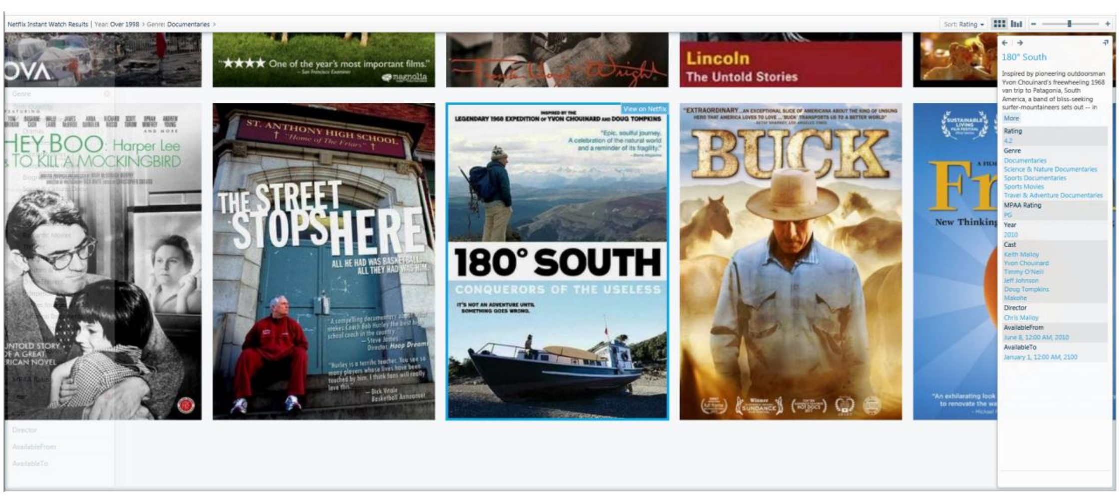

FIGURE 54:DEEPZOOM CONCEPT

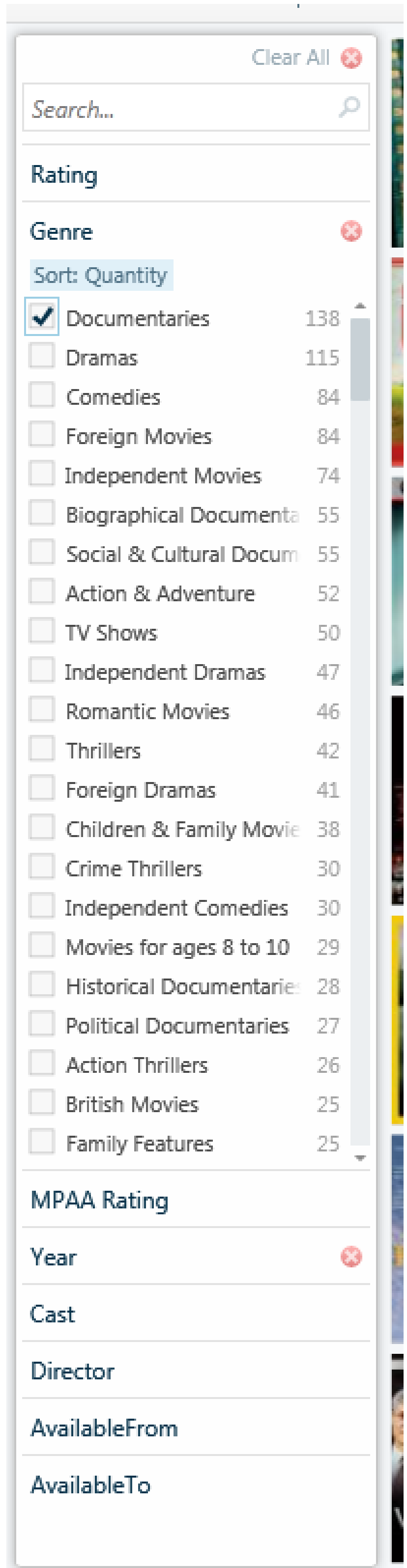

Figure 55: Custom Filter Parameters

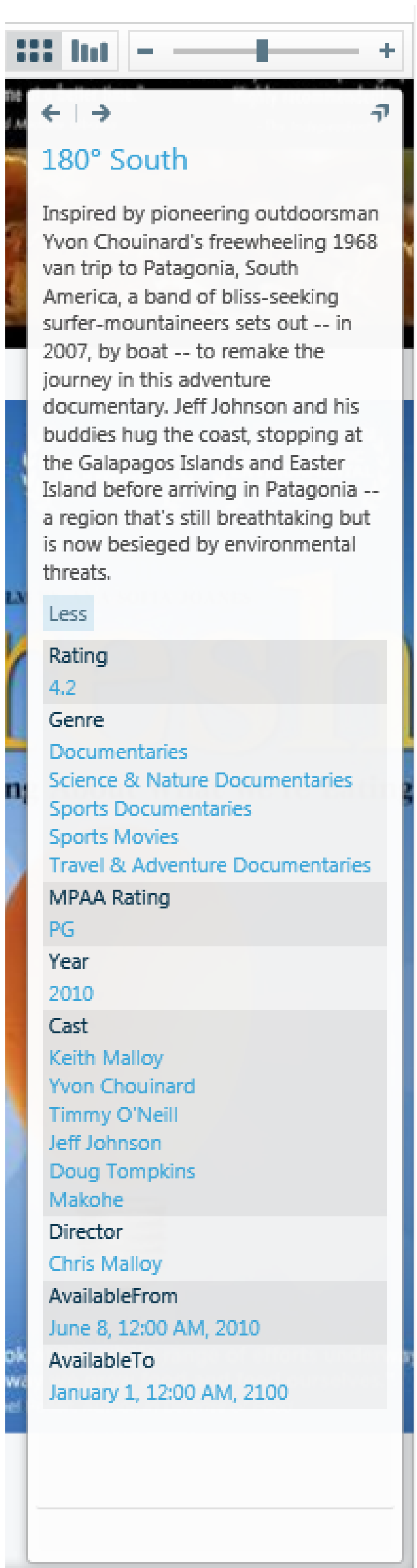

Figure 56: Custom Data Entry & Document Relationships

Although this system has never been used for document management and correlations, it has been recognized that if proper filter tabs are created, this interface would prove to be a strong candidate for facility management data retrieval. With the ability to create relationships and data standards, the user can quickly identify a room, building sector, level, or even a piece of equipment, and narrow in on the documents pertinent to their query. Once they reach the level necessary, the user can scroll though the remaining document and open their source file.

Currently this system is operated by hosting an image set to associate all of the files together. The current obstacle is that in construction documents, other than photograph, every other medium is utilized. In order to wrok beyond this restriction, the developer can create an image from the first page of the document, or construction drawing, and export that as an image, creating the placeholder in the system. Once this image is referenced, the attributes can be added, and the original file type referenced via a hyperlink. Additionally, through the use of an additional filter parameter which identifies the facility name, multiple facility's doucments can be hosted in a common file. This concept would be used my effectively for an owner, such as the New Regional Medical Center, who plans to host multiple buildings within a campus. Additionally, one could step even deeper, adding a campus category, allowing a single document to host all construction and life cycle documents for all of their facilities and assets. Table 18 contain the capabilities of how all of these documents can be organized and related for Facility Management of construction and life cycle documents for the New Regional Medical Center.

Table 18: PivotViewer for Facility Document Management

Filter Parameter	Document Data & Relationships
System	Construction Photos, Submittals, Request for Information, Contract Drawings, Design Model, As-Built Model, Equipment Data Sheet
Zoom Format	JPG, TIFF
Link to Original File	JPG, PDF, RVT, DWG, NWD, DOC, XLS, SKP, Hyperlink, Other
Document Name	Individual Description
Campus	East Norriton
Facility Name	New Regional Medical Center
Building Sector	A, B, C, D, Central Utility, Site
Floor Level	Ground Level, 1, 2, 3, 4, Roof
Room Number	####
Date Added to Database	YYYY-MM-DD
Model/Drawing	Yes, No
CSI Discipline	## - Title
Bid Package #	BP ##
Trade Contractor	Company Name
Trade Contact	Contact – linked to email address
Design Team	Company Name
Design Contact	Contact – linked to email address
Construction Manager	Company Name
Construction Contact	Contact – linked to email address
Asset Management	Hyperlink to external software/file

OUTCOME

This analysis focused on the research into the development of an accessible, easy to use, and updatable, document management system for the facility management team after the construction of the building. Through industry discussion, interface development, and continued feedback from the user group, it was identified that this system is critical to streamlining the workflow of a facility management team. By creating not only a database system for a post-construction document turnover, but one which can be updated, and expanded upon during facility use, this concept leverages technology in a new and innovative way to provide digital toolsets and document controls to the end users.

Through the development of the FM Document Dashboard, difficulties in working in html links surfaced, helping to dictate and develop a file management structure in order to easily store and access documents for reference. Additionally, though the web development of this concept, many of the advantages and disadvantages of opening files beyond a PDF in an internet explorer window. With the application of the research theory in this analysis, recognition was made on the development of a more concise and easy to use photo log of the facility. With this concept, FM Interact came into perspective. With added insight into this software platform, and the capabilities to access the information both locally and over the internet, developed was reached to identify how to host other file formats, and finally the most efficient way to create view filters and set up the document data for the software to build the relationships.

Moving from research insight, into baseline application development through Dreamweaver, and finally into advanced document controls though PivotViewer, this analysis reached well beyond its intention to analyze document exchanges. With the application of both the FM Document Portal and FM Interact, new methods on how to efficiently transition between related file types was created, quickly and accurately accessing the necessary data for facility management through a user friendly interface.

REFLECTION

It is believed that this analysis confirms the capabilities of new approaches to document controls and turnover packages for an owner. Although a digital turnover interface is not included with the original package of the New Regional Medical Center, with development, the concepts shared through this research will permit the Owner to incorporate the ideas into their new healthcare campus in East Norriton, PA. Due to the current state of the industry, and much unknown about value-added features of VDC applications for building turnover, very little is expected. With the release of Penn State's CIC guide for "Owner Execution Planning," great strides will be made to assist Owners and project teams in the proper direction regarding data management and delivery methods.

With the growing appeal of implementing BIM and other data management tools into the modeled components, one must be cautioned if this is necessarily the most efficient package. Although all of the information would be stored and cataloged within the model elements, the information retrieval may not be the most efficient process for a user group. By providing new methods such as an FM Dashboard and FM Interact to host the BIM packages and construction documents in a simple interface, the user group can easily sort through great quantities of documents to find applicable items. Once sorted, they can then continue deeper into the document file, whether it would be a BIM model, a contract document, or photograph, and quickly retrieve their inquiry.

Recommendations & Conclusions

The New Regional Medical Center was analyzed throughout the academic year, providing the basis for the development of research and evaluation of four construction management concepts, centered on the theme of implementing virtual design and construction methods within each of the phases of a project. Once an understanding of the existing conditions was developed, four analyses were conducted to implemented prevalent and new industry technologies into this project. These topics include:

- BIM in Preconstruction
- Redesign of Atrium Enclosure Process
- Redesign of Structural Pour Strip
- Document Management for the Owner

The following conclusions have been reached through the each analysis process, as detailed in this report.

Analysis 1 | BIM in Preconstruction

QTO & Estimating

Model-based estimating is a growing VDC concept within construction firms. Over the past few years, industry leaders have begun developing internal processes in order to identify and understand the capabilities of this method. This analysis investigated the implementation of this strategy for estimating the structural bid packages, identifying strengths, weaknesses, and industry growth.

The structural steel Revit-based estimate produced a cost of $7,710,326, which is 0.50% above schedule of values logged for this system. Additionally, it was 8.82% more accurate than Gilbane's traditional quantity takeoff method, reducing the preconstruction bid package estimate by $635,361. The cast-in-place concrete estimate was not as successful, resulting in a 10.70% deviation for the schedule of values for construction.

It is recommend that firms begin using 5D estimating for the basis of structural steel bid packages (Nahas, 2012) and interior partition bid packages (Kreider, 2009). Additionally, it is recommended that companies continue internal research in Revit-Based Methods concurrent to traditional estimating practices on more complicated modeled systems, such as concrete (Nahas, 2012), and curtain wall systems (Abousaid, 2010). Through implementation and continued development, construction firms can provide input and monitor design firms' evolution towards transferrable parameters and modeled features into an estimating matrix.

Crane Planning & Logistics

As the industry develops into a comprehensive usage of BIM, VDC solutions need to be derived to assist in areas beyond current application, such as estimating and coordination. Through the utilization of modeled components and attribute data, information can be extracted to assist with analysis to determine the most economical construction process for structural steel based on crane logistics.

This analysis developed a Microsoft Excel based visualization that identifies trending data regarding critical picks for steel erection. It was recognized that the workflow process of the structural erection of the New Regional Medical Center contained an oversize crane for 77% of the duration. Through this visual analysis of Revit-based data, it was recognized that construction by Sector is a more efficient process. In total, this analysis identified a new VDC method in order to highlight trending data within a structural steel model, and resulted in a savings of two weeks on the construction schedule, in addition to $315,727 of the project cost.

It is recommended that VDC tactics be investigated in other facets of the industry. As displayed in this analysis, data stored within the models have usage beyond construction document development and facility management information. By capturing this data in new and innovative formats, visual relationships are recognized, identifying areas for improvement or reconsideration on a construction method.

Analysis 2 | Redesign of Atrium Enclosure Process

Prefabrication and unitization of glazing systems have been recognized for developing higher quality, faster installation, and a safer working environment. Similar to the applications of MEP prefabrication, the unitization of glazing units is a trending topic present in the industry. This analysis investigates the consideration of unitization of the atrium's curtain wall. Additionally, it includes a related architectural redesign to facilitate a safer installation process, and the reintroduction of public space removed during design development.

In order to create a safe working environment for the unitization of the curtain wall system, it was recommend by the subcontractor performing the work that floor level access at the exterior wall would assist with the placement and affixing the system to the structure. Paring their review with the recognition that public space for seating in the atrium is limited and would require relocating to the ground level, Level 1 and Level 3 were redesign to include a walkway area along the curtain wall. The costs of this addition amount to $123,455. An aesthetically pleasing space was designed in order to improve constructability and eliminate a high-risk construction process on the site, while also providing a space for patient and visitors to enjoy the greenfield landscape surrounding the hospital. It was recognized that the unitization of the curtain wall system would reduce field assembly duration; however, require a 20-week lead-time to procure and assemble the units. Unitization would have only been logical if the glazing subcontractor was brought into the project earlier to assist with design development.

From this analysis, it is recommended that design teams review their curtain wall systems with a stronger focus. Additionally, obtaining a glazing subcontractor for consultation would also assist in design development in order to ensure that the expected product meets the schedule, cost, and quality level that the owner and construction team expects to produce. With the assistance of a prefabricated glazing system, the construction site requires fewer trades working in high-risk locations, in addition to less equipment on site. Finally, the key to this system being implemented is open communications and consultation during design development and design revisions.

Analysis 3 | Redesign of Structural Pour Strip

Constructability issues versus design decisions are consistently reviewed in order to understand the implication of a chosen system. It is commonly known that a structural pour strip is more difficult to coordinate in construction when compared to a typical building expansion joint. This analysis preforms a cost comparison of the systems to identify if the selected system is the best option for the owner.

This analysis identified that the building's pour strip system is a more cost effective design decision. The choice to utilize the pour strips over expansion joints saved the project approximately $57,800. Although the expansion joint system permitted a simpler construction schedule, a decrease in the size of the foundation system, and slight decrease in the concrete slab and metal deck, these reductions did not offset the increase in other system costs. The analysis also clarified that the building's pour strip system is a more aesthetically pleasing system and is preferred by the Owner.

It is recommended that other design teams and Owners investigate the implications of a pour strip within their facility in lieu of an expansion joint. Although the expansion joint provides a simpler construction method, the aesthetic results and additional costs may not be worthwhile. It has become commonplace that an expansion joint is more efficient; however, it is recommended that the design team or construction management firm use the design alternate process within Autodesk Revit to quickly analyze the cost benefits of a building pour strip, and cross-reference these outcomes with the intentions and goals of the Owner and facility user group.

Analysis 4 | Document Management for the Owner

This analysis focused on the research into the development of an accessible, easy to use, and updatable, document management system for the facility management team after the construction of the building. Through industry discussion, interface development, and continued feedback from the user group, it was identified that this system is critical to streamlining the workflow of a facility management team.

Moving from research insight, into baseline application development through Dreamweaver, and finally into advanced document controls though PivotViewer, this analysis reached well beyond its intention to analyze document exchanges. With the application of both the FM Document Portal and FM Interact, new methods on how to efficiently transition between related file types was created, quickly and accurately accessing the necessary data for facility management through a user friendly interface.

It is believed that this analysis confirms the capabilities of new approaches to document controls and turnover packages for an owner. Although a digital turnover interface is not included with the original package of the New Regional Medical Center, with development, the concepts shared through this research will permit the Owner to incorporate the ideas into their new healthcare campus in East Norriton, PA. By providing new methods such as an FM Dashboard and FM Interact to host BIM packages and construction documents in a simple interface, the user group can easily sort through great quantities of documents to find applicable items.

It is recommended that Owners, notably from Universities and Healthcare Systems, begin to develop their internal goals of document management. Although construction companies will be capable of developing a web based interface and document controls for turnover, larger Owners should outline their own methods in order to streamline and combine all of this facilities into a common system.

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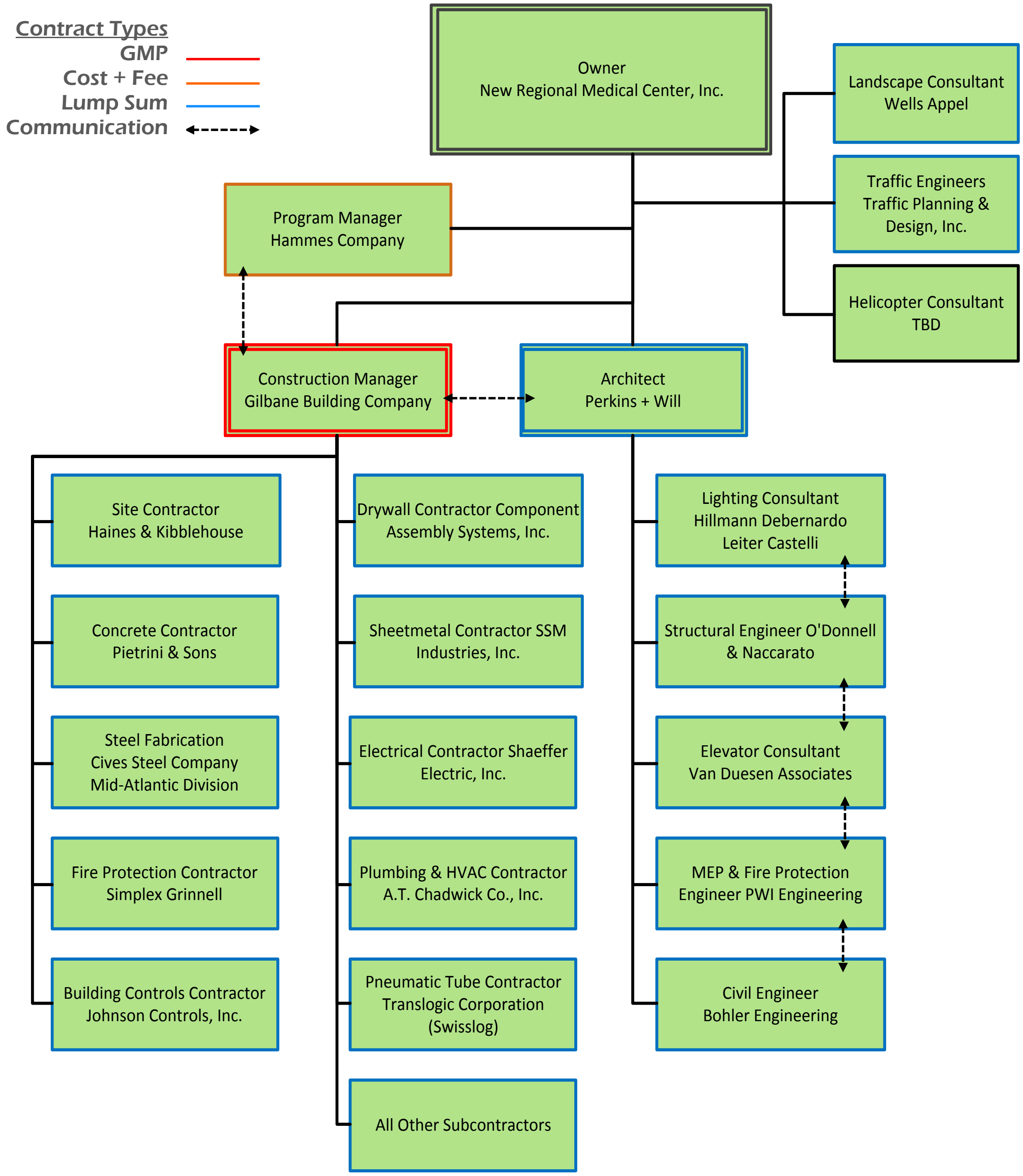
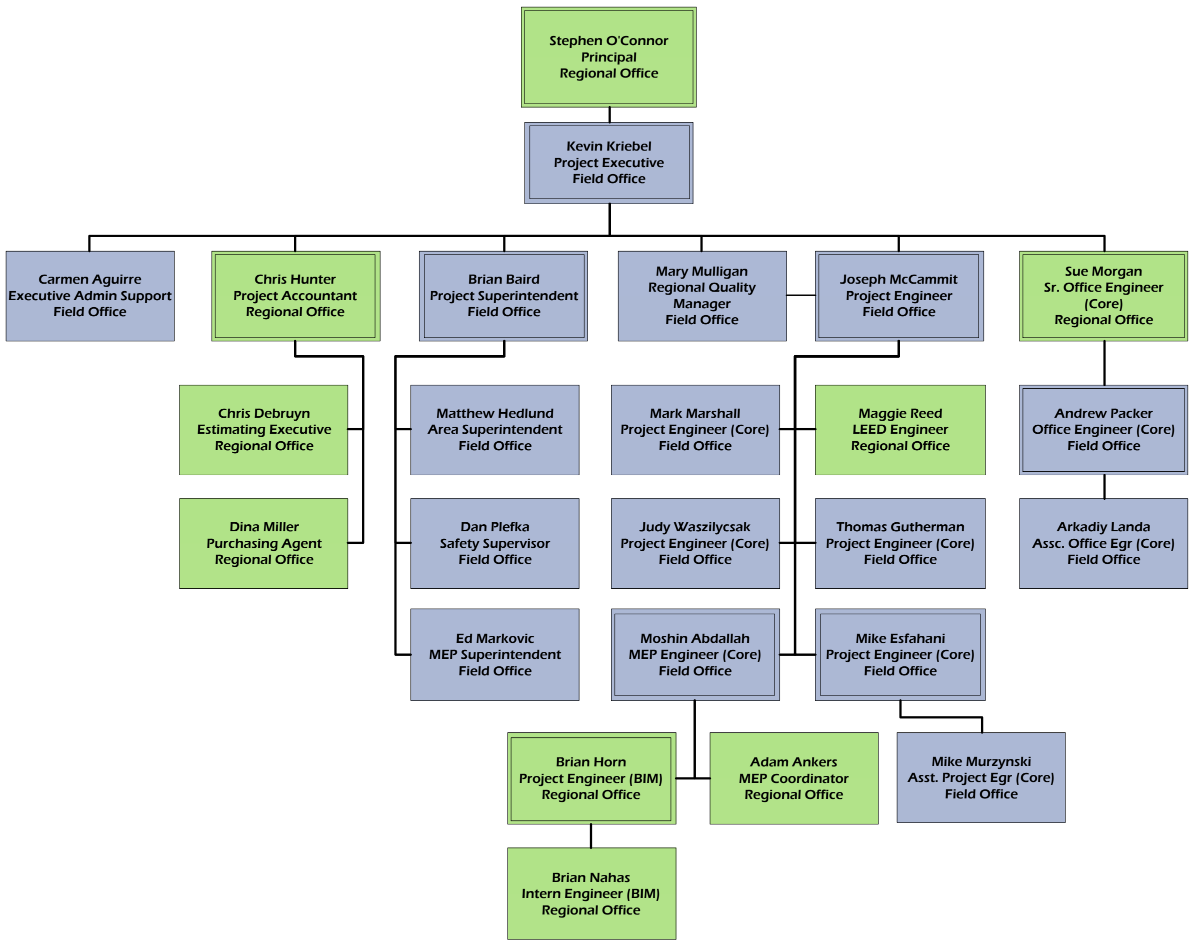
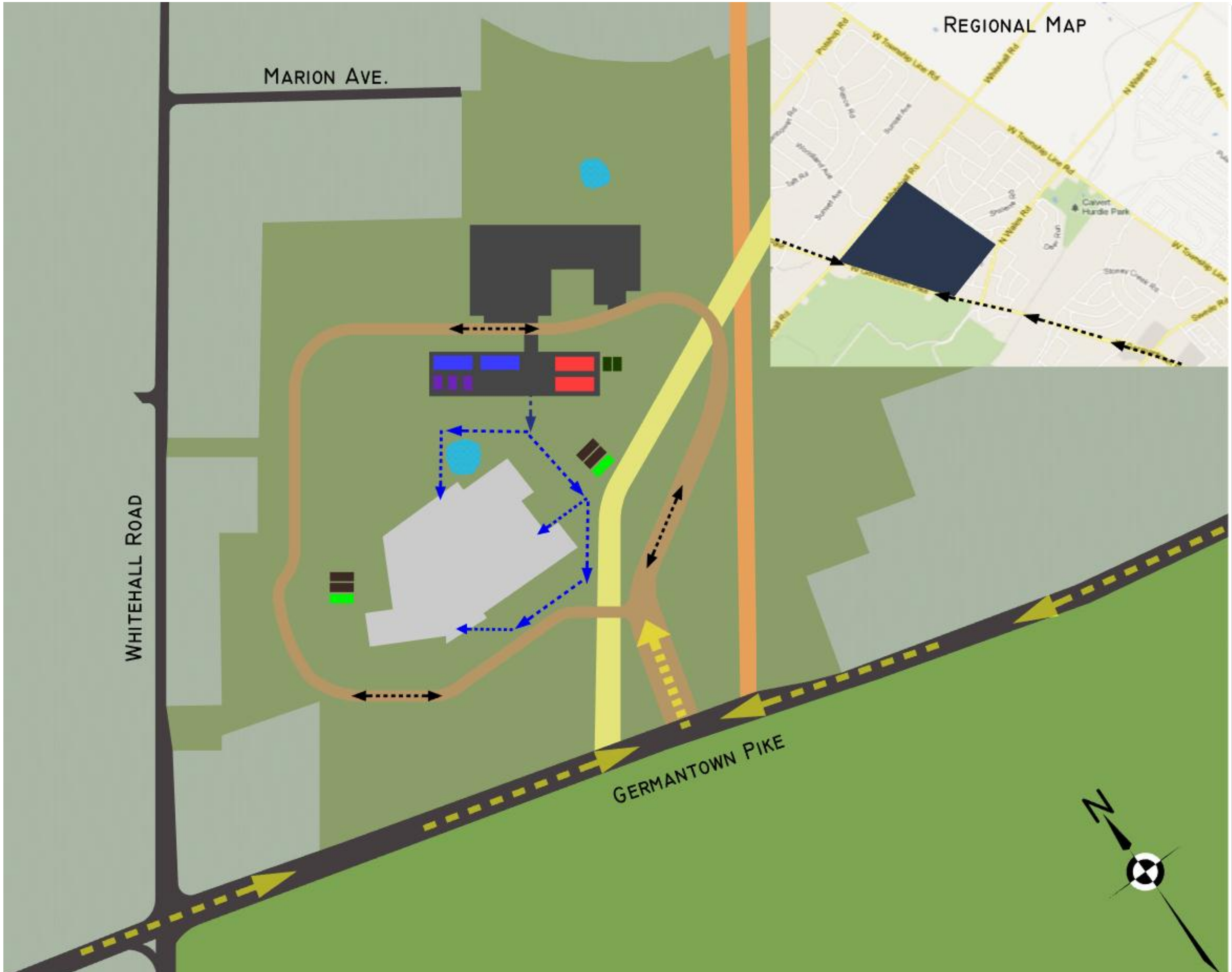
APPENDIX A | ORGANIZATIONAL CHART



APPENDIX B | STAFF ORGANIZATIONAL CHART



APPENDIX C | GENERAL CONDITIONS PLAN



Legend

- Trade Traffic
- Traffic Route
- Site Location
- Natural Gas Pipeline
- Telecom Easement
- Building Footprint
- Delivery Loop
- Project Parking
- Neighborhoods
- Water Feature
- Gilbane's Offices
- Trade Offices
- Trade Storage
- Dumpster
- Recycling
- Temporary Power

NEW REGIONAL MEDICAL CENTER

EAST NORRITON, PA

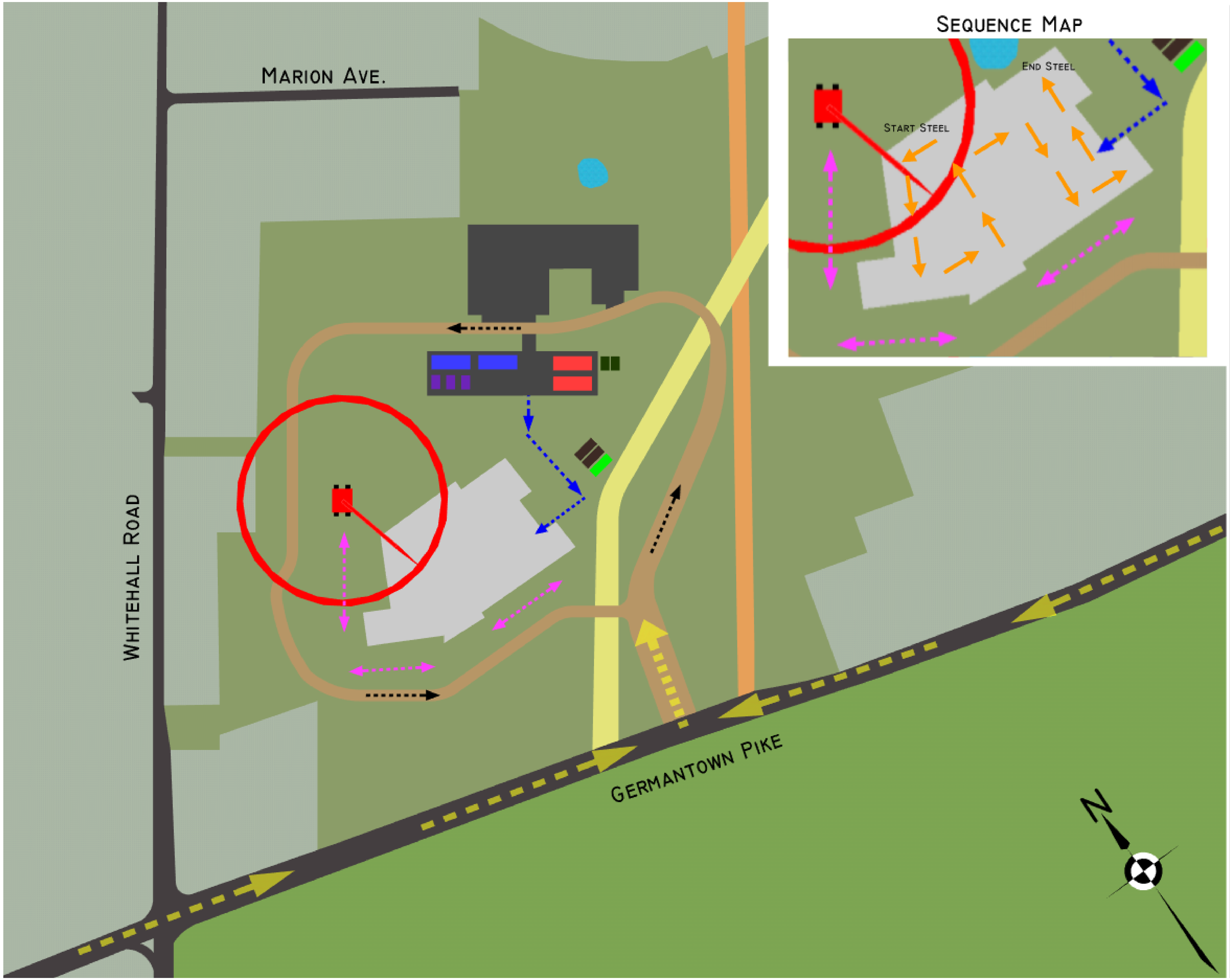
BRIAN NAHAS
CONSTRUCTION MANAGEMENT

SENIOR THESIS
FINAL REPORT

APPENDIX C

GENERAL CONDITIONS PLAN

APPENDIX D | STRUCTURE & ENCLOSURE PLAN



Legend

- Crane Path
- Trade Traffic
- Traffic Route
- Site Location
- Natural Gas Pipeline
- Telecom Easement
- Building Footprint
- Delivery Loop
- Project Parking
- Neighborhoods
- Water Feature
- Gilbane's Offices
- Trade Offices
- Trade Storage
- Dumpster
- Recycling
- Temporary Power

NEW REGIONAL MEDICAL CENTER

EAST NORRITON, PA

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Appendix D

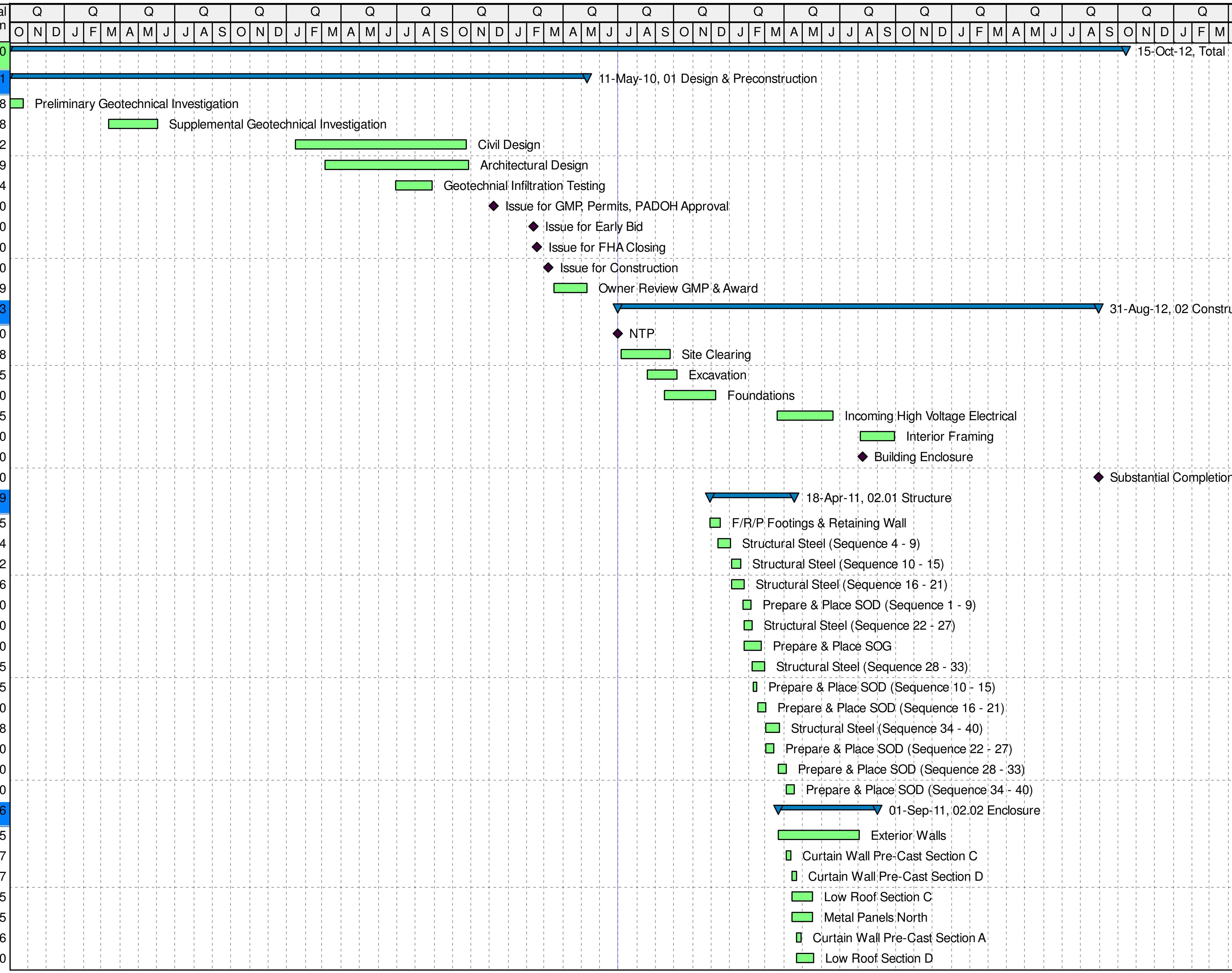
Structure & Enclosure Plan

APPENDIX E | PROJECT SCHEDULE

BRIAN NAHAS

CONTRUCTION MANAGEMENT

Activity Name	Start	Finish	Original Duration
Total	01-Oct-07	15-Oct-12	1300
01 Design & Preconstruction	01-Oct-07	11-May-10	681
Preliminary Geotechnical Investigation	01-Oct-07	24-Oct-07	18
Supplemental Geotechnical Investigation	13-Mar-08	02-Jun-08	58
Civil Design	15-Jan-09	23-Oct-09	202
Architectural Design	05-Mar-09	28-Oct-09	169
Geotechnial Infiltration Testing	30-Jun-09	28-Aug-09	44
Issue for GMP, Permits, PADOH Approval	09-Dec-09		0
Issue for Early Bid	11-Feb-10		0
Issue for FHA Closing	18-Feb-10		0
Issue for Construction	08-Mar-10		0
Owner Review GMP & Award	18-Mar-10	11-May-10	39
02 Construction	01-Jul-10	31-Aug-12	553
NTP	01-Jul-10		0
Site Clearing	06-Jul-10	24-Sep-10	58
Excavation	18-Aug-10	06-Oct-10	35
Foundations	16-Sep-10	09-Dec-10	60
Incoming High Voltage Electrical	21-Mar-11*	20-Jun-11	65
Interior Framing	04-Aug-11	29-Sep-11	40
Building Enclosure	08-Aug-11		0
Substantial Completion	31-Aug-12		0
02.01 Structure	29-Nov-10	18-Apr-11	99
F/R/P Footings & Retaining Wall	29-Nov-1(	17-Dec-10	15
Structural Steel (Sequence 4 - 9)	13-Dec-1(	03-Jan-11	14
Structural Steel (Sequence 10 - 15)	04-Jan-11*	19-Jan-11	12
Structural Steel (Sequence 16 - 21)	04-Jan-11*	25-Jan-11	16
Prepare & Place SOD (Sequence 1 - 9)	24-Jan-11*	04-Feb-11	10
Structural Steel (Sequence 22 - 27)	25-Jan-11*	07-Feb-11	10
Prepare & Place SOG	25-Jan-11*	21-Feb-11	20
Structural Steel (Sequence 28 - 33)	08-Feb-11*	28-Feb-11	15
Prepare & Place SOD (Sequence 10 - 15)	09-Feb-11*	15-Feb-11	5
Prepare & Place SOD (Sequence 16 - 21)	16-Feb-11*	01-Mar-11	10
Structural Steel (Sequence 34 - 40)	01-Mar-11*	24-Mar-11	18
Prepare & Place SOD (Sequence 22 - 27)	02-Mar-11*	15-Mar-11	10
Prepare & Place SOD (Sequence 28 - 33)	22-Mar-11*	04-Apr-11	10
Prepare & Place SOD (Sequence 34 - 40)	05-Apr-11*	18-Apr-11	10
02.02 Enclosure	22-Mar-11	01-Sep-11	116
Exterior Walls	22-Mar-11	03-Aug-11	95
Curtain Wall Pre-Cast Section C	04-Apr-11*	12-Apr-11	7
Curtain Wall Pre-Cast Section D	13-Apr-11*	21-Apr-11	7
Low Roof Section C	13-Apr-11*	17-May-11	25
Metal Panels North	14-Apr-11*	18-May-11	25
Curtain Wall Pre-Cast Section A	22-Apr-11*	29-Apr-11	6
Low Roof Section D	22-Apr-11*	19-May-11	20



Activity
Summary
Milestone

NEW REGIONAL MEDICAL CENTER

EAST NORRITON, PA

Activity Name	Start	Finish	Original Duration
Curtain Wall Pre-Cast Section B	02-May-1	13-May-11	10
High Roof Section A	02-May-1	27-May-11	20
Metal Panels West	02-May-1	13-Jun-11	30
High Roof Section B	20-May-1	17-Jun-11	20
Curtain Wall Atrium	06-Jun-11*	01-Aug-11	40
Metal Panels East	14-Jun-11*	26-Jul-11	30
Metal Panels South	27-Jul-11*	09-Aug-11	10
High Roof Clerestory Curtain Wall	29-Jul-11*	15-Aug-11	12
Ground Floor South Elevation	29-Jul-11*	18-Aug-11	15
Ground Floor East Elevation	19-Aug-11	01-Sep-11	10
02.03 Ground Level	11-Mar-11	25-May-12	310
Top Track	11-Mar-11*	07-Apr-11	20
Spray on Fire Proofing (Interior Columns & Beam	28-Mar-11*	15-Apr-11	15
Frame & Drywall Non-Accessible Walls	08-Apr-11*	12-May-11	25
Electrical Overhead Rough In	02-May-1	26-Jul-11	60
Sheetmetal Overhead Rough In	02-May-1	26-Jul-11	60
HVAC Overhead Piping Rough In	02-May-1	26-Jul-11	60
Med Gas Overhead Piping Rough In	02-May-1	26-Jul-11	60
Pneumatic Tube Overhead Piping Rough In	02-May-1	26-Jul-11	60
Sprinkler Overhead Rough In	02-May-1	26-Jul-11	60
F/A Security Overhead Rough In	10-Jun-11*	19-Aug-11	50
Controls Overhead Rough In	10-Jun-11*	19-Aug-11	50
Med Gas Overhead Distribution	10-Jun-11*	19-Aug-11	50
Complete Frame Partition Walls	20-Jun-11*	01-Aug-11	30
Electrical In-Wall Rough In	30-Jun-11*	23-Sep-11	60
F/A Security In-Wall Rough In	30-Jun-11*	23-Sep-11	60
Controls In-Wall Rough In	30-Jun-11*	23-Sep-11	60
Med Gas In-Wall Rough In	30-Jun-11*	23-Sep-11	60
Pneumatic Tube In-Wall Rough In	30-Jun-11*	23-Sep-11	60
Drywall Paritions & Gypsum Ceiling	08-Sep-11	02-Nov-11	40
Acoustical Ceiling Grid	26-Sep-11	28-Oct-11	25
Light Fixtures in Acoustical Grid	17-Oct-11*	28-Nov-11	30
Diffusers, Grilles, Registers in Acoustical Grid	17-Oct-11*	28-Nov-11	30
Sprinkler Heads	17-Oct-11*	28-Nov-11	30
Final Paint	14-Nov-11	11-Jan-12	40
Electrical In-Wall Finishes	19-Dec-11	27-Mar-12	70
F/A Security In-Wall Finishes	19-Dec-11	27-Mar-12	70
Controls In-Wall Finshes	19-Dec-11	27-Mar-12	70
Med Gas In-Wall Finishes	19-Dec-11	27-Mar-12	70
Pneumatic Tube In-Wall Finishes	19-Dec-11	27-Mar-12	70
Millwork	26-Mar-12*	11-May-12	35
Casework	26-Mar-12*	11-May-12	35
Electrical & Plumbing Tie into Casework	07-May-1	25-May-12	15
02.03 Level 1	08-Apr-11	28-Feb-12	227
Top Track	08-Apr-11*	21-Apr-11	10

Activity

Summary

Milestone

NEW REGIONAL MEDICAL CENTER

EAST NORRITON, PA

Activity Name	Start	Finish	Original Duration
Spray on Fire Proofing (Interior Columns & Beam	15-Apr-11*	28-Apr-11	10
Frame & Drywall Non-Accessible Walls	22-Apr-11*	11-May-11	14
Sheetmetal Overhead Rough In	10-May-1	06-Jul-11	40
HVAC Overhead Piping Rough In	10-May-1	06-Jul-11	40
Med Gas Overhead Piping Rough In	10-May-1	06-Jul-11	40
Pneumatic Tube Overhead Piping Rough In	10-May-1	06-Jul-11	40
Sprinkler Overhead Rough In	10-May-1	06-Jul-11	40
Electrical Overhead Rough In	01-Jun-11*	27-Jul-11	40
F/A Security Overhead Rough In	01-Jun-11*	27-Jul-11	40
Controls Overhead Rough In	01-Jun-11*	27-Jul-11	40
Med Gas Overhead Distribution	01-Jun-11*	27-Jul-11	40
Complete Frame Partition Walls	22-Jun-11*	20-Jul-11	20
Electrical In-Wall Rough In	30-Jun-11*	09-Sep-11	50
F/A Security In-Wall Rough In	30-Jun-11*	09-Sep-11	50
Controls In-Wall Rough In	30-Jun-11*	09-Sep-11	50
Med Gas In-Wall Rough In	30-Jun-11*	09-Sep-11	50
Pneumatic Tube In-Wall Rough In	30-Jun-11*	09-Sep-11	50
Drywall Paritions & Gypsum Ceiling	08-Sep-11	12-Oct-11	25
Acoustical Ceiling Grid	15-Sep-11	12-Oct-11	20
Light Fixtures in Acoustical Grid	03-Oct-11*	28-Oct-11	20
Diffusers, Grilles, Registers in Acoustical Grid	03-Oct-11*	28-Oct-11	20
Sprinkler Heads	03-Oct-11*	28-Oct-11	20
Final Paint	04-Nov-11	02-Dec-11	20
Electrical In-Wall Finishes	14-Nov-11	11-Jan-12	40
F/A Security In-Wall Finishes	14-Nov-11	11-Jan-12	40
Controls In-Wall Finshes	14-Nov-11	11-Jan-12	40
Med Gas In-Wall Finishes	14-Nov-11	11-Jan-12	40
Pneumatic Tube In-Wall Finishes	14-Nov-11	11-Jan-12	40
Millwork	28-Dec-11	15-Feb-12	35
Casework	28-Dec-11	15-Feb-12	35
Electrical & Plumbing Tie into Casework	08-Feb-12*	28-Feb-12	15
02.03 Level 2	22-Apr-11	28-Feb-12	217
Top Track	22-Apr-11*	05-May-11	10
Spray on Fire Proofing (Interior Columns & Beam	02-May-1	13-May-11	10
Frame & Drywall Non-Accessible Walls	05-May-1	24-May-11	14
Sheetmetal Overhead Rough In	23-May-1	19-Jul-11	40
HVAC Overhead Piping Rough In	23-May-1	19-Jul-11	40
Med Gas Overhead Piping Rough In	23-May-1	19-Jul-11	40
Pneumatic Tube Overhead Piping Rough In	23-May-1	19-Jul-11	40
Sprinkler Overhead Rough In	23-May-1	19-Jul-11	40
Electrical Overhead Rough In	06-Jun-11*	01-Aug-11	40
F/A Security Overhead Rough In	06-Jun-11*	01-Aug-11	40
Controls Overhead Rough In	06-Jun-11*	01-Aug-11	40
Med Gas Overhead Distribution	06-Jun-11*	01-Aug-11	40
Complete Frame Partition Walls	27-Jun-11*	25-Jul-11	20

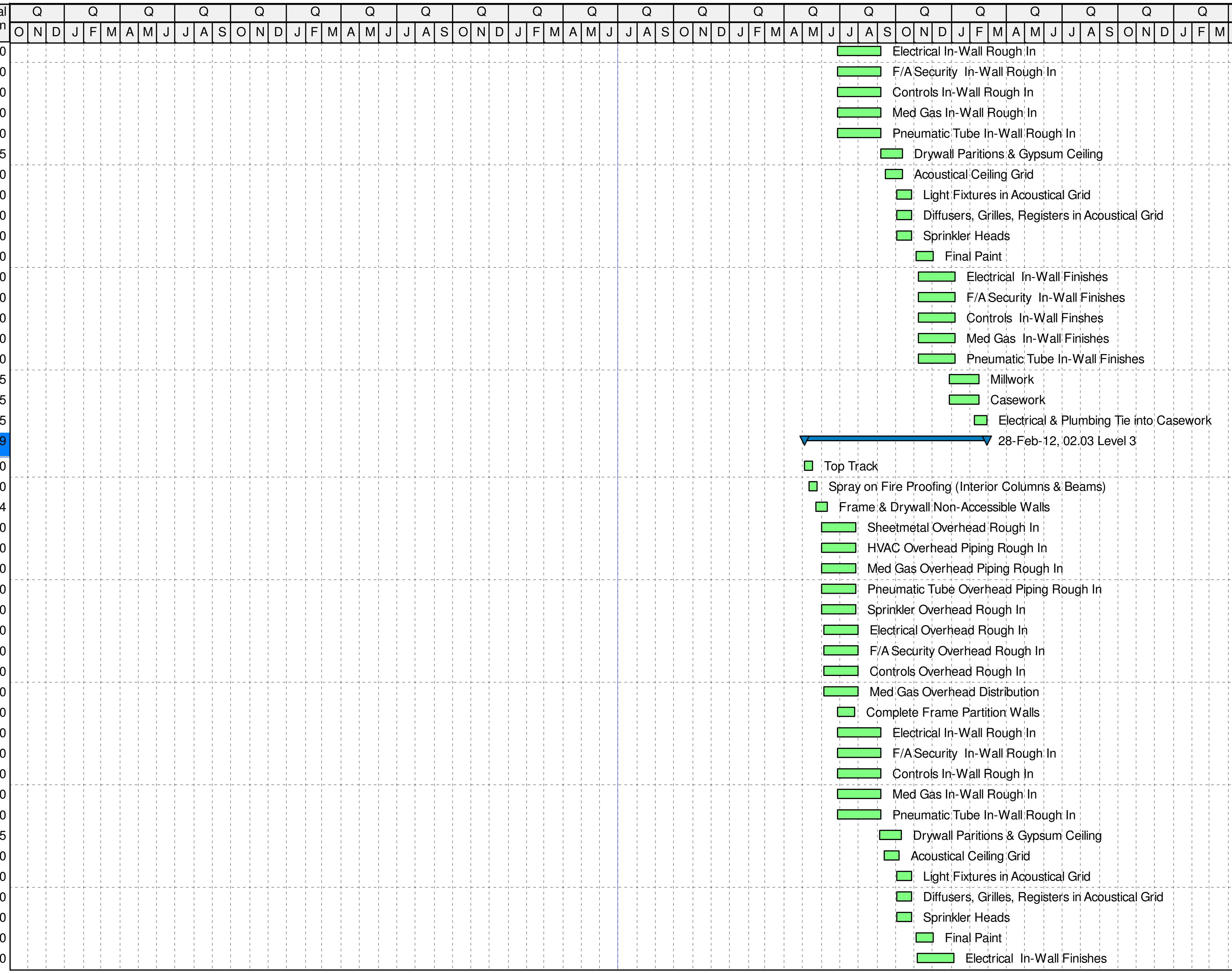
28-Feb-12, 02.03 Level 2

Activity Summary Milestone

BRIAN NAHAS

CONTRUCTION MANAGEMENT

Activity Name	Start	Finish	Original Duration
Electrical In-Wall Rough In	28-Jun-11*	07-Sep-11	50
F/A Security In-Wall Rough In	28-Jun-11*	07-Sep-11	50
Controls In-Wall Rough In	28-Jun-11*	07-Sep-11	50
Med Gas In-Wall Rough In	28-Jun-11*	07-Sep-11	50
Pneumatic Tube In-Wall Rough In	28-Jun-11*	07-Sep-11	50
Drywall Paritions & Gypsum Ceiling	08-Sep-11	12-Oct-11	25
Acoustical Ceiling Grid	15-Sep-11	12-Oct-11	20
Light Fixtures in Acoustical Grid	03-Oct-11*	28-Oct-11	20
Diffusers, Grilles, Registers in Acoustical Grid	03-Oct-11*	28-Oct-11	20
Sprinkler Heads	03-Oct-11*	28-Oct-11	20
Final Paint	04-Nov-11	02-Dec-11	20
Electrical In-Wall Finishes	09-Nov-11	06-Jan-12	40
F/A Security In-Wall Finishes	09-Nov-11	06-Jan-12	40
Controls In-Wall Finshes	09-Nov-11	06-Jan-12	40
Med Gas In-Wall Finishes	09-Nov-11	06-Jan-12	40
Pneumatic Tube In-Wall Finishes	09-Nov-11	06-Jan-12	40
Millwork	28-Dec-11	15-Feb-12	35
Casework	28-Dec-11	15-Feb-12	35
Electrical & Plumbing Tie into Casework	08-Feb-12*	28-Feb-12	15
02.03 Level 3	04-May-11	28-Feb-12	209
Top Track	04-May-11	17-May-11	10
Spray on Fire Proofing (Interior Columns & Beam	11-May-11	24-May-11	10
Frame & Drywall Non-Accessible Walls	23-May-11	10-Jun-11	14
Sheetmetal Overhead Rough In	01-Jun-11*	27-Jul-11	40
HVAC Overhead Piping Rough In	01-Jun-11*	27-Jul-11	40
Med Gas Overhead Piping Rough In	01-Jun-11*	27-Jul-11	40
Pneumatic Tube Overhead Piping Rough In	01-Jun-11*	27-Jul-11	40
Sprinkler Overhead Rough In	01-Jun-11*	27-Jul-11	40
Electrical Overhead Rough In	06-Jun-11*	01-Aug-11	40
F/A Security Overhead Rough In	06-Jun-11*	01-Aug-11	40
Controls Overhead Rough In	06-Jun-11*	01-Aug-11	40
Med Gas Overhead Distribution	06-Jun-11*	01-Aug-11	40
Complete Frame Partition Walls	27-Jun-11*	25-Jul-11	20
Electrical In-Wall Rough In	28-Jun-11*	07-Sep-11	50
F/A Security In-Wall Rough In	28-Jun-11*	07-Sep-11	50
Controls In-Wall Rough In	28-Jun-11*	07-Sep-11	50
Med Gas In-Wall Rough In	28-Jun-11*	07-Sep-11	50
Pneumatic Tube In-Wall Rough In	28-Jun-11*	07-Sep-11	50
Drywall Paritions & Gypsum Ceiling	06-Sep-11	10-Oct-11	25
Acoustical Ceiling Grid	12-Sep-11	07-Oct-11	20
Light Fixtures in Acoustical Grid	03-Oct-11*	28-Oct-11	20
Diffusers, Grilles, Registers in Acoustical Grid	03-Oct-11*	28-Oct-11	20
Sprinkler Heads	03-Oct-11*	28-Oct-11	20
Final Paint	04-Nov-11	02-Dec-11	20
Electrical In-Wall Finishes	07-Nov-11	04-Jan-12	40



Activity | Summary | Milestone

NEW REGIONAL MEDICAL CENTER

EAST NORRITON, PA

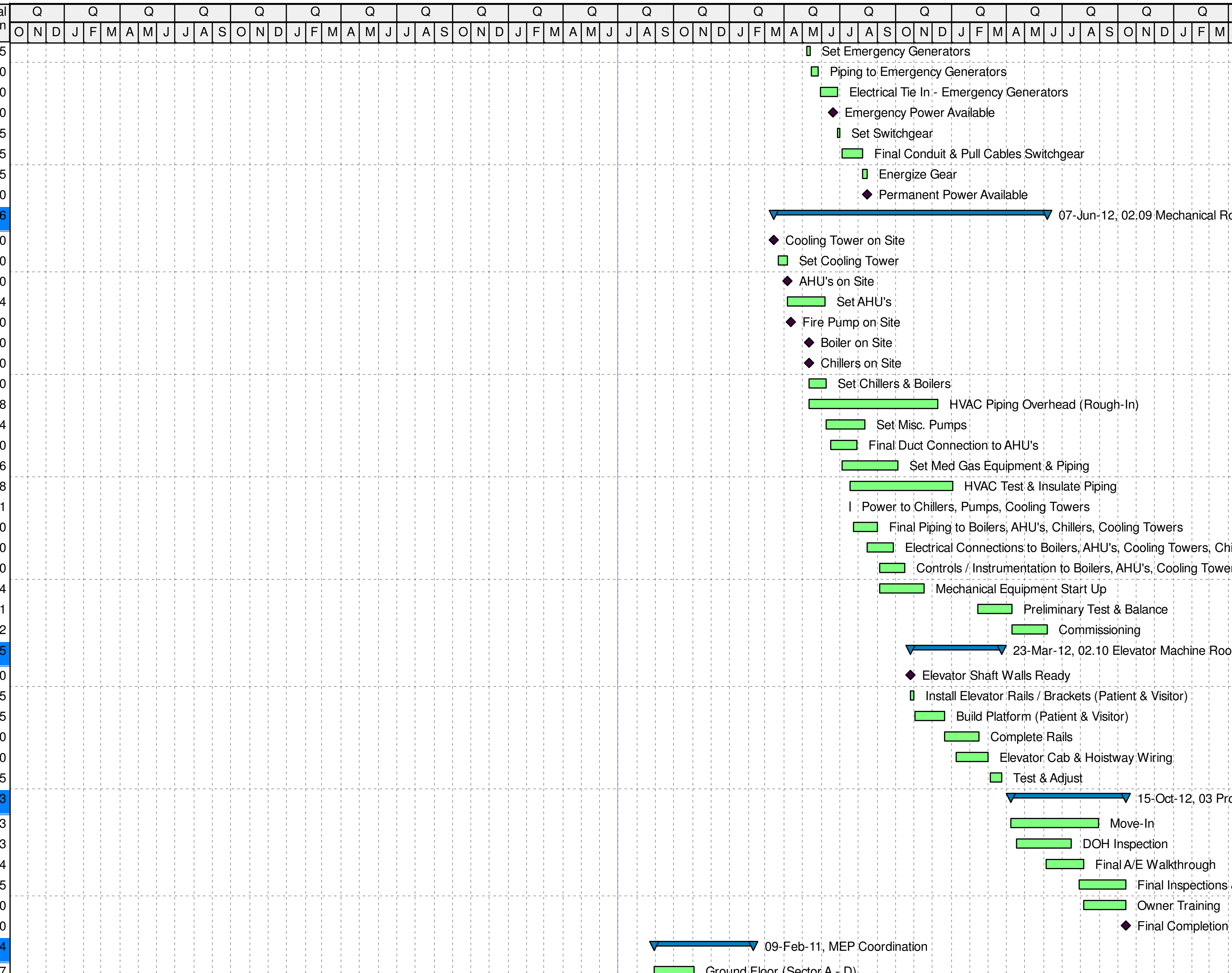
Activity Name	Start	Finish	Original Duration
F/A Security In-Wall Finishes	07-Nov-11	04-Jan-12	40
Controls In-Wall Finishes	07-Nov-11	04-Jan-12	40
Med Gas In-Wall Finishes	07-Nov-11	04-Jan-12	40
Pneumatic Tube In-Wall Finishes	07-Nov-11	04-Jan-12	40
Millwork	28-Dec-11	15-Feb-12	35
Casework	28-Dec-11	15-Feb-12	35
Electrical & Plumbing Tie into Casework	08-Feb-12*	28-Feb-12	15
02.03 Level 4	11-May-11	28-Feb-12	204
Top Track	11-May-11	24-May-11	10
Spray on Fire Proofing (Interior Columns & Beam	18-May-11	01-Jun-11	10
Frame & Drywall Non-Accessible Walls	25-May-11	14-Jun-11	14
Sheetmetal Overhead Rough In	03-Jun-11*	29-Jul-11	40
HVAC Overhead Piping Rough In	03-Jun-11*	29-Jul-11	40
Med Gas Overhead Piping Rough In	03-Jun-11*	29-Jul-11	40
Pneumatic Tube Overhead Piping Rough In	03-Jun-11*	29-Jul-11	40
Sprinkler Overhead Rough In	03-Jun-11*	29-Jul-11	40
Electrical Overhead Rough In	10-Jun-11*	05-Aug-11	40
F/A Security Overhead Rough In	10-Jun-11*	05-Aug-11	40
Controls Overhead Rough In	10-Jun-11*	05-Aug-11	40
Med Gas Overhead Distribution	10-Jun-11*	05-Aug-11	40
Complete Frame Partition Walls	29-Jun-11*	27-Jul-11	20
Electrical In-Wall Rough In	30-Jun-11*	09-Sep-11	50
F/A Security In-Wall Rough In	30-Jun-11*	09-Sep-11	50
Controls In-Wall Rough In	30-Jun-11*	09-Sep-11	50
Med Gas In-Wall Rough In	30-Jun-11*	09-Sep-11	50
Pneumatic Tube In-Wall Rough In	30-Jun-11*	09-Sep-11	50
Drywall Paritions & Gypsum Ceiling	08-Sep-11	12-Oct-11	25
Acoustical Ceiling Grid	15-Sep-11	12-Oct-11	20
Light Fixtures in Acoustical Grid	03-Oct-11*	28-Oct-11	20
Diffusers, Grilles, Registers in Acoustical Grid	03-Oct-11*	28-Oct-11	20
Sprinkler Heads	03-Oct-11*	28-Oct-11	20
Final Paint	04-Nov-11	02-Dec-11	20
Electrical In-Wall Finishes	09-Nov-11	06-Jan-12	40
F/A Security In-Wall Finishes	09-Nov-11	06-Jan-12	40
Controls In-Wall Finshes	09-Nov-11	06-Jan-12	40
Med Gas In-Wall Finishes	09-Nov-11	06-Jan-12	40
Pneumatic Tube In-Wall Finishes	09-Nov-11	06-Jan-12	40
Millwork	28-Dec-11	15-Feb-12	35
Casework	28-Dec-11	15-Feb-12	35
Electrical & Plumbing Tie into Casework	08-Feb-12*	28-Feb-12	15
02.08 Electrical Room	28-Dec-10	15-Aug-11	162
Install Electrical Ductbank	28-Dec-10	11-Jan-11	10
35kv Generator Set on Site		28-Mar-11	0
Switch Gear on Site		01-Apr-11	0
Permanent Power	04-Apr-11*	20-Jun-11	55

Activity | Summary | Milestone

NEW REGIONAL MEDICAL CENTER

EAST NORRITON, PA

Activity Name	Start	Finish	Original Duration
Set Emergency Generators	09-May-1	13-May-11	5
Piping to Emergency Generators	16-May-1	27-May-11	10
Electrical Tie In - Emergency Generators	31-May-1	27-Jun-11	20
Emergency Power Available		20-Jun-11	0
Set Switchgear	27-Jun-11*	01-Jul-11	5
Final Conduit & Pull Cables Switchgear	05-Jul-11*	08-Aug-11	25
Energize Gear	09-Aug-11	15-Aug-11	5
Permanent Power Available		15-Aug-11	0
02.09 Mechanical Room	14-Mar-11	07-Jun-12	316
Cooling Tower on Site		14-Mar-11	0
Set Cooling Tower	23-Mar-11*	05-Apr-11	10
AHU's on Site		05-Apr-11	0
Set AHU's	06-Apr-11*	07-Jun-11	44
Fire Pump on Site		12-Apr-11	0
Boiler on Site		11-May-11	0
Chillers on Site		11-May-11	0
Set Chillers & Boilers	12-May-1	09-Jun-11	20
HVAC Piping Overhead (Rough-In)	12-May-1	09-Dec-11	148
Set Misc. Pumps	10-Jun-11*	11-Aug-11	44
Final Duct Connection to AHU's	17-Jun-11*	29-Jul-11	30
Set Med Gas Equipment & Piping	05-Jul-11*	05-Oct-11	66
HVAC Test & Insulate Piping	18-Jul-11*	03-Jan-12	118
Power to Chillers, Pumps, Cooling Towers	18-Jul-11*	18-Jul-11	1
Final Piping to Boilers, AHU's, Chillers, Cooling To	25-Jul-11*	02-Sep-11	30
Electrical Connections to Boilers, AHU's, Cooling T	16-Aug-11	27-Sep-11	30
Controls / Instrumentation to Boilers, AHU's, Cooli	06-Sep-11	17-Oct-11	30
Mechanical Equipment Start Up	06-Sep-11	18-Nov-11	54
Preliminary Test & Balance	13-Feb-12*	09-Apr-12	41
Commissioning	10-Apr-12*	07-Jun-12	42
02.10 Elevator Machine Room	25-Oct-11	23-Mar-12	105
Elevator Shaft Walls Ready		25-Oct-11	0
Install Elevator Rails / Brackets (Patient & Visitor)	26-Oct-11*	01-Nov-11	5
Build Platform (Patient & Visitor)	02-Nov-11	21-Dec-11	35
Complete Rails	21-Dec-11	16-Feb-12	40
Elevator Cab & Hoistway Wiring	09-Jan-12*	02-Mar-12	40
Test & Adjust	05-Mar-12*	23-Mar-12	15
03 Project Closeout	09-Apr-12	15-Oct-12	133
Move-In	09-Apr-12	31-Aug-12	103
DOH Inspection	17-Apr-12*	16-Jul-12	63
Final A/E Walkthrough	05-Jun-12	06-Aug-12	44
Final Inspections & Certifications	30-Jul-12*	15-Oct-12	55
Owner Training	06-Aug-12	15-Oct-12	50
Final Completion		15-Oct-12	0
MEP Coordination	30-Aug-10	09-Feb-11	114
Ground Floor (Sector A - D)	30-Aug-1(	03-Nov-10	47

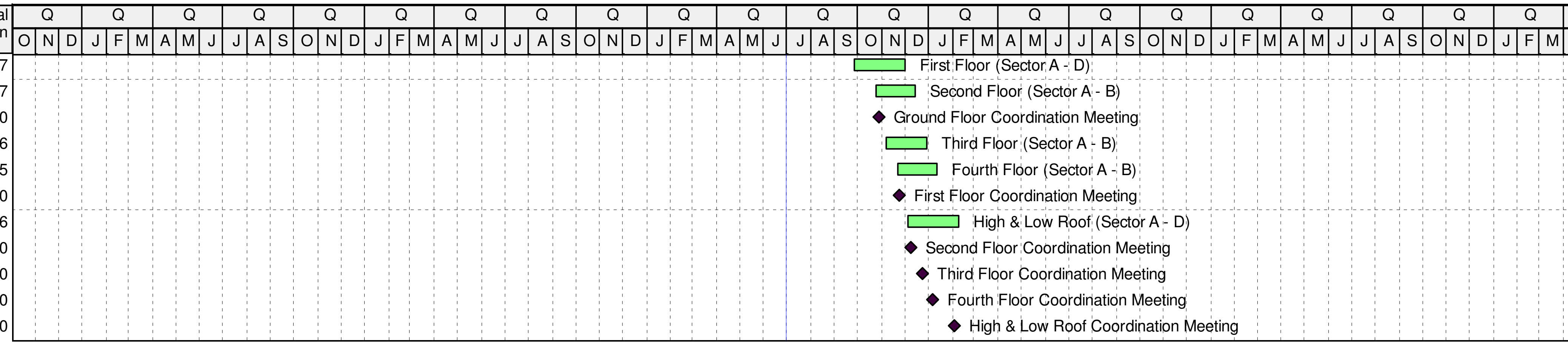


Activity
Summary
Milestone

NEW REGIONAL MEDICAL CENTER

EAST NORRITON, PA

Activity Name	Start	Finish	Original Duration
First Floor (Sector A - D)	27-Sep-1(	01-Dec-10	47
Second Floor (Sector A - B)	25-Oct-10*	15-Dec-10	37
Ground Floor Coordination Meeting		28-Oct-10	0
Third Floor (Sector A - B)	08-Nov-1(	29-Dec-10	36
Fourth Floor (Sector A - B)	22-Nov-1(	12-Jan-11	35
First Floor Coordination Meeting		24-Nov-10	0
High & Low Roof (Sector A - D)	06-Dec-1(	09-Feb-11	46
Second Floor Coordination Meeting		09-Dec-10	0
Third Floor Coordination Meeting		23-Dec-10	0
Fourth Floor Coordination Meeting		06-Jan-11	0
High & Low Roof Coordination Meeting		03-Feb-11	0



Activity Summary
Milestone

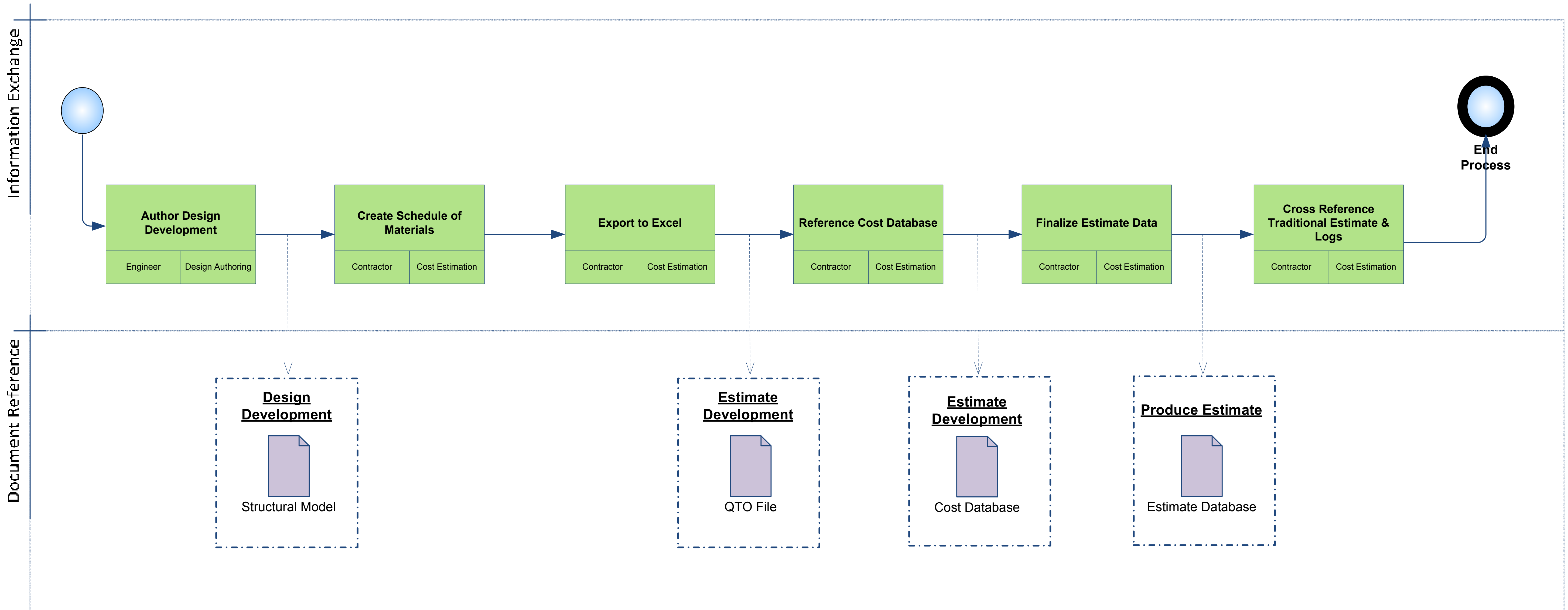
NEW REGIONAL MEDICAL CENTER

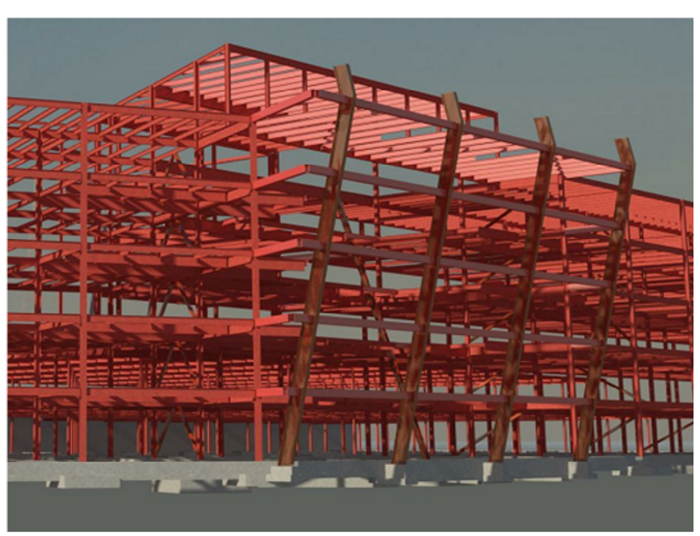
EAST NORRITON, PA

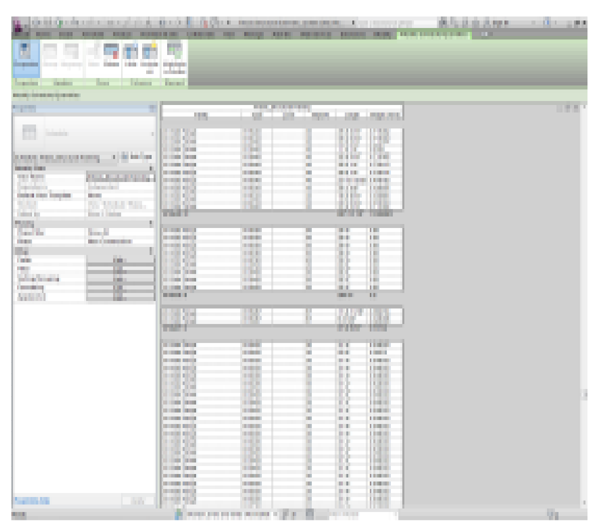
Appendix F | 5D Estimate Process Map

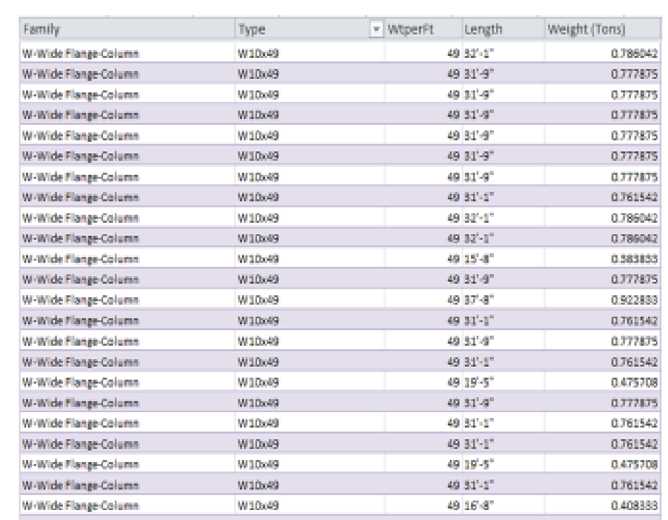
New Regional Medical Center | 5D Estimating Process

East Norriton, PA

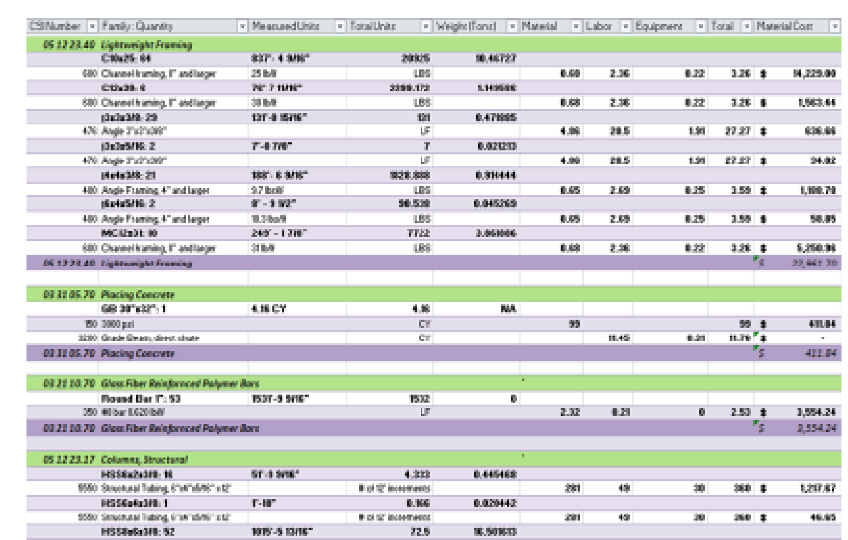








Family	Type	WtperFt	Length	Weight (Tons)
W-Wide Flange-Column	W10x49	49	32'-1"	0.786042
W-Wide Flange-Column	W10x49	49	31'-9"	0.777875
W-Wide Flange-Column	W10x49	49	31'-9"	0.777875
W-Wide Flange-Column	W10x49	49	31'-9"	0.777875
W-Wide Flange-Column	W10x49	49	31'-9"	0.777875
W-Wide Flange-Column	W10x49	49	31'-9"	0.777875
W-Wide Flange-Column	W10x49	49	31'-9"	0.777875
W-Wide Flange-Column	W10x49	49	31'-1"	0.761542
W-Wide Flange-Column	W10x49	49	32'-1"	0.786042
W-Wide Flange-Column	W10x49	49	32'-1"	0.786042
W-Wide Flange-Column	W10x49	49	15'-8"	0.383833
W-Wide Flange-Column	W10x49	49	31'-9"	0.777875
W-Wide Flange-Column	W10x49	49	37'-8"	0.922833
W-Wide Flange-Column	W10x49	49	31'-1"	0.761542
W-Wide Flange-Column	W10x49	49	31'-9"	0.777875
W-Wide Flange-Column	W10x49	49	31'-1"	0.761542
W-Wide Flange-Column	W10x49	49	19'-5"	0.475708
W-Wide Flange-Column	W10x49	49	31'-9"	0.777875
W-Wide Flange-Column	W10x49	49	31'-1"	0.761542
W-Wide Flange-Column	W10x49	49	31'-1"	0.761542
W-Wide Flange-Column	W10x49	49	19'-5"	0.475708
W-Wide Flange-Column	W10x49	49	31'-1"	0.761542
W-Wide Flange-Column	W10x49	49	16'-8"	0.408333
W-Wide Flange-Column	W10x49	49	15'-5"	0.377708



APPENDIX G | 5D ESTIMATE VALUES

Structural Columns

CSI Number	Family	Measured Units	Total Units	Weight (Tons)	Material	Labor	Equipment	Total	Material Cost	Labor Cost	Equipment Cost	Total Cost
05 12 23.40	*Lightweight Framing*											
	ž3x3x3/8: 4	**6'-8 1/8"**	**7**	**NA**								
476	Angle 3"x3"x3/8"		LF		**4.86**	**20.5**	**1.91**	**27.27**	**$ 4.76**	**$ 16.52**	**$ 1.54**	**$ 22.82**
	Screenwall Post 1: 33	**618'-3 3/8"**	**618**	**NA**								
750	Junior Beam, 8"		LF		**12.4**	**22.5**	**2.06**	**36.96**	**$ 7,663.20**	**$ 13,905.00**	**$ 1,273.08**	**$ 22,841.28**
	Screenwall Post 2: 6	**76'-0"**	**76**	**NA**								
750	Junior Beam, 8"		LF		**12.4**	**22.5**	**2.06**	**36.96**	**$ 942.40**	**$ 1,710.00**	**$ 156.56**	**$ 2,808.96**
05 12 23.40	*Lightweight Framing*								*$ 8,610.36*	*$ 15,631.52*	*$ 1,431.18*	***$ 25,673.06***
05 12 23.17	*Columns, Structural*				`							
	HSS4x4x3/8: 10	**117'-2 3/4"**	**9.75**	**0.867496**								
4500	Structural Tubing, 4"x4"x1/4" x 12'		# of 12' increments		**18.6**	**4.55**	**2.8**	**25.95**	**$ 181.35**	**$ 44.36**	**$ 27.30**	**$ 253.01**
	HSS4x4x5/16: 10	**98'-0 3/8"**	**8.16**	**0.725446**								
4500	Structural Tubing, 4"x4"x1/4" x 12'		# of 12' increments		**18.6**	**4.55**	**2.8**	**25.95**	**$ 151.78**	**$ 37.13**	**$ 22.85**	**$ 211.75**
	HSS5x5x3/8: 1	**15'-8"**	**1.33**	**0.174683**								
4550	Structural Tubing, 6"x6"x1/4" x 12'		# of 12' increments		**30.5**	**4.9**	**3**	**38.4**	**$ 40.57**	**$ 6.52**	**$ 3.99**	**$ 51.07**
	HSS6x6x1/4: 3	**37'-4 13/16"**	**3.08**	**0.355291**								
4550	Structural Tubing, 6"x6"x1/4" x 12'		# of 12' increments		**30.5**	**4.9**	**3**	**38.4**	**$ 93.94**	**$ 15.09**	**$ 9.24**	**$ 118.27**
	HSS6x6x3/8: 40	**443'-5 5/16"**	**36.92**	**6.075152**								
4550	Structural Tubing, 6"x6"x1/4" x 12'		# of 12' increments		**30.5**	**4.9**	**3**	**38.4**	**$ 1,126.06**	**$ 180.91**	**$ 110.76**	**$ 1,417.73**
	HSS6x6x5/16: 19	**204'-7 11/16"**	**17.08**	**2.38404**								
4550	Structural Tubing, 6"x6"x1/4" x 12'		# of 12' increments		**30.5**	**4.9**	**3**	**38.4**	**$ 520.94**	**$ 83.69**	**$ 51.24**	**$ 655.87**
	HSS8x8x3/8: 3	**33'-0"**	**2.36**	**0.6204**								
4600	Structural Tubing, 8"x8"x3/8" x 14'		# of 14' increments		**66**	**5.3**	**3.25**	**74.55**	**$ 155.76**	**$ 12.51**	**$ 7.67**	**$ 175.94**
	HSS12x6x3/8: 4	**8'-8"**	**0.5625**	**0.185033**								
5700	Structural Tubing, 12"x8"x1/2" x 16'		# of 16' increments		**12.25**	**5.55**	**3.4**	**21.2**	**$ 6.89**	**$ 3.12**	**$ 1.91**	**$ 11.93**
	HSS12x6x5/16: 2	**32'-7 3/8"**	**2.06**	**0.587039**								
5700	Structural Tubing, 12"x8"x1/2" x 16'		# of 16' increments		**12.25**	**5.55**	**3.4**	**21.2**	**$ 25.24**	**$ 11.43**	**$ 7.00**	**$ 43.67**
05 12 23.17	*Columns, Structural*								*$ 2,302.52*	*$ 394.76*	*$ 241.96*	***$ 2,939.24***
05 12 23.75	*Structural Steel Members*											
	W6x25: 5	**66'-8"**	**67**	**0.833333**								
1502	W12x26		LF		**32**	**3.01**	**1.84**	**36.85**	**$ 1,882.70**	**$ 328.30**	**$ 201.00**	**$ 2,412.00**
	W12x87: 1	**56'-10 9/16"**	**57**	**2.474388**								
5702	W24x84		LF		**104**	**3.55**	**1.6**	**109.15**	**$ 3,762.00**	**$ 302.10**	**$ 185.25**	**$ 4,249.35**
	W14x82: 1	**75'-4"**	**75**	**3.088667**								
5702	W24x84		LF		**104**	**3.55**	**1.6**	**109.15**	**$ 4,950.00**	**$ 397.50**	**$ 243.75**	**$ 5,591.25**
	W24x306: 4	**299'-0"**	**299**	**45.747**								
8102	W36x302		LF		**375**	**3.7**	**1.67**	**380.37**	**$ 19,734.00**	**$ 1,584.70**	**$ 971.75**	**$ 22,290.45**
	W10x49: 1	**53'-4"**	**53**	**NA**								
902	W10x49		LF		**60.5**	**4.82**	**2.95**	**68.27**	**$ 649.25**	**$ 294.15**	**$ 180.20**	**$ 1,123.60**
	W14x90: 2	**119'-6 3/4"**	**120**	**NA**								
2502	W14x120		LF		**149**	**3.68**	**2.25**	**154.93**	**$ 17,880.00**	**$ 441.60**	**$ 270.00**	**$ 18,591.60**
	W8x24: 10	**144'-8 1/2"**	**145**	**1.736509**								
502	W8x31		LF		**38.5**	**4.82**	**2.95**	**46.27**	**$ 1,776.25**	**$ 804.75**	**$ 493.00**	**$ 3,074.00**
	W8x31: 15	**247'-4 7/16"**	**247**	**3.834222**								
502	W8x31		LF		**38.5**	**4.82**	**2.95**	**46.27**	**$ 3,025.75**	**$ 1,370.85**	**$ 839.80**	**$ 5,236.40**
	W8x67: 1	**59'-2 1/4"**	**59**	**1.982781**								
1702	W12x72		LF		**89**	**4.14**	**2.53**	**95.67**	**$ 722.75**	**$ 327.45**	**$ 200.60**	**$ 1,250.80**
	W10x33: 1	**31'-1"**	**31**	**0.512875**								
2302	W14x34		LF		**42**	**3.27**	**2**	**47.27**	**$ 1,302.00**	**$ 101.37**	**$ 62.00**	**$ 1,465.37**
	W10x39: 1	**60'-2 1/4"**	**60**	**1.173656**								
2302	W14x34		LF		**42**	**3.27**	**2**	**47.27**	**$ 2,520.00**	**$ 196.20**	**$ 120.00**	**$ 2,836.20**

Structural Columns

CSI Number	Family	Measured Units	Total Units	Weight (Tons)	Material	Labor	Equipment	Total	Material Cost	Labor Cost	Equipment Cost	Total Cost
	W10x49: 52	**1360'-10 1/2"**	**1361**	**33.341407**								
902	W10x49		LF		**60.5**	**4.82**	**2.95**	**68.27**	**$ 16,672.25**	**$ 7,553.55**	**$ 4,627.40**	**$ 92,915.47**
	W10x60: 14	**447'-10"**	**448**	**13.435**								
1702	W12x72		LF		**89**	**4.14**	**2.53**	**95.67**	**$ 5,488.00**	**$ 2,486.40**	**$ 1,523.20**	**$ 42,860.16**
	W10x68: 1	**32'-9"**	**33**	**1.1135**								
1702	W12x72		LF		**89**	**4.14**	**2.53**	**95.67**	**$ 404.25**	**$ 183.15**	**$ 112.20**	**$ 3,157.11**
	W12x53: 37	**1051'-4 5/16"**	**1051**	**27.861015**								
3902	W18x55		LF		**68**	**4.2**	**1.9**	**74.1**	**$ 71,468.00**	**$ 4,414.20**	**$ 1,996.90**	**$ 77,879.10**
	W12x65: 15	**471'-4"**	**471**	**15.318333**								
1702	W12x72		LF		**89**	**4.14**	**2.53**	**95.67**	**$ 5,769.75**	**$ 2,614.05**	**$ 1,601.40**	**$ 45,060.57**
	W12x72: 18	**388'-4"**	**388**	**13.98**								
1702	W12x72		LF		**89**	**4.14**	**2.53**	**95.67**	**$ 4,753.00**	**$ 2,153.40**	**$ 1,319.20**	**$ 37,119.96**
	W12x79: 29	**907'-7"**	**908**	**35.849542**								
5502	W24x76		LF		**94**	**3.45**	**1.56**	**99.01**	**$ 27,694.00**	**$ 4,449.20**	**$ 2,724.00**	**$ 89,901.08**
	W12x87: 92	**2305'-6 1/4"**	**2306**	**100.290156**								
5702	W24x76		LF		**94**	**3.45**	**1.56**	**99.01**	**$ 28,248.50**	**$ 12,798.30**	**$ 7,840.40**	**$ 228,317.06**
	W12x96: 27	**524'-0"**	**524**	**25.152**								
5902	W27x94		LF		**116**	**3.22**	**1.45**	**120.67**	**$ 60,784.00**	**$ 1,687.28**	**$ 759.80**	**$ 63,231.08**
	W12x106: 4	**117'-4"**	**117**	**6.218667**								
6302	W30x108		LF		**134**	**3.19**	**1.44**	**138.63**	**$ 15,678.00**	**$ 373.23**	**$ 168.48**	**$ 16,219.71**
	W12x120: 17	**473'-11"**	**474**	**28.435**								
2502	W14x120		LF		**149**	**3.68**	**2.25**	**154.93**	**$ 70,626.00**	**$ 1,744.32**	**$ 1,066.50**	**$ 73,436.82**
	W12x136: 2	**31'-4"**	**31**	**2.130667**								
6902	W33x130		LF		**161**	**3.38**	**1.53**	**165.91**	**$ 4,991.00**	**$ 104.78**	**$ 47.43**	**$ 5,143.21**
	W12x152: 1	**29'-4"**	**29**	**2.229333**								
7502	W36x150		LF		**186**	**3.28**	**1.48**	**190.76**	**$ 5,394.00**	**$ 95.12**	**$ 42.92**	**$ 5,532.04**
	W12x170: 15	**324'-5 3/4"**	**324**	**27.580729**								
7702	W36x194		LF		**240**	**3.41**	**1.54**	**244.95**	**$ 77,760.00**	**$ 1,104.84**	**$ 498.96**	**$ 79,363.80**
	W14x90: 2	**119'-10 5/8"**	**120**	**5.394823**								
5902	W27x94		LF		**116**	**3.22**	**1.45**	**120.67**	**$ 13,920.00**	**$ 386.40**	**$ 174.00**	**$ 14,480.40**
	W14x132: 9	**147'-3 9/16"**	**147**	**9.72168**								
6902	W33x130		LF		**161**	**3.38**	**1.53**	**165.91**	**$ 23,667.00**	**$ 496.86**	**$ 224.91**	**$ 24,388.77**
	W14x283: 1	**23'-0"**	**23**	**3.2545**								
8102	W36x302		LF		**375**	**3.7**	**1.67**	**380.37**	**$ 8,625.00**	**$ 85.10**	**$ 38.41**	**$ 8,748.51**
05 12 23.75	***Structural Steel Members***								*$ 500,147.45*	*$ 48,879.15*	*$ 28,533.46*	***$ 975,875.87***

Structural Framing

CSI Number	Family : Quantity	Measured Units	Total Units	Weight (Tons)	Material	Labor	Equipment	Total	Material Cost	Labor Cost	Equipment Cost	Total Cost
05 12 23.40	***Lightweight Framing***											
	C10x25: 64	**837'- 4 9/16"**	**20925**	**10.46727**								
600	Channel framing, 8" and larger	25 lb/lf	LBS		**0.68**	**2.36**	**0.22**	**3.26**	**$ 14,229.00**	**$ 49,383.00**	**$ 4,603.50**	**$ 68,215.50**
	C12x30: 6	**76' 7 11/16"**	**2299.172**	**1.149586**								
600	Channel framing, 8" and larger	30 lb/lf	LBS		**0.68**	**2.36**	**0.22**	**3.26**	**$ 1,563.44**	**$ 5,426.05**	**$ 505.82**	**$ 7,495.30**
	ž3x3x3/8: 29	**131'-0 15/16"**	**131**	**0.471885**								
476	Angle 3"x3"x3/8"		LF		**4.86**	**20.5**	**1.91**	**27.27**	**$ 636.66**	**$ 2,685.50**	**$ 250.21**	**$ 3,572.37**
	ž3x3x5/16: 2	**7'-0 7/8"**	**7**	**0.021213**								
476	Angle 3"x3"x3/8"		LF		**4.86**	**20.5**	**1.91**	**27.27**	**$ 34.02**	**$ 143.50**	**$ 13.37**	**$ 190.89**
	ž4x4x3/8: 21	**188'- 6 9/16"**	**1828.888**	**0.914444**								
400	Angle Framing, 4" and larger	9.7 lbs/lf	LBS		**0.65**	**2.69**	**0.25**	**3.59**	**$ 1,188.78**	**$ 4,919.71**	**$ 457.22**	**$ 6,565.71**
	ž6x4x5/16: 2	**8' - 9 1/2"**	**90.538**	**0.045269**								
400	Angle Framing, 4" and larger	10.3 lbs/lf	LBS		**0.65**	**2.69**	**0.25**	**3.59**	**$ 58.85**	**$ 243.55**	**$ 22.63**	**$ 325.03**
	MC12x31: 10	**249' - 1 7/8"**	**7722**	**3.861886**								
600	Channel framing, 8" and larger	31 lb/lf	LBS		**0.68**	**2.36**	**0.22**	**3.26**	**$ 5,250.96**	**$ 18,223.92**	**$ 1,698.84**	**$ 25,173.72**
05 12 23.40	***Lightweight Framing***								*$ 22,961.70*	*$ 81,025.22*	*$ 7,551.59*	***$ 111,538.52***
03 31 05.70	***Placing Concrete***											
	GB 30"x32": 1	**4.16 CY**	**4.16**	**NA**								
150	3000 psi		CY		**99**			**99**	**$ 411.84**	**$ -**	**$ -**	**$ 411.84**
3200	Grade Beam, direct chute		CY			**11.45**	**0.31**	**11.76**	**$ -**	**$ 47.63**	**$ 1.29**	**$ 48.92**
03 31 05.70	***Placing Concrete***								*$ 411.84*	*$ 47.63*	*$ 1.29*	***$ 460.76***
03 21 10.70	***Glass Fiber Reinfornced Polymer Bars***				`							
	Round Bar 1": 53	**1531'-9 9/16"**	**1532**	**0**								
350	#8 bar 0.620 lb/lf		LF		**2.32**	**0.21**	**0**	**2.53**	**$ 3,554.24**	**$ 321.72**	**$ -**	**$ 3,875.96**
03 21 10.70	***Glass Fiber Reinfornced Polymer Bars***								*$ 3,554.24*	*$ 321.72*	*$ -*	***$ 3,875.96***
05 12 23.17	***Columns, Structural***				`							
	HSS6x2x3/8: 16	**51'-9 9/16"**	**4.333**	**0.445468**								
5550	Structural Tubing, 6"x4"x5/16" x 12'		# of 12' increments		**28.1**	**4.9**	**3**	**36**	**$ 121.77**	**$ 21.23**	**$ 13.00**	**$ 156.00**
	HSS6x4x3/8: 1	**1'-10"**	**0.166**	**0.020442**								
5550	Structural Tubing, 6"x4"x5/16" x 12'		# of 12' increments		**28.1**	**4.9**	**3**	**36**	**$ 4.66**	**$ 0.81**	**$ 0.50**	**$ 5.98**
	HSS8x6x3/8: 52	**1015'-5 13/16"**	**72.5**	**16.501613**								
4600	Structural Tubing, 8"x8"x3/8" x 14'		# of 14' increments		**66**	**5.3**	**3.25**	**74.55**	**$ 4,785.00**	**$ 384.25**	**$ 235.63**	**$ 5,404.88**
	HSS8x6x5/8: 4	**78'-4 3/4"**	**5.57**	**1.983393**								
4600	Structural Tubing, 8"x8"x3/8" x 14'		# of 14' increments		**66**	**5.3**	**3.25**	**74.55**	**$ 367.62**	**$ 29.52**	**$ 18.10**	**$ 415.24**
	HSS10x4x3/8: 24	**288'-2 5/8"**	**20.57**	**4.683552**								
5650	Structural Tubing, 10"x6"x3/8" x 14'		# of 14' increments		**66**	**5.3**	**3.25**	**74.55**	**$ 1,357.62**	**$ 109.02**	**$ 66.85**	**$ 1,533.49**
	HSS10x8x1/2: 29	**812'-7"**	**50.81**	**22.54923**								
4650	Structural Tubing, 10"x10"x1/2" x 16'		# of 16' increments		**12.25**	**5.55**	**3.4**	**21.2**	**$ 622.42**	**$ 282.00**	**$ 172.75**	**$ 1,077.17**
	HSS10x8x5/8: 12	**305'-8 3/8"**	**306**	**10.332524**								
4650	Structural Tubing, 10"x10"x1/2" x 16'		# of 16' increments		**12.25**	**5.55**	**3.4**	**21.2**	**$ 3,748.50**	**$ 1,698.30**	**$ 1,040.40**	**$ 6,487.20**
	HSS12x4x1/4: 13	**68'-7 3/4"**	**4.3125**	**0.885563**								
5700	Structural Tubing, 12"x8"x1/2" x 16'		# of 16' increments		**12.25**	**5.55**	**3.4**	**21.2**	**$ 52.83**	**$ 23.93**	**$ 14.66**	**$ 91.43**
	HSS12x8x5/8: 4	**126'-5 3/16"**	**7.875**	**4.810847**								

Structural Framing

CSI Number	Family : Quantity	Measured Units	Total Units	Weight (Tons)	Material	Labor	Equipment	Total	Material Cost	Labor Cost	Equipment Cost	Total Cost
5700	Structural Tubing, 12"x8"x1/2" x 16'		# of 16' increments		12.25	5.55	3.4	21.2	$ 96.47	$ 43.71	$ 26.78	$ 166.95
	HSS12x8x5/16: 12	**164'-6"**	**10.34**	**10.28**								
5700	Structural Tubing, 12"x8"x1/2" x 16'		# of 16' increments		12.25	5.55	3.4	21.2	$ 126.67	$ 57.39	$ 35.16	$ 219.21
	HSS14x6x5/8: 11	**99'-7 3/8"**	**6.25**	**3.790414**								
5700	Structural Tubing, 12"x8"x1/2" x 16'		# of 16' increments		12.25	5.55	3.4	21.2	$ 76.56	$ 34.69	$ 21.25	$ 132.50
	HSS14x10x1/2: 4	**82'-2 3/4"**	**5.125**	**3.120661**								
5700	Structural Tubing, 12"x8"x1/2" x 16'		# of 16' increments		12.25	5.55	3.4	21.2	$ 62.78	$ 28.44	$ 17.43	$ 108.65
	HSS16x8x1/2: 2	**25'-6"**	**1.59**	**0.967734**								
5700	Structural Tubing, 12"x8"x1/2" x 16'		# of 16' increments		12.25	5.55	3.4	21.2	$ 19.48	$ 8.82	$ 5.41	$ 33.71
	HSS16x8x5/16: 14	**356'-2 3/4"**	**22.25**	**8.691968**								
5700	Structural Tubing, 12"x8"x1/2" x 16'		# of 16' increments		12.25	5.55	3.4	21.2	$ 272.56	$ 123.49	$ 75.65	$ 471.70
	HSS16x12x1/2: 7	**122'-0 13/16"**	**7.626**	**5.468664**								
5700	Structural Tubing, 12"x8"x1/2" x 16'		# of 16' increments		12.25	5.55	3.4	21.2	$ 93.42	$ 42.32	$ 25.93	$ 161.67
	HSS16x12x5/8: 25	**637'-1 9/16"**	**39.8**	**35.04203**								
5700	Structural Tubing, 12"x8"x1/2" x 16'		# of 16' increments		12.25	5.55	3.4	21.2	$ 487.55	$ 220.89	$ 135.32	$ 843.76
	HSS20x8x5/16: 6	**148'-2 7/8"**	**9.25**	**4.24701**								
5700	Structural Tubing, 12"x8"x1/2" x 16'		# of 16' increments		12.25	5.55	3.4	21.2	$ 113.31	$ 51.34	$ 31.45	$ 196.10
	HSS20x12x1/2: 29	**721'-2 3/16"**	**45.06**	**37.140774**								
5700	Structural Tubing, 12"x8"x1/2" x 16'		# of 16' increments		12.25	5.55	3.4	21.2	$ 551.99	$ 250.08	$ 153.20	$ 955.27
	HSS6x6x5/16: 16	**131'-0 7/16"**	**10.92**	**1.526547**								
4550	Structural Tubing, 6"x6"x1/4" x 12'		# of 12' increments		30.5	4.9	3	38.4	$ 333.06	$ 53.51	$ 32.76	$ 419.33
	HSS20x12x1/2 2: 16	**818'-3 13/16"**	**51.125**	**42.143398**								
5700	Structural Tubing, 12"x8"x1/2" x 16'		# of 16' increments		12.25	5.55	3.4	21.2	$ 626.28	$ 283.74	$ 173.83	$ 1,083.85
05 12 23.17	***Columns, Structural***								*$ 13,920.55*	*$ 3,747.49*	*$ 2,296.04*	***$ 19,964.08***
05 12 23.75	***Structural Steel Members***											
	W6x9: 1	**1'-0"**	**1**	**0.0045**								
102	W6x9		LF		11.15	4.42	2.7	18.27	$ 11.15	$ 4.42	$ 2.70	$ 18.27
	W8x15: 24	**137'-4 1/16"**	**137**	**1.030046**								
502	W8x31		LF		38.5	4.82	2.95	46.27	$ 5,274.50	$ 660.34	$ 404.15	$ 6,338.99
	W8x18: 188	**1085'-8 5/8"**	**1086**	**9.771458**								
502	W8x31		LF		38.5	4.82	2.95	46.27	$ 41,811.00	$ 5,234.52	$ 3,203.70	$ 50,249.22
	W8x24: 37	**378'-3 3/8"**	**378**	**4.539396**								
502	W8x31		LF		38.5	4.82	2.95	46.27	$ 14,553.00	$ 1,821.96	$ 1,115.10	$ 17,490.06
	W8x31: 49	**339'-2 9/16"**	**339**	**5.25781**								
502	W8x31		LF		38.5	4.82	2.95	46.27	$ 13,051.50	$ 1,633.98	$ 1,000.05	$ 15,685.53
	W8x40: 30	**265'-1"**	**265**	**5.301632**								
902	W10x49		LF		60.5	4.82	2.95	68.27	$ 16,032.50	$ 1,277.30	$ 781.75	$ 18,091.55
	W8x58: 17	**396'-6"**	**396.5**	**11.498529**								
902	W10x49		LF		60.5	4.82	2.95	68.27	$ 23,988.25	$ 1,911.13	$ 1,169.68	$ 27,069.06
	W10x68: 2	**62'-8"**	**63**	**2.130667**								
1702	W12x72		LF		89	4.14	2.53	95.67	$ 5,607.00	$ 260.82	$ 159.39	$ 6,027.21
	W12x16: 1	**21'-11 15/16"**	**22**	**0.17596**								
1102	W12x16		LF		19.8	3.01	1.84	24.65	$ 435.60	$ 66.22	$ 40.48	$ 542.30
	W12x19: 408	**4843'-1 1/2"**	**4843**	**46.009701**								
1302	W12x22		LF		27	3.01	1.84	31.85	$ 130,761.00	$ 14,577.43	$ 8,911.12	$ 154,249.55
	W12x26: 132	**1369'-2 15/16"**	**4369**	**17.800207**								
1502	W12x26		LF		32	3.01	1.84	36.85	$ 139,808.00	$ 13,150.69	$ 8,038.96	$ 160,997.65

Structural Framing

CSI Number	Family : Quantity	Measured Units	Total Units	Weight (Tons)	Material	Labor	Equipment	Total	Material Cost	Labor Cost	Equipment Cost	Total Cost
	W12x35: 1	**8'-8"**	**9**	**0.151637**								
2203	W14x34		LF		42	3.27	2	47.27	$ 378.00	$ 29.43	$ 18.00	$ 425.43
	W12x40: 135	**1122'-6 11/16"**	**1122.5**	**22.451128**								
3102	W16x40		LF		49.5	3.32	2.03	54.85	$ 55,563.75	$ 3,726.70	$ 2,278.68	$ 61,569.13
	W14x22: 524	**13187'-3 9/16"**	**13187**	**145.06028**								
1902	W14x26		LF		32	2.65	1.62	36.27	$ 421,984.00	$ 34,945.55	$ 21,362.94	$ 478,292.49
	W14x26: 18	**504'-0"**	**504**	**6.552**								
1902	W14x26		LF		32	2.65	1.62	36.27	$ 16,128.00	$ 1,335.60	$ 816.48	$ 18,280.08
	W14x30: 15	**411'-9 1/4"**	**412**	**6.176563**								
2102	W14x30		LF		37	2.95	1.8	41.75	$ 15,244.00	$ 1,215.40	$ 741.60	$ 17,201.00
	W14x34: 46	**715'-5 11/16"**	**715.5**	**12.163026**								
2302	W14x34		LF		42	3.27	2	47.27	$ 30,051.00	$ 2,339.69	$ 1,431.00	$ 33,821.69
	W14x38: 27	**755'-9 3/4"**	**756**	**14.360437**								
3102	W16x40		LF		49.5	3.32	2.03	54.85	$ 37,422.00	$ 2,509.92	$ 1,534.68	$ 41,466.60
	W14x43: 99	**1158'-4 7/8"**	**1158**	**24.905694**								
3102	W16x40		LF		49.5	3.32	2.03	54.85	$ 57,321.00	$ 3,844.56	$ 2,350.74	$ 63,516.30
	W14x48: 33	**902'-0 15/16"**	**902**	**21.649861**								
3702	W18x50		LF		62	4.2	1.9	68.1	$ 55,924.00	$ 3,788.40	$ 1,713.80	$ 61,426.20
	W14x53: 22	**501'-9 1/2"**	**502**	**13.297493**								
3902	W18x55		LF		68	4.2	1.9	74.1	$ 34,136.00	$ 2,108.40	$ 953.80	$ 37,198.20
	W14x109: 6	**78'-1 13/16"**	**78**	**4.259258**								
2502	W14x120		LF		149	3.68	2.25	154.93	$ 11,622.00	$ 287.04	$ 175.50	$ 12,084.54
	W16x31: 135	**3972'-9 1/2"**	**3973**	**61.578257**								
2902	W16x31		LF		38.5	2.95	1.8	43.25	$ 152,960.50	$ 11,720.35	$ 7,151.40	$ 171,832.25
	W16x36: 41	**1037'-4 1/2"**	**1037**	**18.672775**								
3102	W16x40		LF		49.5	3.32	2.03	54.85	$ 51,331.50	$ 3,442.84	$ 2,105.11	$ 56,879.45
	W16x40: 21	**697'-10 1/8"**	**698**	**13.956863**								
3102	W16x40		LF		49.5	3.32	2.03	54.85	$ 34,551.00	$ 2,317.36	$ 1,416.94	$ 38,285.30
	W16x50: 8	**208'-0"**	**208**	**5.2**								
3702	W18x50		LF		62	4.2	1.9	68.1	$ 12,896.00	$ 873.60	$ 395.20	$ 14,164.80
	W16x67: 2	**21'-6 5/16"**	**21.5**	**0.72104**								
4702	W21x68		LF		84	3.7	1.67	89.37	$ 1,806.00	$ 79.55	$ 35.91	$ 1,921.46
	W18x35: 217	**5840'-11 1/8"**	**5841**	**102.216269**								
3302	W18x35		LF		43.5	3.99	1.8	49.29	$ 254,083.50	$ 23,305.59	$ 10,513.80	$ 287,902.89
	W18x40: 36	**1078'-0 3/8"**	**1078**	**21.560655**								
3502	W18x40		LF		49.6	3.99	1.8	55.39	$ 53,468.80	$ 4,301.22	$ 1,940.40	$ 59,710.42
	W18x46: 8	**212'-7 1/4"**	**213**	**4.889896**								
3702	W18x50		LF		62	4.2	1.9	68.1	$ 13,206.00	$ 894.60	$ 404.70	$ 14,505.30
	W18x50: 9	**267'-8 5/8"**	**268**	**6.693003**								
3702	W18x50		LF		62	4.2	1.9	68.1	$ 16,616.00	$ 1,125.60	$ 509.20	$ 18,250.80
	W18x60: 2	**54'-0"**	**54**	**1.62**								
4502	W21x62		LF		76.5	3.7	1.67	81.87	$ 4,131.00	$ 199.80	$ 90.18	$ 4,420.98
	W18x65: 1	**32'-5 7/8"**	**32.5**	**1.05598**								
4702	W21x68		LF		84	3.7	1.67	89.37	$ 2,730.00	$ 120.25	$ 54.28	$ 2,904.53
	W18x76: 4	**77'-7 7/8"**	**78**	**2.951026**								
5502	W24x76		LF		94	3.45	1.56	99.01	$ 7,332.00	$ 269.10	$ 121.68	$ 7,722.78
	W18x86: 2	**66'-6 3/16"**	**66.5**	**2.860098**								
5702	W24x84		LF		104	3.55	1.6	109.15	$ 6,916.00	$ 236.08	$ 106.40	$ 7,258.48

Structural Framing

CSI Number	Family : Quantity	Measured Units	Total Units	Weight (Tons)	Material	Labor	Equipment	Total	Material Cost	Labor Cost	Equipment Cost	Total Cost
	W18x106: 22	**664'-2 1/2"**	**664**	**35.203054**								
6302	W30x108		LF		134	3.19	1.44	138.63	$ 88,976.00	$ 2,118.16	$ 956.16	$ 92,050.32
	W18x130: 1	**9'-2 1/2"**	**9**	**0.598453**								
6902	W33x130		LF		161	3.38	1.53	165.91	$ 1,449.00	$ 30.42	$ 13.77	$ 1,493.19
	W18x143: 7	**209'-7"**	**210**	**14.985371**								
7102	W33x141		LF		174	3.38	1.53	178.91	$ 36,540.00	$ 709.80	$ 321.30	$ 37,571.10
	W18x234: 5	**114'-8 3/8"**	**115**	**13.419696**								
7902	W36x231		LF		286	3.41	1.54	290.95	$ 32,890.00	$ 392.15	$ 177.10	$ 33,459.25
	W18x258: 3	**156'-7 3/16"**	**157**	**20.201026**								
7902	W36x231		LF		286	3.41	1.54	290.95	$ 44,902.00	$ 535.37	$ 241.78	$ 45,679.15
	W21x44: 243	**7114'-9"**	**7115**	**156.524463**								
4102	W21x44		LF		54.5	3.6	1.63	59.73	$ 387,767.50	$ 25,614.00	$ 11,597.45	$ 424,978.95
	W21x50: 44	**1281'-2 3/16"**	**1281**	**32.029572**								
4302	W21x50		LF		62	3.6	1.63	67.23	$ 79,422.00	$ 4,611.60	$ 2,088.03	$ 86,121.63
	W21x55: 17	**529'-4 1/16"**	**524**	**14.556862**								
4502	W21x62		LF		76.5	3.7	1.67	81.87	$ 40,086.00	$ 1,938.80	$ 875.08	$ 42,899.88
	W21x62: 15	**368'-11 7/16"**	**369**	**11.437557**								
4502	W21x62		LF		76.5	3.7	1.67	81.87	$ 28,228.50	$ 1,365.30	$ 616.23	$ 30,210.03
	W21x68: 3	**89'-4 1/4"**	**89**	**3.037974**								
4702	W21x68		LF		84	3.7	1.67	89.37	$ 7,476.00	$ 329.30	$ 148.63	$ 7,953.93
	W21x83: 2	**62'-8"**	**63**	**2.600667**								
5702	W24x84		LF		104	3.55	1.6	109.15	$ 6,552.00	$ 223.65	$ 100.80	$ 6,876.45
	W21x101: 10	**199'-11 15/16"**	**200**	**10.099633**								
6102	W30x99		LF		123	3.19	1.44	127.63	$ 24,600.00	$ 638.00	$ 288.00	$ 25,526.00
	W21x111: 3	**94'-0 5/16"**	**94**	**5.218304**								
6302	W30x108: 49		LF		134	3.19	1.44	138.63	$ 12,596.00	$ 299.86	$ 135.36	$ 13,031.22
	W21x122: 1	**31'-4"**	**31**	**1.911333**								
6902	W33x130		LF		161	3.38	1.53	165.91	$ 4,991.00	$ 104.78	$ 47.43	$ 5,143.21
	W21x132: 4	**125'-4"**	**125**	**8.272**								
6902	W33x130		LF		161	3.38	1.53	165.91	$ 20,125.00	$ 422.50	$ 191.25	$ 20,738.75
	W21x147: 2	**62'-8"**	**63**	**4.606**								
7502	W26x150		LF		186	3.28	1.48	190.76	$ 11,718.00	$ 206.64	$ 93.24	$ 12,017.88
	W24x55: 138	**4196'-5 1/4"**	**4196.5**	**115.402068**								
4902	W24x55		LF		68	3.45	1.56	73.01	$ 285,362.00	$ 14,477.93	$ 6,546.54	$ 306,386.47
	W24x62: 40	**1062'-0 7/16"**	**1062**	**32.923157**								
5102	W24x62		LF		76.5	3.7	1.67	81.87	$ 81,243.00	$ 3,929.40	$ 1,773.54	$ 86,945.94
	W24x68: 17	**523'-0 15/16"**	**523**	**17.784575**								
5302	W24x68		LF		84	3.45	1.56	89.01	$ 43,932.00	$ 1,804.35	$ 815.88	$ 46,552.23
	W24x76: 21	**671'-1 13/16"**	**671**	**25.503735**								
5502	W24x76		LF		94	3.45	1.56	99.01	$ 63,074.00	$ 2,314.95	$ 1,046.76	$ 66,435.71
	W24x84: 3	**84'-5 3/8"**	**84.5**	**3.546886**								
5702	W24x84		LF		104	3.55	1.6	109.15	$ 8,788.00	$ 299.98	$ 135.20	$ 9,223.18
	W24x117: 2	**62'-8 3/16"**	**63**	**3.66683**								
6502	W30x116		LF		144	3.31	1.49	148.8	$ 9,072.00	$ 208.53	$ 93.87	$ 9,374.40
	W24x131: 3	**73'-3 3/4"**	**73**	**4.801811**								
6902	W33x130		LF		161	3.38	1.53	165.91	$ 11,753.00	$ 246.74	$ 111.69	$ 12,111.43
	W24x176: 2	**39'-9 3/8"**	**40**	**3.500602**								
7502	W26x150		LF		186	3.28	1.48	190.76	$ 7,440.00	$ 131.20	$ 59.20	$ 7,630.40

Structural Framing

CSI Number	Family : Quantity	Measured Units	Total Units	Weight (Tons)	Material	Labor	Equipment	Total	Material Cost	Labor Cost	Equipment Cost	Total Cost
	W27x84: 22	**706'-0 5/8"**	**706**	**29.654106**								
5902	W27x94		LF		**116**	**3.22**	**1.45**	**120.67**	**$ 81,896.00**	**$ 2,273.32**	**$ 1,023.70**	**$ 85,193.02**
	W30x90: 14	**372'-6 7/16"**	**372.5**	**16.764225**								
6102	W30x99		LF		**123**	**3.19**	**1.44**	**127.63**	**$ 45,817.50**	**$ 1,188.28**	**$ 536.40**	**$ 47,542.18**
	W30x99: 7	**124'-10 5/8"**	**125**	**6.181903**								
6102	W30x99		LF		**123**	**3.19**	**1.44**	**127.63**	**$ 15,375.00**	**$ 398.75**	**$ 180.00**	**$ 15,953.75**
	W30x108: 49	**1527'-10 5/8"**	**1528**	**82.505812**								
6302	W30x108		LF		**134**	**3.19**	**1.44**	**138.63**	**$ 204,752.00**	**$ 4,874.32**	**$ 2,200.32**	**$ 211,826.64**
	W30x124: 2	**34'-1 3/4"**	**34**	**2.117174**								
6902	W33x130		LF		**161**	**3.38**	**1.53**	**165.91**	**$ 5,474.00**	**$ 114.92**	**$ 52.02**	**$ 5,640.94**
	W33x118: 28	**745'-8 15/16"**	**746**	**43.999046**								
6702	W33x118		LF		**146**	**3.26**	**1.47**	**150.73**	**$ 108,916.00**	**$ 2,431.96**	**$ 1,096.62**	**$ 112,444.58**
	W33x130: 2	**66'-9 3/8"**	**67**	**4.340781**								
6902	W33x130		LF		**161**	**3.38**	**1.53**	**165.91**	**$ 10,787.00**	**$ 226.46**	**$ 102.51**	**$ 11,115.97**
	W33x141: 1	**42'-4"**	**42**	**2.9845**								
7102	W33x141		LF		**174**	**3.38**	**1.53**	**178.91**	**$ 7,308.00**	**$ 141.96**	**$ 64.26**	**$ 7,514.22**
	W33x152: 1	**56'-9 9/16"**	**57**	**4.316442**								
7502	W36x150		LF		**186**	**3.28**	**1.48**	**190.76**	**$ 10,602.00**	**$ 186.96**	**$ 84.36**	**$ 10,873.32**
	W36x135: 5	**170'-8 1/2"**	**171**	**11.522836**								
7302	W36x135		LF		**167**	**3.28**	**1.48**	**171.76**	**$ 28,557.00**	**$ 560.88**	**$ 253.08**	**$ 29,370.96**
	W36x150: 1	**32'-6 3/4"**	**32.5**	**2.442318**								
7502	W36x150		LF		**186**	**3.28**	**1.48**	**190.76**	**$ 6,045.00**	**$ 106.60**	**$ 48.10**	**$ 6,199.70**
	W36x182: 1	**28'-0"**	**28**	**2.548**								
7702	W36x194		LF		**240**	**3.41**	**1.54**	**244.95**	**$ 6,720.00**	**$ 95.48**	**$ 43.12**	**$ 6,858.60**
	W36x231: 1	**72'-0"**	**72**	**8.316**								
7902	W36x231		LF		**286**	**3.41**	**1.54**	**290.95**	**$ 20,592.00**	**$ 245.52**	**$ 110.88**	**$ 20,948.40**
	W36x302: 3	**151'-4"**	**151**	**22.851333**								
8102	W36x302		LF		**375**	**3.7**	**1.67**	**380.37**	**$ 56,625.00**	**$ 558.70**	**$ 252.17**	**$ 57,435.87**
	W36x487: 2	**144'-0"**	**144**	**35.064**								
8102	W36x302		LF		**375**	**3.7**	**1.67**	**380.37**	**$ 54,000.00**	**$ 532.80**	**$ 240.48**	**$ 54,773.28**
	Unistrut P1001: 15	**157'-9 11/16"**	**158**	**0**								
102	W6x9		LF		**11.15**	**4.42**	**2.7**	**18.27**	**$ 1,761.70**	**$ 698.36**	**$ 426.60**	**$ 2,886.66**
05 12 23.75	***Structural Steel Members***								*$ 3,743,346.75*	*$ 223,204.10*	*$ 118,238.39*	***$ 4,084,789.24***

Structural Slab & Decking

CSI Number	Category	Material: Volume	Material: Area	Total Units	Material	Labor	Equipment	Total	Material Cost	Labor Cost	Equipment Cost	Total Cost
05 31 13.50	*Floor Decking*											
	Floor: 1 1/2" Composite Metal Deck: 4		**605 SF**	**605**								
5120	Non-cellular composite decking, galvanized, 1-1/2" deep, 18 gauge			SF	**1.92**	**0.43**	**0.03**	**2.38**	**$ 1,161.60**	**$ 260.15**	**$ 18.15**	**$ 1,439.90**
	Floor: 3" Composite Metal Deck: 26		**113672 SF**	**113672**								
5900	Non-cellular composite decking, galvanized, 3" deep, 18 gauge			SF	**2**	**0.55**	**0.04**	**2.59**	**$ 227,344.00**	**$ 62,519.60**	**$ 4,546.88**	**$ 294,410.48**
	Floor: 3" Composite Metal Deck: 26		**209745 SF**	**209745**								
5900	Non-cellular composite decking, galvanized, 3" deep, 18 gauge			SF	**2**	**0.55**	**0.04**	**2.59**	**$ 419,490.00**	**$ 115,359.75**	**$ 8,389.80**	**$ 543,239.55**
	Floor: 3" Composite Metal Deck: 6		**8361 SF**	**8361**								
5900	Non-cellular composite decking, galvanized, 3" deep, 18 gauge			SF	**2**	**0.55**	**0.04**	**2.59**	**$ 16,722.00**	**$ 4,598.55**	**$ 334.44**	**$ 21,654.99**
	Floor: 3" Composite Metal Deck: 4		**253 SF**	**253**								
5900	Non-cellular composite decking, galvanized, 3" deep, 18 gauge			SF	**2**	**0.55**	**0.04**	**2.59**	**$ 506.00**	**$ 139.15**	**$ 139.15**	**$ 655.27**
05 31 13.50	*Floor Decking*								*$ 665,223.60*	*$ 182,877.20*	*$ 13,428.42*	***$ 861,400.19***
05 31 23.50	*Roof Decking*											
	Floor: 1 1/2" 22 Ga. Metal Roof Deck: 32		**59896 SF**	**59896**								
2400	Open Type, 1-1/2" deep, Type B, 22 Ga.			SF	**1.02**	**0.31**	**0.02**	**1.35**	**$ 61,093.92**	**$ 18,567.76**	**$ 1,197.92**	**$ 80,859.60**
	Floor: 1 1/2" 22 Ga. Metal Roof Deck: 6		**1365 SF**	**1365**								
2400	Open Type, 1-1/2" deep, Type B, 22 Ga.			SF	**1.02**	**0.31**	**0.02**	**1.35**	**$ 1,392.30**	**$ 423.15**	**$ 27.30**	**$ 1,842.75**
05 31 23.50	*Roof Decking*								*$ 62,486.22*	*$ 18,990.91*	*$ 1,225.22*	***$ 82,702.35***
03 31	*Structural Concrete*											
	Foundation Slab: 8" Foundation Slab	**155.41 CF**	**233 SF**	**5.76**								
1500	6" to 10" Thick, Pumped			CY	**0**	**14.7**	**4.92**	**19.62**	**$ -**	**$ 84.67**	**$ 28.34**	**$ 113.01**
200	3500 psi			CY	**99.5**	**0**	**0**	**99.5**	**$ 573.12**	**$ -**	**$ -**	**$ 573.12**
	Foundation Slab: 12" Foundation Slab	**1039.78 CF**	**1040 SF**	**38.51**								
400	12" Thick, Pumped			CY	**0**	**39**	**13.1**	**52.1**	**$ -**	**$ 1,501.89**	**$ 504.48**	**$ 2,006.37**
200	3500 psi			CY	**99.5**	**0**	**0**	**99.5**	**$ 3,831.75**	**$ -**	**$ -**	**$ 3,831.75**
	Foundation Slab: 18" Foundation Slab	**25.89 CF**	**17 SF**	**25.89**								
600	18" Thick, Pumped			CY	**0**	**26**	**18.75**	**44.75**	**$ -**	**$ 673.14**	**$ 485.44**	**$ 1,158.58**
200	3500 psi			CY	**99.5**	**0**	**0**	**99.5**	**$ 2,576.06**	**$ -**	**$ -**	**$ 2,576.06**
	Foundation Slab: 24" Foundation Slab	**501.42 CF**	**251 SF**	**18.57**								
800	24" Thick, Pumped			CY	**0**	**25.5**	**8.55**	**34.05**	**$ -**	**$ 473.54**	**$ 158.77**	**$ 632.31**
200	3500 psi			CY	**99.5**	**0**	**0**	**99.5**	**$ 1,847.72**	**$ -**	**$ -**	**$ 1,847.72**
	Floor: 2 1/2" NW Concrete	**167.96 CF**	**1008 SF**	**6.22**								
1400	Elevated Slabs, less than 6" thick, pumped			CY	**0**	**16.8**	**5.6**	**22.4**	**$ -**	**$ 104.50**	**$ 34.83**	**$ 139.33**
200	3500 psi			CY	**99.5**	**0**	**0**	**99.5**	**$ 618.89**	**$ -**	**$ -**	**$ 618.89**
	Floor: 3 1/4" LW Concrete	**91035.16 CF**	**349575 SF**	**3371.67**								
1400	Elevated Slabs, less than 6" thick, pumped			CY	**0**	**16.8**	**5.6**	**22.4**	**$ -**	**$ 56,644.06**	**$ 18,881.35**	**$ 75,525.41**
200	3500 psi			CY	**99.5**	**0**	**0**	**99.5**	**$ 335,481.17**	**$ -**	**$ -**	**$ 335,481.17**
	Floor: 3 1/4" NW Concrete	**3628.89 CF**	**13935 SF**	**134.4**								
1400	Elevated Slabs, less than 6" thick, pumped			CY	**0**	**16.8**	**5.6**	**22.4**	**$ -**	**$ 2,257.92**	**$ 752.64**	**$ 3,010.56**
200	3500 psi			CY	**99.5**	**0**	**0**	**99.5**	**$ 13,372.80**	**$ -**	**$ -**	**$ 13,372.80**
	Floor: 4" Concrete	**21173.80 CF**	**63521 SF**	**784.21**								
1400	Elevated Slabs, less than 6" thick, pumped			CY	**0**	**16.8**	**5.6**	**22.4**	**$ -**	**$ 13,174.73**	**$ 4,391.58**	**$ 17,566.30**
200	3500 psi			CY	**99.5**	**0**	**0**	**99.5**	**$ 78,028.90**	**$ -**	**$ -**	**$ 78,028.90**
	Floor: 4" NW Concrete	**123.11 CF**	**422 SF**	**4.55**								
1400	Elevated Slabs, less than 6" thick, pumped			CY	**0**	**16.8**	**5.6**	**22.4**	**$ -**	**$ 76.44**	**$ 25.48**	**$ 101.92**
200	3500 psi			CY	**99.5**	**0**	**0**	**99.5**	**$ 452.73**	**$ -**	**$ -**	**$ 452.73**
	Floor: 5" NW Concrete	**63151.17 CF**	**189453 SF**	**2338.93**								
1400	Elevated Slabs, less than 6" thick, pumped			CY	**0**	**16.8**	**5.6**	**22.4**	**$ -**	**$ 39,294.02**	**$ 13,098.01**	**$ 52,392.03**
200	3500 psi			CY	**99.5**	**0**	**0**	**99.5**	**$ 232,723.54**	**$ -**	**$ -**	**$ 232,723.54**
	Floor: 6" Concrete	**17002.65 CF**	**34027 SF**	**629.73**								
1500	Elevated Slabs, 6" to 8" Pumped			CY	**0**	**14.7**	**4.92**	**19.62**	**$ -**	**$ 9,257.03**	**$ 3,098.27**	**$ 12,355.30**
200	3500 psi			CY	**99.5**	**0**	**0**	**99.5**	**$ 62,658.14**	**$ -**	**$ -**	**$ 62,658.14**
	Floor: 6" Concrete (loading dock)	**25.68 CF**	**51 SF**	**0.95**								
1500	Elevated Slabs, 6" to 8" Pumped			CY	**0**	**14.7**	**4.92**	**19.62**	**$ -**	**$ 13.97**	**$ 4.67**	**$ 18.64**
200	3500 psi			CY	**99.5**	**0**	**0**	**99.5**	**$ 94.53**	**$ -**	**$ -**	**$ 94.53**
	Floor: 8" Concrete	**18143.23 CF**	**27215 SF**	**671.97**								

Structural Slab & Decking

CSI Number	Category	Material: Volume	Material: Area	Total Units	Material	Labor	Equipment	Total	Material Cost	Labor Cost	Equipment Cost	Total Cost
1500	Elevated Slabs, 6" to 8" Pumped			CY	0	14.7	4.92	19.62	$ -	$ 9,877.96	$ 3,306.09	$ 13,184.05
200	3500 psi			CY	99.5	0	0	99.5	$ 66,861.02	$ -	$ -	$ 66,861.02
	Floor: 8" Concrete S.O.G.	**810.67 CF**	**1216 SF**	**1216**								
1500	Elevated Slabs, 6" to 8" Pumped			CY	0	14.7	4.92	19.62	$ -	$ 17,875.20	$ 5,982.72	$ 23,857.92
4840	SOG (3500psi), no reinforcing			CY	2.59	0.88	0.01	3.48	$ 3,149.44	$ -	$ -	$ 3,149.44
	Floor: 8" NW Concrete	**900.22 CF**	**2274 SF**	**33.34**								
1500	Elevated Slabs, 6" to 8" Pumped			CY	0	14.7	4.92	19.62	$ -	$ 490.10	$ 164.03	$ 654.13
200	3500 psi			CY	99.5	0	0	99.5	$ 3,317.33	$ -	$ -	$ 3,317.33
03 31	***Structural Concrete***								*$ 805,587.09*	*$ 151,799.15*	*$ 50,916.71*	***$ 1,008,302.95***
03 22 05.50	***Welded Wire Fabric- ASTM A185***											
	Floor: 2 1/2" NW Concrete	**167.96 CF**	**1008 SF**	**10.08**								
200	W6x6-W2.1xW2.1 WWF			C-SF	18.9	25	0	43.9	$ 190.51	$ 252.00	$ -	$ 442.51
	Floor: 3 1/4" LW Concrete	**91035.16 CF**	**349575 SF**	**3495.75**								
200	W6x6-W2.1xW2.1 WWF			C-SF	18.9	25	0	43.9	$ 66,069.68	$ 87,393.75	$ -	$ 153,463.43
	Floor: 3 1/4" NW Concrete	**3628.89 CF**	**13935 SF**	**139.35**								
200	W6x6-W2.1xW2.1 WWF			C-SF	18.9	25	0	43.9	$ 2,633.72	$ 3,483.75	$ -	$ 6,117.47
	Floor: 4" Concrete	**21173.80 CF**	**63521 SF**	**635.21**								
300	W6x6-W2.9xW2.9 WWF			C-SF	21.5	26.5	0	48	$ 13,657.02	$ 16,833.07	$ -	$ 30,490.08
	Floor: 4" NW Concrete	**123.11 CF**	**422 SF**	**4.22**								
300	W6x6-W2.9xW2.9 WWF			C-SF	21.5	26.5	0	48	$ 90.73	$ 111.83	$ -	$ 202.56
	Floor: 5" NW Concrete	**63151.17 CF**	**189453 SF**	**1894.53**								
300	W6x6-W2.9xW2.9 WWF			C-SF	21.5	26.5	0	48	$ 40,732.40	$ 50,205.05	$ -	$ 90,937.44
	Floor: 6" Concrete	**17002.65 CF**	**34027 SF**	**340.27**								
200	W6x6-W2.1xW2.1 WWF			C-SF	18.9	25	0	43.9	$ 6,431.10	$ 8,506.75	$ -	$ 14,937.85
	Floor: 6" Concrete (loading dock)	**25.68 CF**	**51 SF**	**0.51**								
200	W6x6-W2.1xW2.1 WWF			C-SF	18.9	25	0	43.9	$ 9.64	$ 12.75	$ -	$ 22.39
	Floor: 8" Concrete	**18143.23 CF**	**27215 SF**	**272.15**								
200	W6x6-W2.1xW2.1 WWF			C-SF	18.9	25	0	43.9	$ 5,143.64	$ 6,803.75	$ -	$ 11,947.39
	Floor: 8" Concrete S.O.G.	**810.67 CF**	**1216 SF**	**12.16**								
300	W6x6-W2.9xW2.9 WWF			C-SF	21.5	26.5	0	48	$ 261.44	$ 322.24	$ -	$ 583.68
	Floor: 8" NW Concrete	**900.22 CF**	**2274 SF**	**22.74**								
300	W6x6-W2.9xW2.9 WWF			C-SF	21.5	26.5	0	48	$ 488.91	$ 602.61	$ -	$ 1,091.52
03 22 05.50	***Welded Wire Fabric- ASTM A185***								*$ 135,708.77*	*$ 174,527.54*	*$ -*	***$ 310,236.31***

Structural Foundations

CSI Number	Family and Type	Count	Material: Volume	Reinforcing	Total Units	Material	Labor	Equipmen	Total	Material Cost	Labor Cost	Equipment Cost	Total Cost
03 03 53.40	***Concrete In Place***												
	ON-Spread Footing - 4ksf	**204**	**74175.28**		**2747.23**								
3848	Spread Footings (4000psi) over 5 CY				CY	**190**	**61.5**	**0.31**	251.81	**$ 521,973.70**	**$ 168,954.65**	**$ 851.64**	**$ 691,779.99**
03 03 53.40	***Concrete In Place***									*$ 521,973.70*	*$ 168,954.65*	*$ 851.64*	***$ 691,779.99***
03 21 05	***Reinforcing Steel***												
	Reinforcing Bars	**16**		**#4 EWB**	**16**								
100	#4 Bars				Bars	**4.55**	**6.35**	**0**	**10.9**	**$ 72.80**	**$ 101.60**	**$ -**	**$ 174.40**
	Reinforcing Bars	**13**		**#5 EWB**	**13**								
105	#5 Bars				Bars	**5.55**	**6.35**	**0**	**11.9**	**$ 72.15**	**$ 82.55**	**$ -**	**$ 154.70**
	Reinforcing Bars	**27**		**#6 EWB**	**27**								
110	#6 Bars				Bars	**6.4**	**8.05**	**0**	**14.45**	**$ 172.80**	**$ 217.35**	**$ -**	**$ 390.15**
	Reinforcing Bars	**12**		**#7 EWB**	**12**								
120	#7 Bars				Bars	**7.45**	**9.3**	**0**	**16.75**	**$ 89.40**	**$ 111.60**	**$ -**	**$ 201.00**
	Reinforcing Bars	**64**		**#8 EWB**	**64**								
300	#8 Bars				Bars	**21.9**	**10.5**	**0**	**32.4**	**$ 1,401.60**	**$ 672.00**	**$ -**	**$ 2,073.60**
	Reinforcing Bars	**15**		**#9 EW T&B**	**15**								
305	#9 Bars				Bars	**14.1**	**25**	**7.15**	**46.25**	**$ 211.50**	**$ 375.00**	**$ 107.25**	**$ 693.75**
	Reinforcing Bars	**13**		**#9 EWB**	**13**								
305	#9 Bars				Bars	**14.1**	**25**	**7.15**	**46.25**	**$ 183.30**	**$ 325.00**	**$ 92.95**	**$ 601.25**
	Reinforcing Bars	**24**		**#10 EWB**	**24**								
310	#10 Bars				Bars	**15.7**	**28**	**7.9**	**51.6**	**$ 376.80**	**$ 672.00**	**$ 189.60**	**$ 1,238.40**
	Reinforcing Bars	**10**		**#9 LW T&B**	**10**								
305	#9 Bars				Bars	**14.1**	**25**	**7.15**	**46.25**	**$ 141.00**	**$ 250.00**	**$ 71.50**	**$ 462.50**
	Reinforcing Bars	**12**		**#7 SW T&B**	**12**								
120	#7 Bars				Bars	**7.45**	**9.3**	**0**	**16.75**	**$ 89.40**	**$ 111.60**	**$ -**	**$ 201.00**
	Reinforcing Bars	**12**		**#8 LWB**	**12**								
300	#8 Bars				Bars	**21.9**	**10.5**	**0**	**32.4**	**$ 262.80**	**$ 126.00**	**$ -**	**$ 388.80**
	Reinforcing Bars	**24**		**#8 SWB**	**24**								
300	#8 Bars				Bars	**21.9**	**10.5**	**0**	**32.4**	**$ 525.60**	**$ 252.00**	**$ -**	**$ 777.60**
	Reinforcing Bars	**20**		**#10 LWB w/ #10@12" SWB**	**20**								
310	#10 Bars				Bars	**15.7**	**28**	**7.9**	**51.6**	**$ 314.00**	**$ 560.00**	**$ 158.00**	**$ 1,032.00**
	Reinforcing Bars	**20**		**#10 LWB w/ #10@12" SWB**	**20**								
310	#10 Bars				Bars	**15.7**	**28**	**7.9**	**51.6**	**$ 314.00**	**$ 560.00**	**$ 158.00**	**$ 1,032.00**
03 21 05	***Reinforcing Steel***									*$ 4,227.15*	*$ 4,416.70*	*$ 777.30*	***$ 9,421.15***

Structural Foundation Walls

CSI Number	Category	Family and Type	Concrete PSI	Material: Volume	Reinforcing	Units	Material	Labor	Equipmer	Total	Material Cost	Labor Cost	Equipment Cost	Total Cost
03 03 53.40	***Concrete In Place***													
	Wall Foundation: BW1: 1	**Wall Foundation: BW1**	**3000**	**108.73 CF**	**(3) #4 LWB #4@24 SWB**	**4.03**								
3851	Spread Footings (3000psi) under 5 CY					CY	**103**	**61.5**	**0.31**	**164.81**	**$ 414.78**	**$ 247.66**	**$ 1.25**	**$ 663.70**
	Wall Foundation: F20.12: 31	**Wall Foundation: F20.12**	**3000**	**1524.65 CF**	**(93) #4 LWB. #4@24" SWB**	**56.47**								
3850	Spread Footings (3000psi) over 5 CY					CY	**171**	**61.5**	**0.31**	**232.81**	**$ 9,656.12**	**$ 3,472.81**	**$ 17.51**	**$ 13,146.44**
	Wall Foundation: F40.12: 1	**Wall Foundation: F40.12**	**3000**	**106.77 CF**	**(5) #4 LWB #4@24 SWB**	**3.95**								
3851	Spread Footings (3000psi) under 5 CY					CY	**103**	**61.5**	**0.31**	**164.81**	**$ 407.31**	**$ 243.20**	**$ 1.23**	**$ 651.73**
03 03 53.40	***Concrete In Place***										*$ 10,478.21*	*$ 3,963.68*	*$ 19.98*	***$ 14,461.86***
03 21 05	***Reinforcing Steel***													
	Reinforcing Bars				**(105) #4 LWB #4@24 SWB**	**105**								
100	#4 Bars					Bars	**4.55**	**6.35**	**0**	**10.9**	**$ 477.75**	**$ 666.75**	**$ -**	**$ 1,144.50**
03 21 05	***Reinforcing Steel***										*$ 477.75*	*$ 666.75*	*$ -*	***$ 1,144.50***

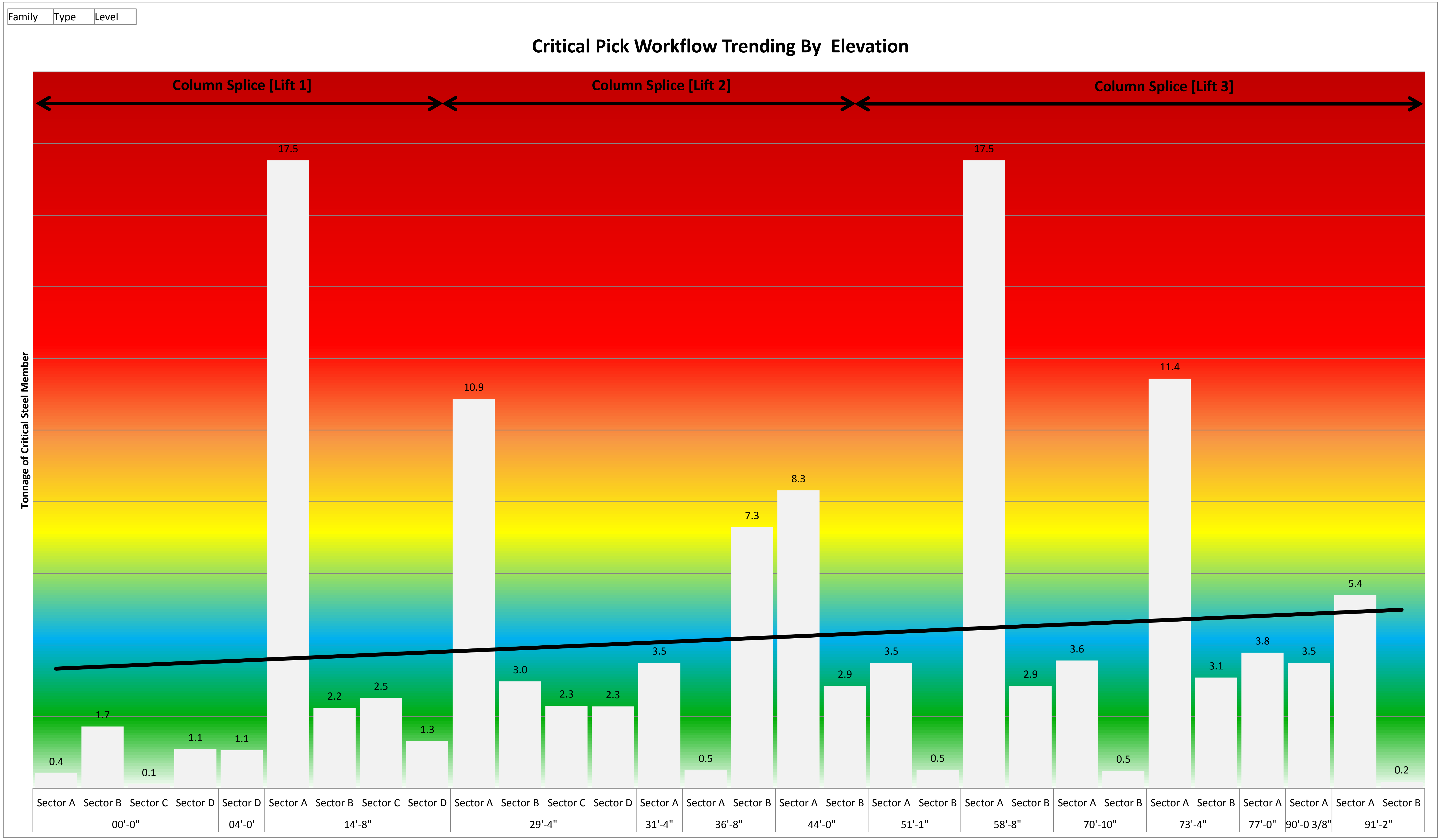
Structural Walls

CSI Number	Category	Material: Volun	Concrete PSI	Reinforcing	Total Units	Material	Labor	Equipment	Total	Material Cost	Labor Cost	Equipment Cost	Total Cost
03 03 53.40	***Concrete In Place***												
	Wall Foundation	**43537.32**	**3000**	**Not Provided in Model**	**1612.5**								
3850	Spread Footings (3000psi) over 5 CY				CY	**171**	**61.5**	**0.31**	**251.81**	**$ 275,737.50**	**$ 99,168.75**	**$ 499.88**	**$ 406,043.63**
	Basic Wall: Generic	**2439.24**	**3000**	**Not Provided in Model**	**90.3**								
3850	Spread Footings (3000psi) over 5 CY				CY	**171**	**61.5**	**0.31**	**0**	**$ 15,441.30**	**$ 5,553.45**	**$ 27.99**	**$ -**
	Basic Wall: Retaining	**48557.98**	**3000**	**Not Provided in Model**	**1798.4**								
3850	Spread Footings (3000psi) over 5 CY				CY	**171**	**61.5**	**0.31**	**0**	**$ 307,526.40**	**$ 110,601.60**	**$ 557.50**	**$ -**
03 03 53.40	***Concrete In Place***									*$ 598,705.20*	*$ 215,323.80*	*$ 1,085.37*	***$ 406,043.63***

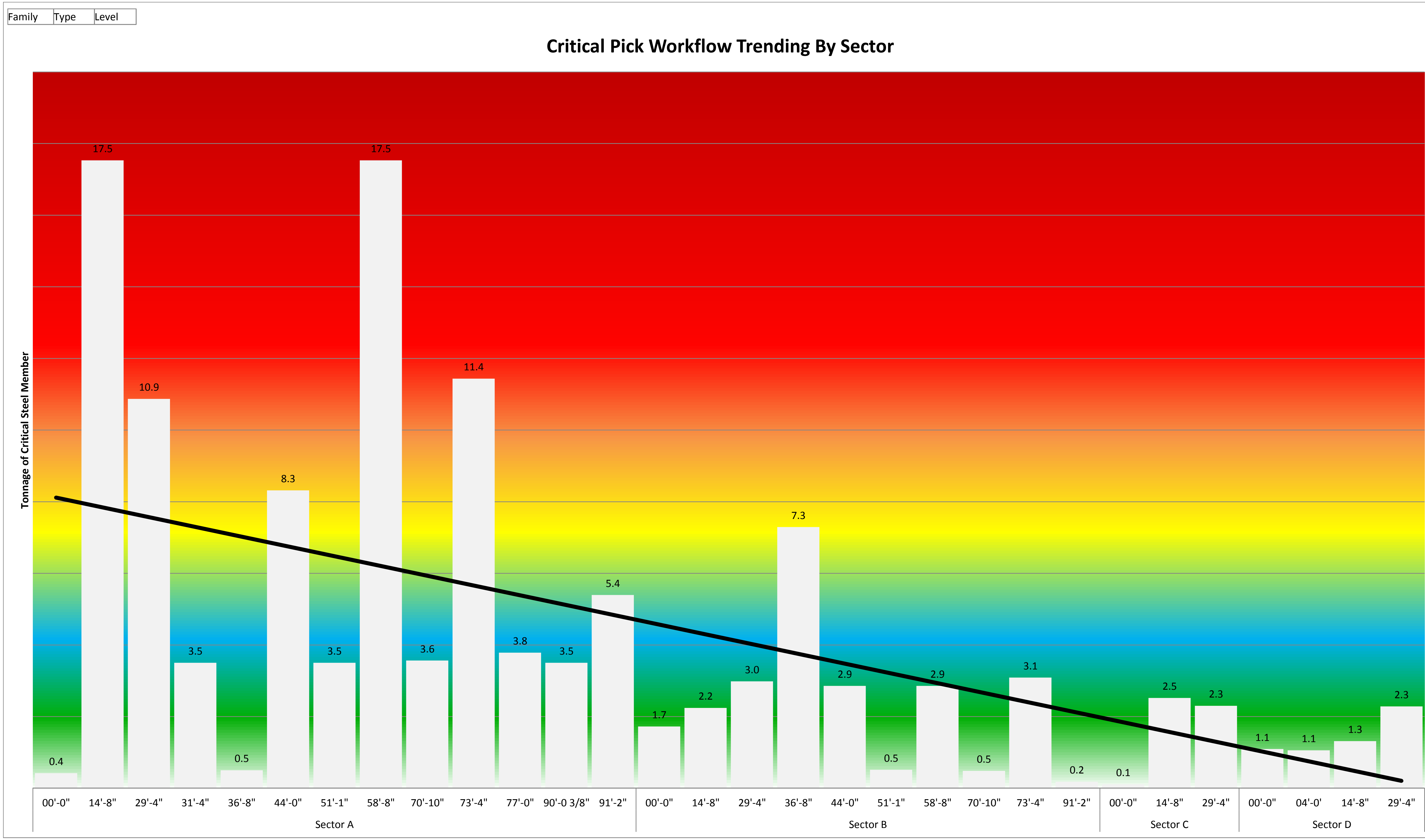
Structural Concrete Piers

CSI Number	Category	Family and Type	Concrete PS	Material: Volume	Reinforcing	Units	Material	Labor	Equipment	Total	Material Cost	Labor Cost	Equipment Cost	Total Cost
03 03 53.40	*Concrete In Place*													
	Concrete Pier	**P48: 1**	**4000**	**122.67 CF**	**See Below**	**4.54**								
3849	Spread Footings (4000psi) under 5 CY					CY	**171**	**61.5**	**0.31**	**232.81**	**$ 776.91**	**$ 279.42**	**$ 1.41**	**$ 1,057.73**
		P3036: 1	**4000**	**93.42 CF**	**See Below**	**3.46**								
3849	Spread Footings (4000psi) under 5 CY					CY	**171**	**61.5**	**0.31**	**232.81**	**$ 591.66**	**$ 212.79**	**$ 1.07**	**$ 805.52**
		P20: 9	**4000**	**98.24 CF**	**See Below**	**3.64**								
3849	Spread Footings (4000psi) under 5 CY					CY	**171**	**61.5**	**0.31**	**232.81**	**$ 622.19**	**$ 223.77**	**$ 1.13**	**$ 847.08**
		P24: 2	**4000**	**78.67 CF**	**See Below**	**2.91**								
3849	Spread Footings (4000psi) under 5 CY					CY	**171**	**61.5**	**0.31**	**232.81**	**$ 498.24**	**$ 179.19**	**$ 0.90**	**$ 678.34**
		P26: 40	**4000**	**1741.44 CF**	**See Below**	**64.50**								
3848	Spread Footings (4000psi) over 5 CY					CY	**190**	**61.5**	**0.31**	**251.81**	**$ 12,254.58**	**$ 3,966.61**	**$ 19.99**	**$ 16,241.19**
		P30: 25	**4000**	**887.10 CF**	**See Below**	**32.86**								
3848	Spread Footings (4000psi) over 5 CY					CY	**190**	**61.5**	**0.31**	**251.81**	**$ 6,242.56**	**$ 2,020.62**	**$ 10.19**	**$ 8,273.36**
		P34: 1	**4000**	**28.10 CF**	**See Below**	**1.04**								
3849	Spread Footings (4000psi) under 5 CY					CY	**171**	**61.5**	**0.31**	**232.81**	**$ 177.97**	**$ 64.01**	**$ 0.32**	**$ 242.29**
		P48: 2	**4000**	**244.60 CF**	**See Below**	**9.06**								
3848	Spread Footings (4000psi) over 5 CY					CY	**190**	**61.5**	**0.31**	**251.81**	**$ 1,721.26**	**$ 557.14**	**$ 2.81**	**$ 2,281.21**
03 03 53.40	*Concrete In Place*										*$ 22,885.36*	*$ 7,503.55*	*$ 37.82*	***$ 30,426.73***
03 21 05	*Reinforcing Steel*													
	Reinforcing Bars				**(16) #10 VERT. w/ #3 TIES @ 12"**	**16**								
310	#10 Bars					**Bars**	**15.7**	**28**	**7.9**	**51.6**	**$ 251.20**	**$ 448.00**	**$ 126.40**	**$ 825.60**
	Reinforcing Bars				**(16) #10 VERT. w/ #3 TIES @ 12"**	**16**								
310	#10 Bars					**Bars**	**15.7**	**28**	**7.9**	**51.6**	**$ 251.20**	**$ 448.00**	**$ 126.40**	**$ 825.60**
	Reinforcing Bars				**(72) #8 VERT. w/ #3 TIES @ 12"**	**72**								
300	#8 Bars					**Bars**	**21.9**	**10.5**	**0**	**32.4**	**$ 1,576.80**	**$ 756.00**	**$ -**	**$ 2,332.80**
	Reinforcing Bars				**(16) #8 VERT. w/ #3 TIES @ 12"**	**16**								
300	#8 Bars					**Bars**	**21.9**	**10.5**	**0**	**32.4**	**$ 350.40**	**$ 168.00**	**$ -**	**$ 518.40**
	Reinforcing Bars				**(320) #9 VERT. w/ #3 TIES @ 12"**	**320**								
305	#9 Bars					**Bars**	**14.1**	**25**	**7.15**	**46.25**	**$ 4,512.00**	**$ 8,000.00**	**$ 2,288.00**	**$ 14,800.00**
	Reinforcing Bars				**(300) #8 VERT. w/ #3 TIES @ 12"**	**300**								
300	#8 Bars					**Bars**	**21.9**	**10.5**	**0**	**32.4**	**$ 6,570.00**	**$ 3,150.00**	**$ -**	**$ 9,720.00**
	Reinforcing Bars				**(10) #10 VERT. w/ #3 TIES @ 12"**	**10**								
310	#10 Bars					**Bars**	**15.7**	**28**	**7.9**	**51.6**	**$ 157.00**	**$ 280.00**	**$ 79.00**	**$ 516.00**
	Reinforcing Bars				**(16) #9 VERT. w/ #3 TIES @ 12"**	**16**								
305	#9 Bars					**Bars**	**14.1**	**25**	**7.15**	**46.25**	**$ 225.60**	**$ 400.00**	**$ 114.40**	**$ 740.00**
03 21 05	*Reinforcing Steel*										*$ 13,894.20*	*$ 13,650.00*	*$ 2,734.20*	***$ 30,278.40***

APPENDIX H | CRANE SEQUENCE TRENDING CHARTS



Family
Type
Level
Critical Pick Workflow Trending By Elevation
Column Splice [Lift 1]
Column Splice [Lift 2]
Column Splice [Lift 3]
Tonnage of Critical Steel Member
0.4
1.7
0.1
1.1
1.1
17.5
2.2
2.5
1.3
10.9
3.0
2.3
2.3
3.5
0.5
7.3
8.3
2.9
3.5
0.5
17.5
2.9
3.6
0.5
11.4
3.1
3.8
3.5
5.4
0.2
Sector A Sector B Sector C Sector D
00'-0"
Sector D
04'-0'
Sector A Sector B Sector C Sector D
14'-8"
Sector A Sector B Sector C Sector D
29'-4"
Sector A
31'-4"
Sector A Sector B
36'-8"
Sector A Sector B
44'-0"
Sector A Sector B
51'-1"
Sector A Sector B
58'-8"
Sector A Sector B
70'-10"
Sector A Sector B
73'-4"
Sector A
77'-0"
Sector A
90'-0 3/8"
Sector A Sector B
91'-2"



Family
Type
Level
Critical Pick Workflow Trending By Sector
Tonnage of Critical Steel Member
0.4
17.5
10.9
3.5
0.5
8.3
3.5
17.5
3.6
11.4
3.8
3.5
5.4
1.7
2.2
3.0
7.3
2.9
0.5
2.9
0.5
3.1
0.2
0.1
2.5
2.3
1.1
1.1
1.3
2.3
00'-0"
14'-8"
29'-4"
31'-4"
36'-8"
44'-0"
51'-1"
58'-8"
70'-10"
73'-4"
77'-0"
90'-0 3/8"
91'-2"
00'-0"
14'-8"
29'-4"
36'-8"
44'-0"
51'-1"
58'-8"
70'-10"
73'-4"
91'-2"
00'-0"
14'-8"
29'-4"
00'-0"
04'-0'
14'-8"
29'-4"
Sector A
Sector B
Sector C
Sector D

APPENDIX I | CRANE LOAD CHART

Manitowoc

Grove TMS9000E
Product Guide

Features

- 90 t (110 USt) capacity
- 11,2 m - 43,3 m (36 ft - 142 ft) five-section full power boom
- Patented TWIN-LOCK™ boom pinning system
- 10 m - 17 m (33 ft - 56 ft) bi-fold lattice swingaway extension
- Optional lattice insert extensions for a 72,2 m (237 ft) maximum tip height
- Tiltable superstructure cab
- Up to 21 300 kg (48,500 lb) counterweight with hydraulic removal system

Features

MEGAFORM™ boom

The Grove MEGAFORM™ boom shape eliminates weight and increases capacity compared to conventional shapes. The unique TWIN-LOCK™ boom pinning system automatically pins the sections in position using two horizontal large diameter pins. A single cylinder inside the boom reduces weight which has been used elsewhere to strengthen the machine.

Counterweight

Up to 21 999 kg (48,500 lb) of counterweight can be power installed and removed from the superstructure cab — allowing for easy transport to and from the job site.

Crane Control system

Crane functions are controlled by ECOS (Electronic Crane Operating System) with CAN-BUS. The EKS5 load moment indicator provides detailed feedback and control of the crane's operating functions.

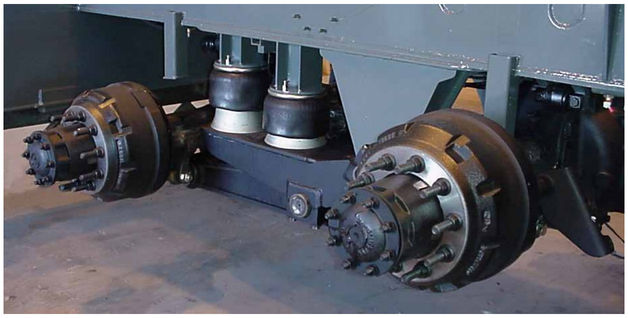
CraneSTAR is an exclusive and innovative crane asset management system that helps improve your profitability and reduce costs by remotely monitoring critical crane data. Visit www.cranestar.com for more information.

Outriggers

Two-stage inverted jack outriggers provide three position settings – 0%, 50% and 100%.

Power luffing extension

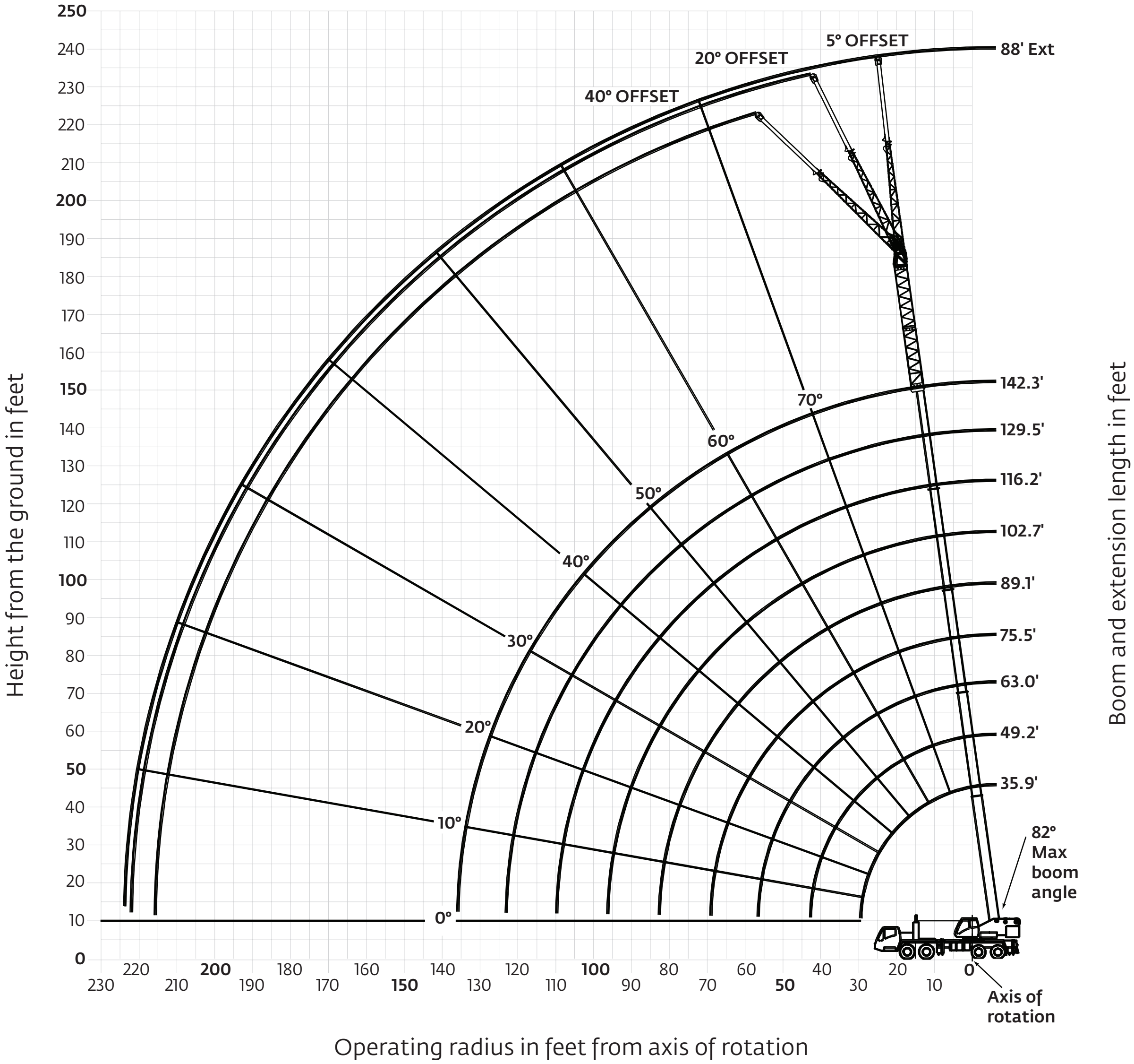
For improved up-and-over reach, a power luffing extension is available on the TMS9000E hydraulically offsettable from the superstructure cab, 5° to 40°.

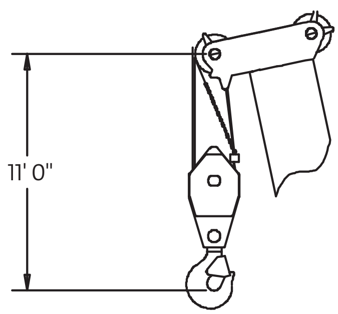


Suspension

Standard front and rear air ride suspension provides a comfortable ride at 105 kph (65 mph).

33 ft -56 ft hydraulic lattice extension with two 16 ft inserts





Dimensions area for largest Grove furnished hookblook and headache ball, with anti-two block activated.

THIS CHART IS ONLY A GUIDE AND SHOULD NOT BE USED TO OPERATE THE CRANE.
The individual crane's load chart, operating instructions and other instructional plates must be read and understood prior to operating the crane.

Load charts

142 ft
Fixed lengths

33 ft - 56 ft
72 ft - 88 ft
Hydraulic luffing
swingaway/stationary

48,500 lb

100%
24 ft 0 in

360°

Pounds (thousands)

Feet	142.3' + 33' 5°	5°-20°	20°-40°	142.3' + 56' 5°	5°-20°	20°-40°	142.3' + 72' 5°	5°-20°	20°-40°	142.3' + 88' 5°	5°-20°	20°-40°
35	13,800											
40	13,800			8600								
45	13,800	13,800		8600								
50	13,800	13,800	12,200	8600			7000			5520		
55	13,800	13,800	12,000	8600	8600		7000			5520		
60	13,800	13,800	12,200	8600	8600		7000	7000		5520		
65	13,800	13,800	12,200	8600	8600		7000	7000		5520		
70	13,800	13,800	12,200	8600	8380		7000	7000		5520	5520	
75	13,600	13,450	12,200	8600	8160	6750	7000	7000	6360	5520	5520	
80	12,900	12,850	12,200	8600	7930	6640	7000	7000	6360	5520	5520	5300
85	12,200	12,200	12,200	8600	7720	6530	7000	7000	6360	5520	5460	5300
90	11,550	11,550	11,550	8600	7530	6440	7000	7000	6360	5520	5400	5300
95	10,950	10,950	11,000	8600	7340	6350	7000	7000	6350	5520	5330	5300
100	10,400	10,400	10,450	8370	7170	6270	7000	7000	6270	5440	5270	5270
105	9870	9870	9940	8130	7010	6200	7000	7000	6200	5350	5210	5210
110	9290	9290	9460	7890	6870	6140	7000	6810	6140	5270	5140	5140
115	8750	8750	8930	7670	6730	6090	6800	6600	6090	5180	5080	5080
120	8250	8250	8420	7460	6610	6050	6580	6400	6040	5100	5020	5020
125	7780	7780	7940	7260	6490	6010	6360	6200	6000	5020	4970	4970
130	7280	7280	7460	7080	6390	5990	6160	6020	5970	4940	4890	4890
135	6680	6680		6760	6260	5970	5960	5840	5840	4860	4820	4820
140	6130	6130		6470	6200	5970	5730	5680	5680	4760	4720	4720
145	5620	5620		6150	6130	5970	5460	5460	5520	4600	4570	4570
150	5150	5150		5660	5660	5950	5210	5210	5370	4450	4420	4420
155	4710	4710		5210	5210	5470	4970	4970	5130	4300	4280	4280
160	4310			4790	4790		4630	4630	4890	4160	4150	4150
165	3940			4400	4400		4240	4240	4500	4020	4020	4020
170				4040	4040		3870	3870		3800	3800	3910
175				3690	3690		3520	3520		3450	3450	3710
180				3370	3370		3200	3200		3120	3120	3350
185				3040			2860	2860		2790	2790	
190							2540	2540		2460	2460	
195							2230	2230		2160	2160	
200							1940			1870	1870	
205							1660			1590	1590	
210										1330	1330	
215										1080		

THIS CHART IS ONLY A GUIDE AND SHOULD NOT BE USED TO OPERATE THE CRANE.
The individual crane's load chart, operating instructions and other instructional plates must be read and understood prior to operating the crane.

Load handling

33 ft - 56 ft folding boom extension (luffing or manual)		
	657 lb hookblock	
	Without	With
*33 ft extension (erected)	6600 lb	10,800 lb
*56 ft extension (erected)	12,300 lb	19,300 lb

*Reduction of main boom capacities

When lifting over main boom nose with 33 ft or 56 ft extension erected, the outriggers must be fully extended or 50% extended (15 ft 5 in spread)

NOTE: All load handling devices and boom attachments are considered part of the load and suitable allowances MUST BE MADE for their combined weights. Weights are for Grove furnished equipment.

Auxiliary boom nose	133 lb

Hookblocks and headache balls:	
80 Ust, 5-sheave	1609 lb +
60 USt, 5-sheave	1281 lb +
40 Ust, 3-sheave	1019 lb +
25 Ust, 1-sheave	657 lb +
8.3 Ust, overhaul ball	355 lb +

+ Refer to rating plate for actual weight.

When lifting over extension and/or jib combinations, deduct total weight of all load handling devices reeved over main boom nose directly from swingaway or jib capacity.

Hoists	Cable specs	Permissible line pulls	Nominal cable length
Main and auxiliary	19 mm (3/4 in) Caser Eurolift Rotation Resistant Min. breaking strength 78,683 lb	15,736 lb	738 ft
Main and auxiliary	19 mm (3/4 in) Endurance Dyform 34 LR Rotation Resistant, Left Lang Lay Min. Breaking Strength 80,000 lb	15,736 lb	738 ft
Main and auxiliary	19 mm (3/4 in) 35x7 Class Rotation Resistant Min. breaking strength 85,800 lb	17,160 lb	702 ft

The approximate weight of 3/4 in wire rope is 1.5 lb/ft

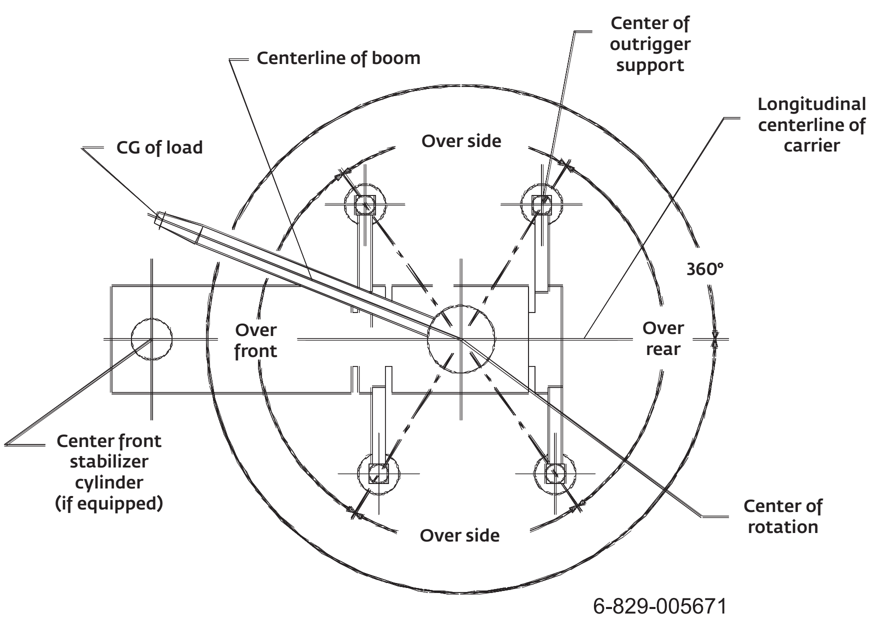
Hoist performance			
Wire rope layer	Hoist line pools	Drum rope capacity (ft)	
	Available lb*	Layer	Total
1	22,122	109.95	109.95
2	20,247	120.14	230.09
3	18,665	130.32	360.41
4	17,312	140.50	500.91
5	16,142	150.68	651.59
6	15,120	160.87	812.46

*Max lifting capacity

19 mm Casar Eurolift: 15,736 lb

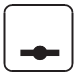
19 mm 35x7 Class: 17,160 lb

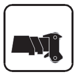
Working area diagram



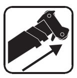
Bold lines determine the limiting position of any load for operation within working areas indicated.

Symbols glossary

 **Axles**

 **Boom**

 **Boom elevation**

 **Boom extension**

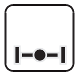
 **Boom length**

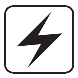
 **Boom nose**

 **Brakes**

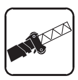
 **Cab**

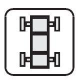
 **Counterweight**

 **Drive**

 **Electrical system**

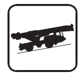
 **Engine**

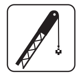
 **Extension**

 **Frame**

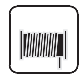
 **Fuel tank capacity**

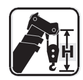
 **Gear**

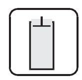
 **Grade**

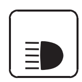
 **Height (no max)**

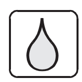
 **Heavy duty jib**

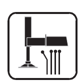
 **Hoist**

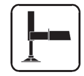
 **Hookblock**

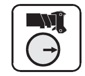
 **Hydraulic system**

 **Lights**

 **Oil**

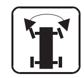
 **Outrigger controls**

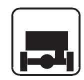
 **Outriggers**

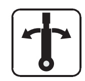
 **Radius**

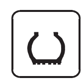
 **Rotation**

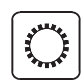
 **Speed**

 **Steering**

 **Suspension**

 **Swing**

 **Tires**

 **Transmission**

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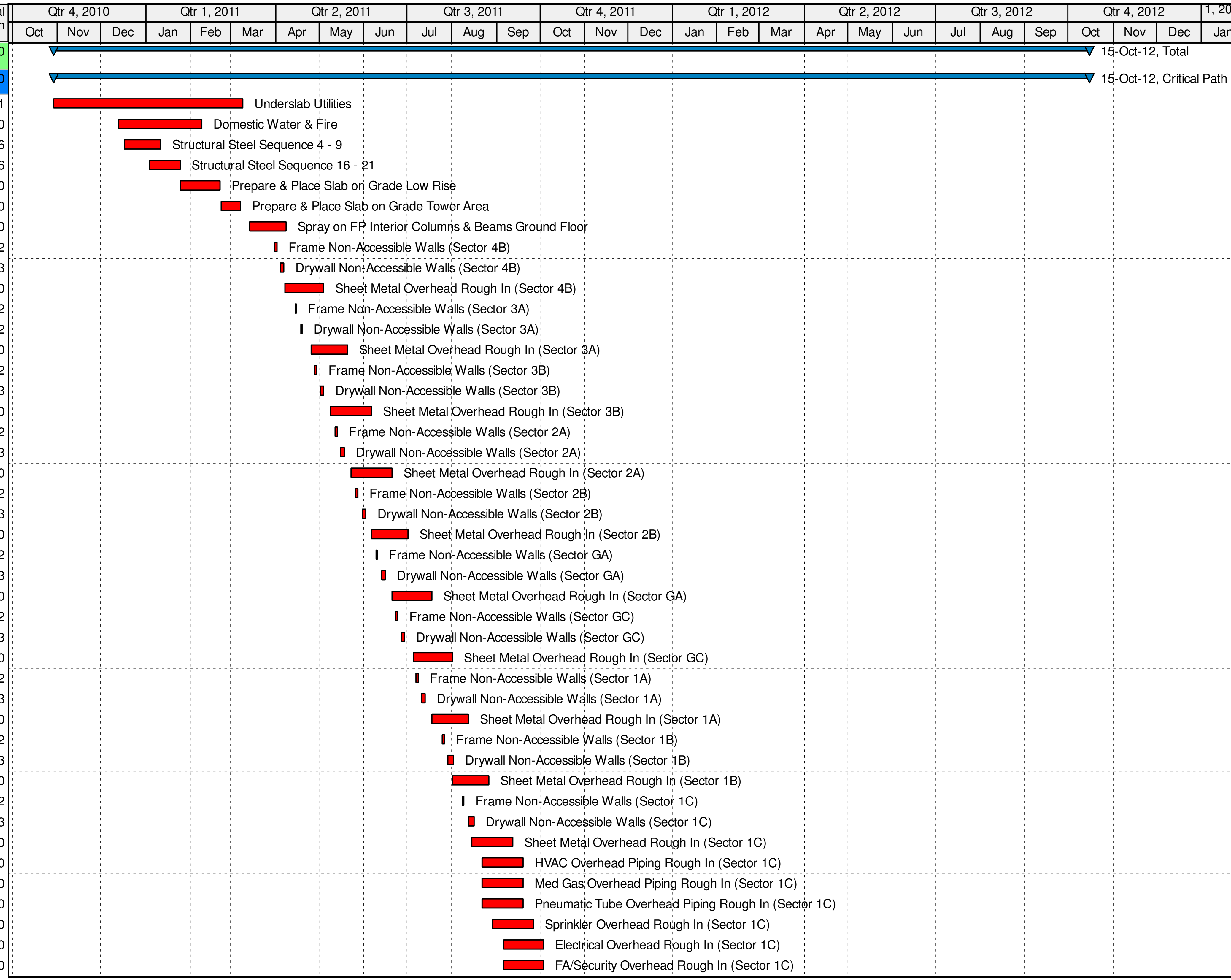
APPENDIX J | CRITICAL PATH SCHEDULE

AE 481W - Senior Thesis

BRIAN NAHAS

CONTRUCTION MANAGEMENT

Activity Name	Start	Finish	Original Duration
Total	29-Oct-10	15-Oct-12	500
Critical Path	29-Oct-10	15-Oct-12	500
Underslab Utilities	29-Oct-10*	09-Mar-11	91
Domestic Water & Fire	13-Dec-1(	08-Feb-11	40
Structural Steel Sequence 4 - 9	17-Dec-1(	11-Jan-11	16
Structural Steel Sequence 16 - 21	03-Jan-11*	24-Jan-11	16
Prepare & Place Slab on Grade Low Rise	25-Jan-11*	21-Feb-11	20
Prepare & Place Slab on Grade Tower Area	22-Feb-11*	07-Mar-11	10
Spray on FP Interior Columns & Beams Ground F	14-Mar-11*	08-Apr-11	20
Frame Non-Accessible Walls (Sector 4B)	31-Mar-11*	01-Apr-11	2
Drywall Non-Accessible Walls (Sector 4B)	04-Apr-11*	06-Apr-11	3
Sheet Metal Overhead Rough In (Sector 4B)	07-Apr-11*	04-May-11	20
Frame Non-Accessible Walls (Sector 3A)	14-Apr-11*	15-Apr-11	2
Drywall Non-Accessible Walls (Sector 3A)	18-Apr-11*	19-Apr-11	2
Sheet Metal Overhead Rough In (Sector 3A)	25-Apr-11*	20-May-11	20
Frame Non-Accessible Walls (Sector 3B)	28-Apr-11*	29-Apr-11	2
Drywall Non-Accessible Walls (Sector 3B)	02-May-1'	04-May-11	3
Sheet Metal Overhead Rough In (Sector 3B)	09-May-1'	06-Jun-11	20
Frame Non-Accessible Walls (Sector 2A)	12-May-1'	13-May-11	2
Drywall Non-Accessible Walls (Sector 2A)	16-May-1'	18-May-11	3
Sheet Metal Overhead Rough In (Sector 2A)	23-May-1'	20-Jun-11	20
Frame Non-Accessible Walls (Sector 2B)	26-May-1'	27-May-11	2
Drywall Non-Accessible Walls (Sector 2B)	31-May-1'	02-Jun-11	3
Sheet Metal Overhead Rough In (Sector 2B)	06-Jun-11*	01-Jul-11	20
Frame Non-Accessible Walls (Sector GA)	09-Jun-11*	10-Jun-11	2
Drywall Non-Accessible Walls (Sector GA)	13-Jun-11*	15-Jun-11	3
Sheet Metal Overhead Rough In (Sector GA)	20-Jun-11*	18-Jul-11	20
Frame Non-Accessible Walls (Sector GC)	23-Jun-11*	24-Jun-11	2
Drywall Non-Accessible Walls (Sector GC)	27-Jun-11*	29-Jun-11	3
Sheet Metal Overhead Rough In (Sector GC)	05-Jul-11*	01-Aug-11	20
Frame Non-Accessible Walls (Sector 1A)	07-Jul-11*	08-Jul-11	2
Drywall Non-Accessible Walls (Sector 1A)	11-Jul-11*	13-Jul-11	3
Sheet Metal Overhead Rough In (Sector 1A)	18-Jul-11*	12-Aug-11	20
Frame Non-Accessible Walls (Sector 1B)	25-Jul-11*	26-Jul-11	2
Drywall Non-Accessible Walls (Sector 1B)	29-Jul-11*	02-Aug-11	3
Sheet Metal Overhead Rough In (Sector 1B)	01-Aug-11	26-Aug-11	20
Frame Non-Accessible Walls (Sector 1C)	08-Aug-11	09-Aug-11	2
Drywall Non-Accessible Walls (Sector 1C)	12-Aug-11	16-Aug-11	3
Sheet Metal Overhead Rough In (Sector 1C)	15-Aug-11	12-Sep-11	20
HVAC Overhead Piping Rough In (Sector 1C)	22-Aug-11	19-Sep-11	20
Med Gas Overhead Piping Rough In (Sector 1C)	22-Aug-11	19-Sep-11	20
Pneumatic Tube Overhead Piping Rough In (Secto	22-Aug-11	19-Sep-11	20
Sprinkler Overhead Rough In (Sector 1C)	29-Aug-11	26-Sep-11	20
Electrical Overhead Rough In (Sector 1C)	06-Sep-11	03-Oct-11	20
FA/Security Overhead Rough In (Sector 1C)	06-Sep-11	03-Oct-11	20



Activity Summary
Milestone

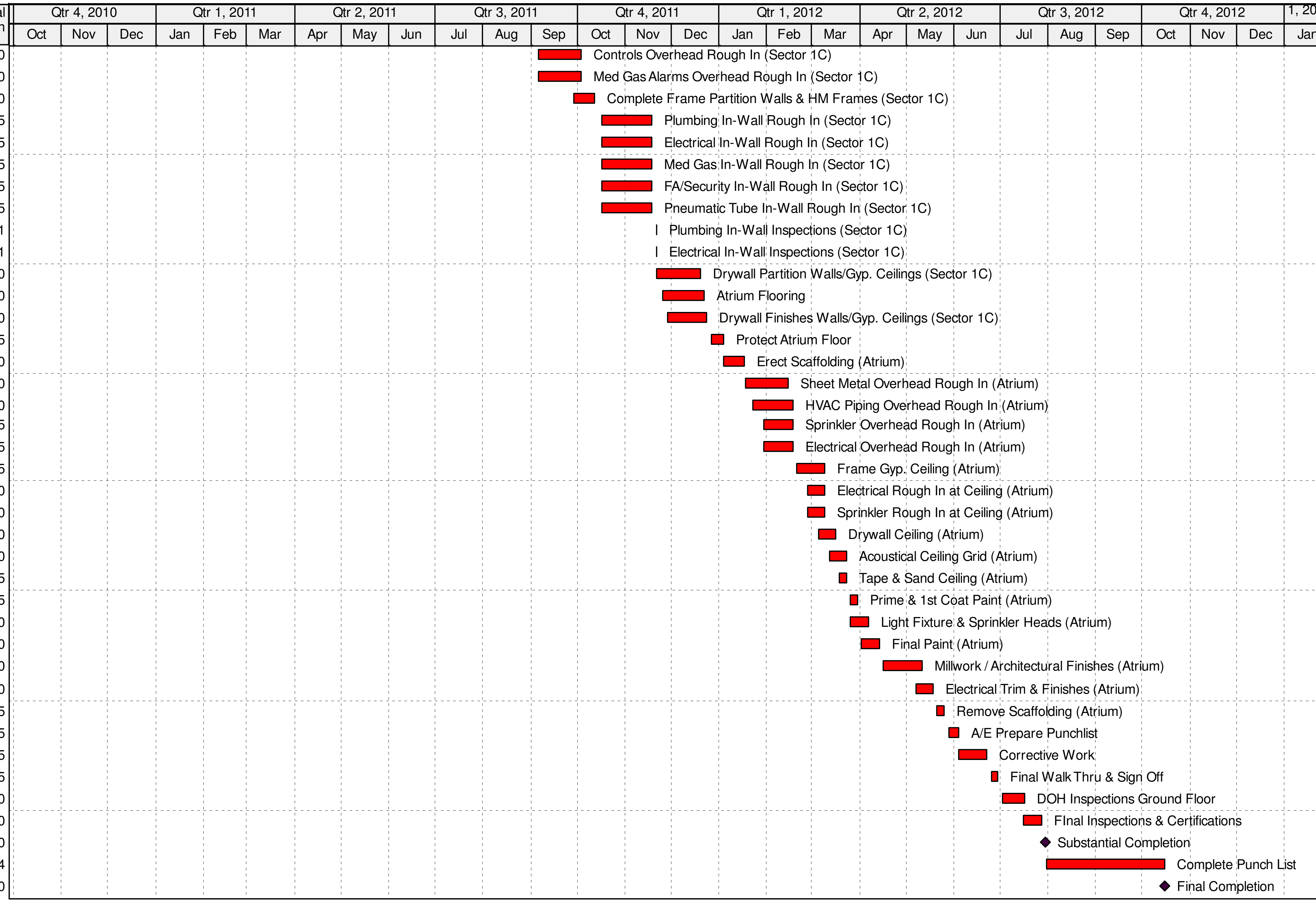
NEW REGIONAL MEDICAL CENTER

EAST NORRITON, PA

BRIAN NAHAS

CONTRUCTION MANAGEMENT

Activity Name	Start	Finish	Original Duration
Controls Overhead Rough In (Sector 1C)	06-Sep-11	03-Oct-11	20
Med Gas Alarms Overhead Rough In (Sector 1C)	06-Sep-11	03-Oct-11	20
Complete Frame Partition Walls & HM Frames (S	29-Sep-11	12-Oct-11	10
Plumbing In-Wall Rough In (Sector 1C)	17-Oct-11*	18-Nov-11	25
Electrical In-Wall Rough In (Sector 1C)	17-Oct-11*	18-Nov-11	25
Med Gas In-Wall Rough In (Sector 1C)	17-Oct-11*	18-Nov-11	25
FA/Security In-Wall Rough In (Sector 1C)	17-Oct-11*	18-Nov-11	25
Pneumatic Tube In-Wall Rough In (Sector 1C)	17-Oct-11*	18-Nov-11	25
Plumbing In-Wall Inspections (Sector 1C)	21-Nov-11	21-Nov-11	1
Electrical In-Wall Inspections (Sector 1C)	21-Nov-11	21-Nov-11	1
Drywall Partition Walls/Gyp. Ceilings (Sector 1C)	21-Nov-11	19-Dec-11	20
Atrium Flooring	25-Nov-11	22-Dec-11	20
Drywall Finishes Walls/Gyp. Ceilings (Sector 1C)	28-Nov-11	23-Dec-11	20
Protect Atrium Floor	27-Dec-11	03-Jan-12	5
Erect Scaffolding (Atrium)	04-Jan-12*	17-Jan-12	10
Sheet Metal Overhead Rough In (Atrium)	18-Jan-12*	14-Feb-12	20
HVAC Piping Overhead Rough In (Atrium)	23-Jan-12*	17-Feb-12	20
Sprinkler Overhead Rough In (Atrium)	30-Jan-12*	17-Feb-12	15
Electrical Overhead Rough In (Atrium)	30-Jan-12*	17-Feb-12	15
Frame Gyp. Ceiling (Atrium)	20-Feb-12*	09-Mar-12	15
Electrical Rough In at Ceiling (Atrium)	27-Feb-12*	09-Mar-12	10
Sprinkler Rough In at Ceiling (Atrium)	27-Feb-12*	09-Mar-12	10
Drywall Ceiling (Atrium)	05-Mar-12*	16-Mar-12	10
Acoustical Ceiling Grid (Atrium)	12-Mar-12*	23-Mar-12	10
Tape & Sand Ceiling (Atrium)	19-Mar-12*	23-Mar-12	5
Prime & 1st Coat Paint (Atrium)	26-Mar-12*	30-Mar-12	5
Light Fixture & Sprinkler Heads (Atrium)	26-Mar-12*	06-Apr-12	10
Final Paint (Atrium)	02-Apr-12*	13-Apr-12	10
Millwork / Architectural Finishes (Atrium)	16-Apr-12*	11-May-12	20
Electrical Trim & Finishes (Atrium)	07-May-1	18-May-12	10
Remove Scaffolding (Atrium)	21-May-1	25-May-12	5
A/E Prepare Punchlist	29-May-1	04-Jun-12	5
Corrective Work	04-Jun-12*	22-Jun-12	15
Final Walk Thru & Sign Off	25-Jun-12*	29-Jun-12	5
DOH Inspections Ground Floor	02-Jul-12*	16-Jul-12	10
FInal Inspections & Certifications	16-Jul-12*	27-Jul-12	10
Substantial Completion	30-Jul-12*		0
Complete Punch List	31-Jul-12*	15-Oct-12	54
Final Completion	15-Oct-12*		0



Activity Summary
Milestone

NEW REGIONAL MEDICAL CENTER

EAST NORRITON, PA

APPENDIX K | POUR STOP QTO & ESTIMATE

Ground Level Sector A & B										
CSI Number	**System**	**Total Units**	**Material**	**Labor**	**Equipment**	**Total**	**Material Cost**	**Labor Cost**	**Equipment Cost**	**Total Cost**
03 31	***Structural Concrete***									
	Floor: 4" NW Concrete	**6.64**								
4840	SOG (3500psi), no reinforcing	CY	2.59	0.88	0.01	3.48	$ 17.20	$ 5.84	$ 0.07	$ 23.11
200	3500 psi	CY	99.5	0	0	99.5	$ 660.68	$ -	$ -	$ 660.68
03 22 05.50	***Welded Wire Fabric- ASTM A185***									
	W6x6-W1.4xW1.4 WWF	**8.2**								
200	W6x6-W2.1xW2.1 WWF	C-SF	18.9	25	0	43.9	$ 154.98	$ 205.00	$ -	$ 359.98

First Level Sector A & B										
CSI Number	**System**	**Total Units**	**Material**	**Labor**	**Equipment**	**Total**	**Material Cost**	**Labor Cost**	**Equipment Cost**	**Total Cost**
05 12 23.17	***Columns, Structural***									
	W14x48: 4	**224**								
3702	W18x50	LF	62	4.2	1.9	68.1	$ 13,888.00	$ 940.80	$ 425.60	$ 15,254.40
	W14x43: 2	**104**								
3102	W16x40	LF	49.5	3.32	2.03	54.85	$ 5,148.00	$ 345.28	$ 211.12	$ 5,704.40
05 31 13.50	***Floor Decking***									
	3" 18 Gage Lok-Floor Composite Deck	**410**								
5900	Non-cellular composite decking, galvanized, 3" deep, 18 gauge	SF	2	0.55	0.04	2.59	$ 820.00	$ 225.50	$ 16.40	$ 1,061.90
03 31	***Structural Concrete***									
	Floor: 3 1/4" LW Concrete	**6.64**								
1400	Elevated Slabs, less than 6" thick, pumped	CY	0	16.8	5.6	22.4	$ -	$ 111.55	$ 37.18	$ 148.74
200	3500 psi	CY	99.5	0	0	99.5	$ 660.68	$ -	$ -	$ 660.68
03 22 05.50	***Welded Wire Fabric- ASTM A185***									
	W6x6-W2.0xW2.0 WWF	**8.2**								
200	W6x6-W2.1xW2.1 WWF	C-SF	18.9	25	0	43.9	$ 154.98	$ 205.00	$ -	$ 359.98

Second Level Sector A & B										
CSI Number	**System**	**Total Units**	**Material**	**Labor**	**Equipment**	**Total**	**Material Cost**	**Labor Cost**	**Equipment Cost**	**Total Cost**
05 12 23.17	***Columns, Structural***									
	W14x48: 4	**224**								
3702	W18x50	LF	62	4.2	1.9	68.1	$ 13,888.00	$ 940.80	$ 425.60	$ 15,254.40
	W14x43: 2	**104**								
3102	W16x40	LF	49.5	3.32	2.03	54.85	$ 5,148.00	$ 345.28	$ 211.12	$ 5,704.40
05 31 13.50	***Floor Decking***									
	3" 18 Gage Lok-Floor Composite Deck	**410**								
5900	Non-cellular composite decking, galvanized, 3" deep, 18 gauge	SF	2	0.55	0.04	2.59	$ 820.00	$ 225.50	$ 16.40	$ 1,061.90
03 31	***Structural Concrete***									
	Floor: 3 1/4" LW Concrete	**6.64**								
1400	Elevated Slabs, less than 6" thick, pumped	CY	0	16.8	5.6	22.4	$ -	$ 111.55	$ 37.18	$ 148.74
200	3500 psi	CY	99.5	0	0	99.5	$ 660.68	$ -	$ -	$ 660.68
03 22 05.50	***Welded Wire Fabric- ASTM A185***									
	W6x6-W2.0xW2.0 WWF	**8.2**								
200	W6x6-W2.1xW2.1 WWF	C-SF	18.9	25	0	43.9	$ 154.98	$ 205.00	$ -	$ 359.98

Third Level Sector A & B										
CSI Number	**System**	**Total Units**	**Material**	**Labor**	**Equipment**	**Total**	**Material Cost**	**Labor Cost**	**Equipment Cost**	**Total Cost**
05 12 23.17	***Columns, Structural***									
	W14x48: 4	**224**								
3702	W18x50	LF	62	4.2	1.9	68.1	$ 13,888.00	$ 940.80	$ 425.60	$ 15,254.40
	W14x43: 2	**104**								
3102	W16x40	LF	49.5	3.32	2.03	54.85	$ 5,148.00	$ 345.28	$ 211.12	$ 5,704.40
05 31 13.50	***Floor Decking***									
	3" 18 Gage Lok-Floor Composite Deck	**410**								
5900	Non-cellular composite decking, galvanized, 3" deep, 18 gauge	SF	2	0.55	0.04	2.59	$ 820.00	$ 225.50	$ 16.40	$ 1,061.90
03 31	***Structural Concrete***									
	Floor: 3 1/4" LW Concrete	**6.64**								
1400	Elevated Slabs, less than 6" thick, pumped	CY	0	16.8	5.6	22.4	$ -	$ 111.55	$ 37.18	$ 148.74
200	3500 psi	CY	99.5	0	0	99.5	$ 660.68	$ -	$ -	$ 660.68
03 22 05.50	***Welded Wire Fabric- ASTM A185***									
	W6x6-W2.0xW2.0 WWF	**8.2**								
200	W6x6-W2.1xW2.1 WWF	C-SF	18.9	25	0	43.9	$ 154.98	$ 205.00	$ -	$ 359.98

Fourth Level Sector A & B										
CSI Number	**System**	**Total Units**	**Material**	**Labor**	**Equipment**	**Total**	**Material Cost**	**Labor Cost**	**Equipment Cost**	**Total Cost**
05 12 23.17	***Columns, Structural***									
	W14x48: 4	**224**								
3702	W18x50	LF	62	4.2	1.9	68.1	$ 13,888.00	$ 940.80	$ 425.60	$ 15,254.40
	W14x43: 2	**104**								
3102	W16x40	LF	49.5	3.32	2.03	54.85	$ 5,148.00	$ 345.28	$ 211.12	$ 5,704.40
05 31 13.50	***Floor Decking***									
	3" 18 Gage Lok-Floor Composite Deck	**410**								
5900	Non-cellular composite decking, galvanized, 3" deep, 18 gauge	SF	2	0.55	0.04	2.59	$ 820.00	$ 225.50	$ 16.40	$ 1,061.90
03 31	***Structural Concrete***									
	Floor: 3 1/4" LW Concrete	**6.64**								
1400	Elevated Slabs, less than 6" thick, pumped	CY	0	16.8	5.6	22.4	$ -	$ 111.55	$ 37.18	$ 148.74
200	3500 psi	CY	99.5	0	0	99.5	$ 660.68	$ -	$ -	$ 660.68
03 22 05.50	***Welded Wire Fabric- ASTM A185***									
	W6x6-W2.0xW2.0 WWF	**8.2**								
200	W6x6-W2.1xW2.1 WWF	C-SF	18.9	25	0	43.9	$ 154.98	$ 205.00	$ -	$ 359.98

Penthouse Level Sector A & B										
CSI Number	**System**	**Total Units**	**Material**	**Labor**	**Equipment**	**Total**	**Material Cost**	**Labor Cost**	**Equipment Cost**	**Total Cost**
05 12 23.17	***Columns, Structural***									
	W14x43: 6	**328**								
3102	W16x40	LF	49.5	3.32	2.03	54.85	$ 16,236.00	$ 1,088.96	$ 665.84	$ 17,990.80
05 31 13.50	***Floor Decking***									
	3" 18 Gage Lok-Floor Composite Deck	**246**								
5900	Non-cellular composite decking, galvanized, 3" deep, 18 gauge	SF	2	0.55	0.04	2.59	$ 492.00	$ 135.30	$ 9.84	$ 637.14
	1 1/2" 22 Gage Type 'B' Metal Roof Deck	**221.4**								
2400	Open Type, 1-1/2" deep, Type B, 22 Ga.	SF	1.02	0.31	0.02	1.35	$ 225.83	$ 68.63	$ 4.43	$ 298.89
03 31	***Structural Concrete***									
	Floor: 3 1/4" LW Concrete	**2.656**								
1400	Elevated Slabs, less than 6" thick, pumped	CY	0	16.8	5.6	22.4	$ -	$ 44.62	$ 14.87	$ 59.49
200	3500 psi	CY	99.5	0	0	99.5	$ 264.27	$ -	$ -	$ 264.27
	Floor: 5" NW Concrete	**3.984**								
1400	Elevated Slabs, less than 6" thick, pumped	CY	0	16.8	5.6	22.4	$ -	$ 66.93	$ 22.31	$ 89.24
200	3500 psi	CY	99.5	0	0	99.5	$ 396.41	$ -	$ -	$ 396.41
03 22 05.50	***Welded Wire Fabric- ASTM A185***									
	W6x6-W2.0xW2.0 WWF	**3.28**								
200	W6x6-W2.1xW2.1 WWF	C-SF	18.9	25	0	43.9	$ 61.99	$ 82.00	$ -	$ 143.99
	W6x6-W2.9xW2.9 WWF	**4.92**								
300	W6x6-W2.9xW2.9 WWF	C-SF	21.5	26.5	0	48	$ 105.78	$ 130.38	$ -	$ 236.16

Column Systems										
CSI Number	**System**	**Total Units**	**Material**	**Labor**	**Equipment**	**Total**	**Material Cost**	**Labor Cost**	**Equipment Cost**	**Total Cost**

CSI Number	System	Total Units	Material	Labor	Equipment	Total	Material Cost	Labor Cost	Equipment Cost	Total Cost
05 12 23.17	***Columns, Structural***									
	W12x87	**336.3333333**								
5702	W24x76	LF	**94**	**3.45**	**1.56**	**99.01**	**$ 31,615.33**	**$ 1,160.35**	**$ 524.68**	**$ 33,300.36**
	W12x120	**55.5**								
2502	W14x120	LF	**149**	**3.68**	**2.25**	**154.93**	**$ 8,269.50**	**$ 204.24**	**$ 124.88**	**$ 8,598.62**
	W12x106	**86.5**								
6302	W30x108	LF	**134**	**3.19**	**1.44**	**138.63**	**$ 11,591.00**	**$ 275.94**	**$ 124.56**	**$ 11,991.50**
	W12x79	**74**								
5502	W24x76	LF	**94**	**3.45**	**1.56**	**99.01**	**$ 6,956.00**	**$ 255.30**	**$ 115.44**	**$ 7,326.74**
Foundation Systems										
CSI Number	**System**	**Total Units**	**Material**	**Labor**	**Equipment**	**Total**	**Material Cost**	**Labor Cost**	**Equipment Cost**	**Total Cost**
03 03 53.40	***Concrete In Place***									
	Footing: 3' Thick Concrete	**15.56**								
3848	Spread Footings (4000psi) over 5 CY	CY	**190**	**61.5**	**0.31**	**251.81**	**$ 2,955.56**	**$ 956.67**	**$ 4.82**	**$ 3,917.04**
	Footing: 2'-6" Thick Concrete	**34.65**								
3848	Spread Footings (4000psi) over 5 CY	CY	**190**	**61.5**	**0.31**	**251.81**	**$ 6,584.03**	**$ 2,131.15**	**$ 10.74**	**$ 8,725.92**
	Footing: 2'-10" Thick Concrete	**32.79**								
3848	Spread Footings (4000psi) over 5 CY	CY	**190**	**61.5**	**0.31**	**251.81**	**$ 6,230.71**	**$ 2,016.78**	**$ 10.17**	**$ 8,257.66**
	Footing: 4'-6" Thick Concrete	**153.33**								
3848	Spread Footings (4000psi) over 5 CY	CY	**190**	**61.5**	**0.31**	**251.81**	**$ 29,133.33**	**$ 9,430.00**	**$ 47.53**	**$ 38,610.87**
03 21 05	***Reinforcing Steel***									
	Reinforcing Bars	**82**								
300	#8 Bars	Bars	**21.9**	**10.5**	**0**	**32.4**	**$ 1,795.80**	**$ 861.00**	**-**	**$ 2,656.80**
	Reinforcing Bars	**24**								
120	#7 Bars	Bars	**7.45**	**9.3**	**0**	**16.75**	**$ 178.80**	**$ 223.20**	**-**	**$ 402.00**
	Reinforcing Bars	**40**								
310	#10 Bars	Bars	**15.7**	**28**	**7.9**	**51.6**	**$ 628.00**	**$ 1,120.00**	**$ 316.00**	**$ 2,064.00**

Pour Strip System Total Cost	**$**	**239,772.05**

APPENDIX L | EXPANSION JOINT STRUCTURAL ANALYSIS

EXPANSION JOINT SIZING

DESIGN TEMPERATURE:

$\Delta T = (T_W - T_m)$ OR $(T_m - T_c)$ [WHICHEVER IS GREATER]

T_m = MEAN CONSTRUCTION SEASON TEMP. : 55°
T_W = SUMMER EXTREME W_b : 91°
T_c = WINTER EXTREME D_b : 11°

] APPENDIX B OF MEEBS FROM ASHRAE 1997.

$\Delta T = (36°F)$ OR $(44°F)$
ΔT = 44°F GOVERNS

*REFERENCE PHILADELPHIA AIRPORT DATA

ALLOWABLE BUILDING LENGTH:
PER FIGURE 1 IN TECH REPORT 65 [EXP. JOINTS IN BLDGS]

DESIGN TEMP = 44°F
ALLOWABLE LENGTH = 250'
↳ NON-RECTANGULAR CONFIGURATION [ANY MATERIAL]

CORRECTION FACTORS:
A/C & HEAT +15%
LATERAL BRACE AT ENDS RELATIVE TO JOINT −25%

250' × (.9) = 225' ALLOWABLE LENGTH

BUILDING LENGTH : 556' → USE 2 JOINTS IN PATIENT TOWER
↳ CAN PLACE IN TYP. SPACE OF POUR STRIP.
@ 125' FROM EXTERIOR EDGE OF BUILDING

EXP. JOINT TO EXTEND OVER ENTIRE HEIGHT OF BUILDING
↳ TOP OF FOUNDATION THROUGH ROOF.
→ CAN SHARE A FOOTING.

UPPER BOUND CALCULATION → HORIZONTAL JOINT CLOSING

$UB = 6 \times 10^{6} \cdot \Delta t_e \cdot L$

L = EFFECTIVE LENGTH
$\Delta t_e = (T_W - T_c)$

$UB = 6 \times 10^{-6} \times 80°F \cdot 125'$
$UB = .06'$

CONSTRUCTION TOLERANCE & SEALANT → EXP. JOINT WIDTH

$W = C_1 \cdot UB$

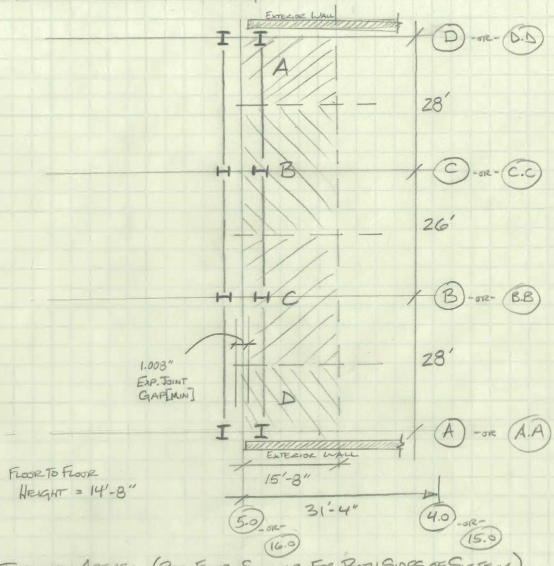
$C_1 = 1.4$ FOR HEATED & A/C BUILDINGS

EJ-TMM-200W-W
EJ-TMM-200-W
2" OPENING 7.75" SYSTEM

$W = 1.4 \cdot .06$
$W = .084$ Ft = 1.008 INCHES → USE NYSTROM DOUBLE SEAM

STRUCTURAL ANALYSIS PROCESS

PROPOSED SYSTEM 1 GRID BLOCK = 4'



FLOOR TO FLOOR
HEIGHT = 14'-8"

TRIBUTARY AREAS (PER FLOOR, SIMILAR FOR BOTH SIDES OF SYSTEM)

FLOOR
- A → (14')(15'-8") = 219.38 ft^2
- B → (27')(15'-8") = 423.09 ft^2
- C → (27')(15'-8") = 423.09 ft^2
- D → (14')(15'-8") = 219.38 ft^2

$K_{LL}A_T$ = (82')(31'-4") = 2569.33 ft^2

WALL*
- TYPICAL FLOOR → (14'-8")(15'-8") = 229.78 ft^2
- TOP FLOOR → (22'-0")(15'-8") = 344.67 ft^2

* ASSUME EXTERIOR COLUMNS AT D5.0 & A5.0 CARRY 1 STORY OF EXTERIOR PRECAST & GLAZING SYSTEM & 1.5 STORIES AT TOP FLOOR TO ACCOUNT FOR ROOF PARAPET.

LIVE LOAD REDUCTIONS

PENTHOUSE
→ 0.4
4TH FLOOR
→ 0.4
3RD FLOOR
→ 0.4
2ND FLOOR
→ 0.4
1ST FLOOR
→ 0.4
GROUND FLOOR

LOAD CALCULATIONS

REQUIREMENTS ON S-001.
SHOWN IN TABLES IN REPORT.

FLOOR LOADS →
DL : 65 PSF
LL : 100 PSF

ROOF LOADS →
DL : 45 PSF (MECH) / 25 PSF (TYP)
LL : 30 PSF
S : 26 PSF

EXTERIOR PRECAST LOAD →
DL : 100 PSF (150 PCF @ 8" THICK)

* $KL = 14'-8"$ = USE $KL = 15'$
* USE ALL W12's TO CORRESPOND WITH REST OF COLUMN SYSTEM
* USE $1.2D + 1.6L\,[+0.5S]$

COLUMN D-5.0 & A-5.0 [D.D-16.0 & A-A-16.0] BOTH COLUMNS

PENTHOUSE: $1.2(25)(219.38) + 1.6(26)(219.38) = 15.7^k$

4TH FLOOR: $\overbrace{\underset{[\text{TYP. ROOF}]}{}1.2(25)(219.38) + .5(26)(219.38)}^{9.4^k} + \overbrace{1.2(65)(219.38) + 1.2(100)(344.67)}^{58.47^k}$
$+ \underbrace{1.6(0.4)(100)(1)(219.38)}_{14^k} = 81.87^k$

3RD FLOOR: $9.4^k + \overbrace{1.2(65)(219.38) + 1.2(100)(229.78)}^{44.7^k} + [58.47^k] + 2[14^k]$
$= 140.57^k$

2ND FLOOR: $9.4^k + 58.47^k + 2[44.7^k] + 3[14^k] = 199.27^k$

1ST FLOOR: $9.4^k + 58.47^k + 3[44.7^k] + 4[14^k] = 257.97^k$

GROUND: $9.4^k + 58.47^k + 4[44.7^k] + 5[14^k] = 316.67^k$

			FROM TABLE 4-1 AISC
PENTHOUSE	15.7k	SIZE @ 81.87 k	W12×40
4TH FLOOR	81.87 k		
		SPLICE	
3RD FLOOR	140.57 k	SIZE @ 199.27 k	W12×40
2ND FLOOR	199.27 k		
		SPLICE	
1ST FLOOR	257.97 k	SIZE @ 316.67 k	W12×50
GROUND	316.67 k		

COLUMN B.5.0 & C.5.0 [B.B-16.0 & C.C-16.0] BOTH COLUMNS

PENTHOUSE : $1.2(45)(423.09) + 1.6(26)(423.09) = 40.4^k$

4TH FLOOR : $\underbrace{1.2(45)(423.09) + 0.5(26)(423.09)}_{28.34^k} + \underbrace{1.2(65)(423.09)}_{33^k}$
$\underbrace{+1.6(0.4)(100)(1)(423.09)}_{27.08^k} = 88.42^k$

3RD FLOOR : $28.34^k + 2[33^k] + 2[27.08^k] = 148.5^k$

2ND FLOOR : $28.34^k + 3[33^k] + 3[27.08^k] = 208.58^k$

1ST FLOOR : $28.34^k + 4[33^k] + 4[27.08^k] = 268.66^k$

GROUND : $28.34^k + 5[33^k] + 5[27.08^k] = 328.74^k$

			FROM TABLE 4-1 AISC
PENTHOUSE	40.4^k	SIZE @ 88.42^k	W12×40
4TH FLOOR	88.42^k		
		SPLICE	
3RD FLOOR	148.5^k	SIZE @ 208.53^k	W12×40
2ND FLOOR	208.58^k		
		SPLICE	
1ST FLOOR	268.66^k	SIZE @ 328.74^k	W12×50
GROUND	328.74^k		

COLUMN SELF WEIGHT:

W12×40 (×2)
W12×50 (×1)

$[40(2) + 50] \times 14.67' = 1907.1\text{ lbs} \rightarrow 19.07^k$

LOAD @ COLUMNS A-5.0, A.A-16.0, D-5.0, D.D-16.0
$316.67^k + 19.07^k = 335.74^k$

LOAD @ COLUMNS B-5.0, B.B-16.0, C-5.0, C.C-16.0
$328.74 + 19.07^k = 347.81^k$

BASE PLATE SIZE : 2×20×1'-3"
ANCHOR RODS : 4 (1"ϕ)
} SIM TO W12×53 ON SHEET S-400

20

Table 4–1 (continued) Available Strength in Axial Compression, kips

W Shapes

W12

F_y = 50 ksi

Shape		W12×									
Wt/ft		58		53		50		45		40	
Design		P_n/Ω_c	$\phi_c P_n$	P_n/Ω_c	$\phi_c P_n$	P_n/Ω_c	$\phi_c P_n$	P_n/Ω_c	$\phi_c P_n$	P_n/Ω_c	$\phi_c P_n$
		ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD
Effective length KL (ft) with respect to least radius of gyration r_y	0	510	767	466	701	437	657	393	590	350	526
	6	481	722	438	659	396	595	356	534	316	475
	7	470	707	429	644	382	574	343	516	305	458
	8	459	689	418	628	367	551	329	495	292	439
	9	446	670	406	610	350	526	314	472	279	419
	10	432	649	393	590	332	499	298	448	264	397
	11	417	627	379	569	314	471	281	422	249	375
	12	401	603	364	547	294	443	264	396	234	351
	13	385	578	349	525	275	413	246	370	218	328
	14	368	553	333	501	255	384	228	343	202	304
	15	350	527	317	477	236	354	211	317	186	280
	16	333	500	301	452	217	326	193	291	171	257
	17	315	473	284	427	198	297	176	265	156	234
	18	297	446	268	402	180	270	160	241	141	212
	19	279	420	251	376	162	244	144	217	127	191
	20	262	393	235	353	146	220	130	196	115	172
	22	227	342	204	306	121	182	108	162	94.8	142
	24	195	293	174	261	102	153	90.4	136	79.6	120
	26	166	249	148	222	86.6	130	77.0	116	67.9	102
	28	143	215	127	192	74.6	112	66.4	99.8	58.5	88.0
	30	125	187	111	167	65.0	97.7	57.9	87.0	51.0	76.6
	32	109	165	97.6	147	57.1	85.9	50.9	76.4	44.8	67.3
	34	97.0	146	86.5	130						
	36	86.5	130	77.1	116						
	38	77.6	117	69.2	104						
	40	70.1	105	62.5	93.9						
Properties											
P_{wo} (kips)		74.4	112	67.6	101	70.3	106	60.0	90.0	49.9	74.9
P_{wi} (kips/in.)		12.0	18.0	11.5	17.3	12.3	18.5	11.2	16.8	9.83	14.8
P_{wb} (kips)		83.2	125	73.2	110	88.5	133	65.7	98.7	44.8	67.4
P_{fb} (kips)		76.6	115	61.9	93.0	76.6	115	61.9	93.0	49.6	74.5
L_p (ft)		8.87		8.76		6.92		6.89		6.85	
L_r (ft)		29.9		28.2		23.9		22.4		21.1	
A_g (in.^{2})		17.0		15.6		14.6		13.1		11.7	
I_x (in.^{4})		475		425		391		348		307	
I_y (in.^{4})		107		95.8		56.3		50.0		44.1	
r_y (in.)		2.51		2.48		1.96		1.95		1.94	
Ratio r_x/r_y		2.10		2.11		2.64		2.64		2.64	
$P_{ex}(KL^2)/10^4$ (k-in.^{2})		13600		12200		11200		9960		8790	
$P_{ey}(KL^2)/10^4$ (k-in.^{2})		3060		2740		1610		1430		1260	

ASD	LRFD	Note: Heavy line indicates Kl/r equal to or greater than 200.
$\Omega_c = 1.67$	$\phi_c = 0.90$	

Table 4–1 (continued) Available Strength in Axial Compression, kips

W Shapes

F_y = 50 ksi

W10

Shape		W10×											
Wt/ft		112		100		88		77		68		60	
Design		P_n/Ω_c	$\phi_c P_n$	P_n/Ω_c	$\phi_c P_n$	P_n/Ω_c	$\phi_c P_n$	P_n/Ω_c	$\phi_c P_n$	P_n/Ω_c	$\phi_c P_n$	P_n/Ω_c	$\phi_c P_n$
		ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD
Effective length KL (ft) with respect to least radius of gyration r_y	0	986	1480	880	1320	776	1170	678	1020	598	899	528	794
	6	936	1410	834	1250	734	1100	641	963	565	850	499	750
	7	918	1380	818	1230	720	1080	628	944	554	833	489	734
	8	898	1350	800	1200	703	1060	614	922	541	813	477	717
	9	876	1320	780	1170	685	1030	598	898	527	792	464	698
	10	852	1280	758	1140	666	1000	580	872	511	768	450	677
	11	826	1240	734	1100	646	969	561	844	495	744	436	655
	12	799	1200	709	1070	623	936	542	814	477	717	420	631
	13	770	1160	683	1030	600	901	521	783	459	690	404	606
	14	740	1110	656	986	575	865	500	751	440	661	387	581
	15	709	1070	628	944	551	827	477	718	420	632	369	565
	16	678	1020	600	901	525	789	455	684	400	602	351	528
	17	646	970	571	858	499	751	432	650	380	571	333	501
	18	613	922	542	814	474	712	409	615	360	541	315	474
	19	581	873	512	770	448	673	386	581	339	510	297	447
	20	549	825	483	726	422	634	364	546	319	480	279	420
	22	485	729	426	640	371	558	319	479	280	421	244	367
	24	424	637	371	558	323	485	276	415	242	364	211	317
	26	365	549	319	479	277	416	236	355	207	311	180	270
	28	315	473	275	413	239	358	204	306	178	268	155	233
	30	274	412	239	360	208	312	178	267	155	234	135	203
	32	241	362	210	316	183	274	156	234	137	205	119	179
	34	214	321	186	280	162	243	138	208	121	182	105	158
	36	191	286	166	250	144	217	123	185	108	162	93.9	141
	38	171	257	149	224	129	195	111	166	96.9	146	84.2	127
	40	154	232	135	202	117	176	99.8	150	87.4	131	76.0	114
Properties													
P_{wo} (kips)		220	330	184	275	150	225	121	182	99.5	149	82.6	124
P_{wi} (kips/in.)		25.2	37.8	22.7	34.0	20.2	30.3	17.7	26.5	15.7	23.5	14.0	21.0
P_{wb} (kips)		948	1420	692	1040	488	733	328	493	229	344	163	245
P_{fb} (kips)		292	439	235	353	183	276	142	213	111	167	86.5	130
L_p (ft)		9.47		9.36		9.29		9.18		9.15		9.08	
L_r (ft)		64.3		57.7		51.1		45.2		40.6		36.6	
A_g (in.^{2})		32.9		29.4		25.9		22.6		20.0		17.6	
I_x (in.^{4})		716		623		534		455		394		341	
I_y (in.^{4})		236		207		179		154		134		116	
r_y (in.)		2.68		2.65		2.63		2.60		2.59		2.57	
Ratio r_x/r_y		1.74		1.74		1.73		1.73		1.71		1.71	
$P_{ex}(KL^2)/10^4$ (k-in.^{2})		20500		17800		15300		13000		11300		9760	
$P_{ey}(KL^2)/10^4$ (k-in.^{2})		6750		5920		5120		4410		3840		3320	

ASD	LRFD
$\Omega_c = 1.67$	$\phi_c = 0.90$

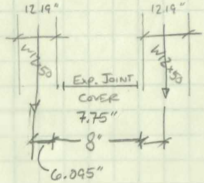
FOOTING DESIGN & DETAIL:

↳ CASE 1: TYPICAL @ A-5.0, D-5.0, D.D-16.0

↳ CASE 1A: TYPICAL @ A.A-16.0

↳ CASE 2: TYPICAL @ B-5.0, B.B-16.0, C-5.0, C.C-16.0

CASE 1: $P = 335.74^k$ ⟶ 2 INSTANCES @ 10.095" FROM CENTER
20in × 20in BASE PLATE EACH
SQUARE - CONCRETE FOOTING
4000 PSI 28-DAY STRENGTH
BEARING CAPACITY OF 4000 PSF (30" FROST)



CASE 1A: $P = 335.74^k$ @ 10.095" ℄ ×2
20in × 20in BASE PLATE EACH
COMBINED 48" × 48" CONC. PIER @ 12'-8" HEIGHT
SQUARE - CONCRETE FOOTING
4000 PSI 28 DAY STRENGTH
BEARING CAPACITY OF 4000 PSF (30" FROST)

CASE 2: $P = 347.81^k$ @ 10.095' ℄ ×2
20in × 20in BASE PLATE EACH
SQUARE CONCRETE FOOTING
4000 PSI 28 DAY STRENGTH
BEARING CAPACITY OF 4000 PSF (30" FROST)

NOTE: AS THE TWO COLUMNS WILL LOAD WITH EQUAL LOADS, THE RESULTANT OF THE APPLIED LOADS WILL COINCIDE WITH THE CENTROID OF THE FOOTING. HOWEVER, AS THE TWO COLUMNS ARE SO CLOSE, THEIR INDIVIDUAL FOOTINGS WOULD OVERLAP, REQUIRING A SHARED FOOTING [& PIER AS REQUIRED].

CASE 1: CALCULATION

$P = 2 \times (335.74) = 671.48^k$

LOCATION OF RESULTANT @ 5.0475" (OR AT ℄ OF FOOTING)

$q_A \geq \frac{P}{A} \rightarrow 4\,\text{ksf} \geq \frac{671.48}{B^2}$

$B \geq 12.95'$

USE 13' × 13' FOOTING

$P_D = [9.4^k + 58.47^k + 4[44.7]^k + 19.07^k] \times 2 = 531.48^k$

$P_L = [5[14^k]] \times 2 = 140^k$

$$P_u = 1.2 P_D + 1.6 P_L$$
$$P_u = 1.2[531.48^k] + 1.6[140^k] = 861.776^k$$

$$q = \frac{P_u}{A}$$
$$q = \frac{861.776^k}{(13')^2} = 5.099 \text{ KSF}$$

$$5.099 \text{ ksf} \times 6.39 \frac{\text{PSI}}{\text{KSF}} = 35.13 \text{ PSI}$$

$$V_c = \phi 4\sqrt{f'_c}$$
$$V_c = 0.75(4)\sqrt{4000 \text{ PSI}}$$
$$V_c = 189.74 \text{ PSI}$$

$$d^2(4v_c + q) + d(2v_c + q)(b+c) = q(B^2 - bc)$$

$$d^2(4(190) + 35) + d(2(190) + 35)(20'' + 20'') = 35[(156)^2 - (20'')(20'')]$$

$$d^2(795) + d(16{,}600) = 837{,}760$$

$$d = 23.7''$$

$$h = d + 3'' + d_b$$
$$h = 23.7'' + 3'' + 0.625''$$
$$h = 27.325''$$

USE $h = 30''$

$$d_L = 30'' - 3'' - 0.5(0.625'') = 26.69''$$
$$d_S = 30'' - 3'' - 1.5(0.625'') = 26.06''$$

CHECK WIDE BEAM SHEAR

$$V_{u_L} = 5.099 \text{ ksf}\left[\frac{13' - 1.67'}{2} - 2.22'\right] = 17.57^k$$
$$V_{u_S} = 5.099 \text{ ksf}\left[\frac{13' - 1.67'}{2} - 2.17'\right] = 17.82^k$$

$$\phi V_n = \phi 2\sqrt{f'_c}\, bd$$

$$\phi V_n = 0.75(2)\sqrt{4000}(20'')(26.06'')$$
$$\phi V_n = 49{,}445 \text{ lbs}$$

$$\phi V_n = 49.4^k \geq 17.8^k = V_u$$

LONG DIRECTION

$$l = \frac{1}{2}\left[13' - \left(\frac{20'' + 13.8''}{2}\right)\left(\frac{1'}{12'}\right)\right] = 5.80'$$

$$M_u = \frac{ql^2}{2}$$

$$M_u = \frac{5.099\,ksf\,(5.8')^2}{2} = 85.77'k$$

$$a = \frac{A_s f_y}{0.85 f'_c b}$$

$$a = \frac{A_s(60ksi)}{0.85(4ksi)(20'')} \rightarrow a = 0.88A_s$$

$$M_u = \phi M_n = \phi A_s f_y\left(d - \frac{a}{2}\right)$$

$$85.77'k(12in/ft) = 0.9A_s(60ksi)\left(26.69'' - \frac{0.88A_s}{2}\right)$$

$$19.06 = 26.69A_s - .44A_s^2$$

$$A_s = 0.723\,in^2$$

USE #6 @ 6in O.C. $A_s = 0.88$

$$\rho = \frac{A_s}{bh} = \frac{0.88}{(20'')(30'')} = 0.0014 < 0.0018 \quad \times$$

USE #7 @ 6in O.C. $A_s = 1.2$

$$\rho = \frac{1.2}{(20)(30)} = 0.002 \geq 0.0018 \quad \underline{OK}$$

$$a = 0.88A_s = 0.88(1.2) = 1.056''$$

$$c = \frac{a}{0.85} = \frac{1.056''}{0.85} = 1.24''$$

$$\varepsilon_s = \frac{0.003}{c}(d-c)$$

$$\varepsilon_s = \frac{0.003}{1.24''}(26.69'' - 1.24'') = 0.0616\,in/in \geq 0.005\,in/in \quad \underline{OK}$$

SPACING IS OK BY INSPECTION

→ USE (26) #7 BARS

SHORT DIRECTION

$$l = \left(\frac{13'-6''}{2}\right)\left(\frac{1'}{12''}\right) = 6.25'$$

$$M_u = \frac{5.099\text{ ksf}(6.25')^2}{2} = 99.59'^k$$

$$a = \frac{A_s(60\text{ ksi})}{0.85(4)(20)} = a = 0.88A_s$$

$$M_u = \phi M_n = \phi A_s f_y\left(d - \frac{a}{2}\right)$$

$$99.59'^k(12\text{ in/ft}) = 0.9A_s(60)\left(26.06'' - \frac{0.88A_s}{2}\right)$$

$$22.13 = 26.06A_s - .44A_s$$

$$A_s = 0.86\text{ in}^2$$

USE #7 @ 6in O.C. $A_s = 1.2$

ρ OK

ε_s OK

SPACING IS OK BY INSPECTION

→ USE (26) #7 BARS EACH WAY

$\beta = \frac{13'}{13'} = 1$ → 1(26 BARS) = 26 BARS.

SPACING OK BY INSPECTION

$$\phi B_n = \phi .85 f'_c A_1 \sqrt{\frac{A_2}{A_1}}$$

$$A_1 = (20'')(20'') = 400\text{ in}^2$$

$$A_2 = (156'')(156'') = 24336\text{ in}^2$$

$$\sqrt{\frac{24336}{400}} = 7.8 > 2$$

$$\phi B_n = 0.65(.85)(4\text{ ksi})(400\text{ in}^2)(2) = 1768^k$$

$$\phi B_n = 1768^k \geq 861.776^k$$

CASE 1A.

$P = 2 \times (335.74) = 671.48^k$
$P_D = 531.48^k$
$P_L = 140^k$

$q_A \geq \frac{P}{A} \rightarrow 4 \text{ KSF} \geq \frac{671.48^k}{B^2}$

$B \geq 12.95'$

USE $13' \times 13'$ FOOTING

$P_u = 1.2 P_D + 1.6 P_L$
$P_u = 1.2[531.48] + 1.6[140] = 861.776^k$

$q = \frac{P_u}{A} \rightarrow 5.099 \text{ KSF} = 35.13 \text{ PSI}$

$V_c = 189.74 \text{ PSI}$

2-WAY SHEAR STRESS CONTROLS BY INSPECTION

$$d^2\left(v_c + \frac{q}{4}\right) + d\left(V_c + \frac{q}{2}\right)\omega = \frac{q}{4}(BL - \omega^2)$$

$$d^2\left(190 + \frac{35.13}{4}\right) + d\left(190 + \frac{35.13}{2}\right)(48'') = \frac{35.13}{4}\left((156'')^2 - (48'')^2\right)$$

$$198.78\, d^2 + 9963.12\, d = 193{,}496.04$$

$d = 14.95''$

$h = 14.95'' + 3'' + .625''$
$h = 18.575''$

USE $h = 24''$

$d = 24'' - 3'' - .625'' = 20.375''$

$l = \frac{13-4}{2} = 4.5'$

$M_u = \frac{q l^2}{2} = \frac{5.099(4.5)^2}{2} = 51.63'^k$

$a = \frac{A_s f_y}{.85 f'_c b} = \frac{A_s(60)}{.85(4)(24'')} = 0.735 A_s$

$M_u = \phi M_n = \phi A_s f_y\left(d - \frac{a}{2}\right)$

$51.63(12) = .9 A_s(60)\left(20.375'' - \frac{.735 A_s}{2}\right)$

$$11.47 = 20.375 A_s - .3675 A_s^2$$
$$A_s = 0.57 \text{ in}^2$$

USE #5 @ 6in o.c. $A_s = 0.62 \text{ in}^2$

$$\rho = \frac{A_s}{bh} = \frac{0.62}{(24)(24)} = .00107 < .0018 \quad X$$

USE #6 @ 6in o.c. $A_s = 0.88 \text{ in}^2$

$$\rho = \frac{.88}{(24)(24)} = 0.0015 < 0.0018 \quad X$$

USE #7 @ 6in o.c. $A_s = 1.20 \text{ in}^2$

$$\rho = \frac{1.2}{(24)(24)} = 0.00208 \geq 0.0018 \quad \underline{OK}$$

$$a = 0.735 A_s = 0.735(1.2) = 0.882''$$

$$c = \frac{a}{0.85} = \frac{.882}{.85} = 1.037''$$

$$\varepsilon_s = \frac{0.003}{c}(d - c)$$

$$\varepsilon_s = \frac{0.003}{1.037}(20.375 - 1.037) = 0.0559 \geq 0.005 \text{ in/in}$$

$$\therefore \phi = .9$$

SPACING IS OK BY INSPECTION

USE (26) #7 BARS EACH WAY.

$$\phi B_n = \phi .85 f'_c A_1$$
$$= .65(.85)(4)(48'')^2$$
$$= 5092 \text{ k}$$

$$\phi B_n = 5092 \text{k} \geq 861.776^k = P_u$$

$$A_{s_{min}} = 0.005 A_{col}$$

$$A_{s_{min}} = 0.005(48'')^2$$

$$A_{s_{min}} = 11.52''$$

USE (12) #9 $A_s = 12 \text{ in}^2$

CASE 2: CALCULATION

$P = 2 \times (347.81^k) = 695.62^k$

LOCATION OF RESULTANT @ ℄ OF FOOTING

$q_A \geq \frac{P}{A} \rightarrow 4\text{ KSF} \geq \frac{695.62}{B^2}$

$B \geq 13.18'$

USE 13.5' × 13.5' FOOTING

$P_D = [28.34^k + 5[33^k] + 19.07^k] \times 2 = 424.82^k$

$P_L = [5[27.08^k]] \times 2 = 270.8^k$

$P_u = 1.2 P_D + 1.6 P_L$

$P_u = 1.2(424.82) + 1.6(270.8) = 943.06^k$

$q = \frac{P_u}{A}$

$q = \frac{943.06^k}{(13.5')^2} = 5.17\text{ KSF} \rightarrow 35.65\text{ PSI}$

$V_c = \phi 4 \sqrt{f'_c} = 189.74\text{ PSI}$

$d^2(4(190) + 36) + d(2(190) + 36)(20'' + 20'') = 36[(162)^2 - (20)(20)]$

$d^2(796) + d(16640) = 930,384$

$d = 25.3''$

$h = 25.3'' + 3'' + .625''$

$h \sim 28.9''$

USE $h = 30''$

$d_L = 26.69''$

$d_S = 26.06''$

CHECK WIDE BEAM

$V_{uL} = 5.17\text{ KSF}\left[\frac{13.5 - 1.67'}{2} - 2.22'\right] = 19.1^k$

$V_{uS} = 5.17\text{ KSF}\left[\frac{13.5 - 1.62}{2} - 2.17'\right] = 19.4^k$

$\phi V_n = \phi 2 \sqrt{f'_c}\, bd = 49.4^k$

$\phi V_n = 49.4^k \geq 19.4^k$

$$M_u = \phi M_n = \phi A_s f_y \left(d - \frac{a}{2}\right)$$

$$M_u = \frac{5.17\left(\frac{13.5 - .5}{2}\right)}{2} = 109.21^k$$

$$109.21(12) = 0.9 A_s (60)\left(26.06'' - \frac{.88 A_s}{2}\right)$$

$$24.27^k = 26.06 A_s - .44 A_s^2$$

$$A_s = 0.91 \text{ in}^2$$

USE #7 @ 6in O.C.

ρ OK

ε_s OK

SPACING IS OK BY INSPECTION

→ USE (27) #7 BARS EACH WAY

$$\phi B_n = \phi .85 f_c' A_1 \sqrt{\frac{A_2}{A_1}}$$

$$A_1 = 400 \text{ in}^2$$
$$A_2 = 13.5^2 = 26244 \text{ in}^2$$

$$\sqrt{\frac{26244}{400}} = 8.1 > 2$$

$$\phi B_n = .65(.85)(4)(400)(2) = 1768^k$$

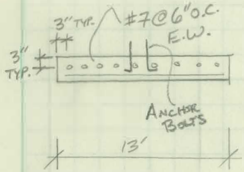
$$\phi B_n = 1768^k \geq 861.776^k$$

CASE 1

13' × 13' @ 30"

(26) #7 BARS E.W.

@ 6" O.C.

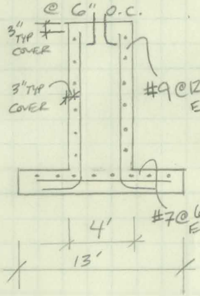


CASE 1A

13' × 13' @ 30"

(26) #7 BARS E.W.

@ 6" O.C.

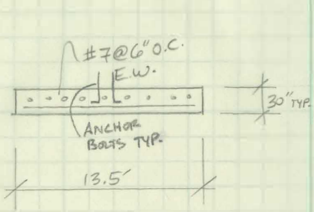


CASE 2

13.5' × 13.5' @ 30"

(27) #7 BARS E.W.

@ 6" O.C.



APPENDIX M | EXPANSION JOINT QTO & ESTIMATE

Ground Level Sector A & B										
CSI Number	System	Total Units	Material	Labor	Equipment	Total	Material Cost	Labor Cost	Equipment Cost	Total Cost
03 31	***Structural Concrete***									
	Floor: 4" NW Concrete	**6.64**								
4840	SOG (3500psi), no reinforcing	CY	**2.59**	**0.88**	**0.01**	**3.48**	**$ 17.20**	**$ 5.84**	**$ 0.07**	**$ 23.11**
200	3500 psi	CY	**99.5**	**0**	**0**	**99.5**	**$ 660.68**	**$ -**	**$ -**	**$ 660.68**
03 22 05.50	***Welded Wire Fabric- ASTM A185***									
	W6x6-W1.4xW1.4 WWF	**4.1**								
200	W6x6-W2.1xW2.1 WWF	C-SF	**18.9**	**25**	**0**	**43.9**	**$ 77.49**	**$ 102.50**	**$ -**	**$ 179.99**

First Level Sector A & B										
CSI Number	System	Total Units	Material	Labor	Equipment	Total	Material Cost	Labor Cost	Equipment Cost	Total Cost
05 12 23.17	***Columns, Structural***									
	W14x48: 4	**224**								
3702	W18x50	LF	**62**	**4.2**	**1.9**	**68.1**	**$ 13,888.00**	**$ 940.80**	**$ 425.60**	**$ 15,254.40**
	W14x43: 2	**104**								
3102	W16x40	LF	**49.5**	**3.32**	**2.03**	**54.85**	**$ 5,148.00**	**$ 345.28**	**$ 211.12**	**$ 5,704.40**
05 31 13.50	***Floor Decking***									
	3" 18 Gage Lok-Floor Composite Deck	**396.5**								
5900	Non-cellular composite decking, galvanized, 3" deep, 18 gauge	SF	**2**	**0.55**	**0.04**	**2.59**	**$ 793.00**	**$ 218.08**	**$ 15.86**	**$ 1,026.94**
03 31	***Structural Concrete***									
	Floor: 3 1/4" LW Concrete	**5.8**								
1400	Elevated Slabs, less than 6" thick, pumped	CY	**0**	**16.8**	**5.6**	**22.4**	**$ -**	**$ 97.44**	**$ 32.48**	**$ 129.92**
200	3500 psi	CY	**99.5**	**0**	**0**	**99.5**	**$ 577.10**	**$ -**	**$ -**	**$ 577.10**
03 22 05.50	***Welded Wire Fabric- ASTM A185***									
	W6x6-W2.0xW2.0 WWF	**4.1**								
200	W6x6-W2.1xW2.1 WWF	C-SF	**18.9**	**25**	**0**	**43.9**	**$ 77.49**	**$ 102.50**	**$ -**	**$ 179.99**
05 12 23.40	***Lightweight Framing***									
	ž3x3x5/16	**324**								
476	Angle 3"x3"x3/8"	LF	**4.86**	**20.5**	**1.91**	**27.27**	**$ 6,642.00**	**$ 618.84**	**$ 618.84**	**$ 8,835.48**

Second Level Sector A & B										
CSI Number	System	Total Units	Material	Labor	Equipment	Total	Material Cost	Labor Cost	Equipment Cost	Total Cost
05 12 23.17	***Columns, Structural***									
	W14x48: 4	**224**								
3702	W18x50	LF	**62**	**4.2**	**1.9**	**68.1**	**$ 13,888.00**	**$ 940.80**	**$ 425.60**	**$ 15,254.40**
	W14x43: 2	**104**								
3102	W16x40	LF	**49.5**	**3.32**	**2.03**	**54.85**	**$ 5,148.00**	**$ 345.28**	**$ 211.12**	**$ 5,704.40**
05 31 13.50	***Floor Decking***									
	3" 18 Gage Lok-Floor Composite Deck	**396.5**								
5900	Non-cellular composite decking, galvanized, 3" deep, 18 gauge	SF	**2**	**0.55**	**0.04**	**2.59**	**$ 793.00**	**$ 218.08**	**$ 15.86**	**$ 1,026.94**
03 31	***Structural Concrete***									
	Floor: 3 1/4" LW Concrete	**5.8**								
1400	Elevated Slabs, less than 6" thick, pumped	CY	**0**	**16.8**	**5.6**	**22.4**	**$ -**	**$ 97.44**	**$ 32.48**	**$ 129.92**
200	3500 psi	CY	**99.5**	**0**	**0**	**99.5**	**$ 577.10**	**$ -**	**$ -**	**$ 577.10**
03 22 05.50	***Welded Wire Fabric- ASTM A185***									
	W6x6-W2.0xW2.0 WWF	**4.1**								
200	W6x6-W2.1xW2.1 WWF	C-SF	**18.9**	**25**	**0**	**43.9**	**$ 77.49**	**$ 102.50**	**$ -**	**$ 179.99**
05 12 23.40	***Lightweight Framing***									
	ž3x3x5/16	**324**								
476	Angle 3"x3"x3/8"	LF	**4.86**	**20.5**	**1.91**	**27.27**	**$ 6,642.00**	**$ 618.84**	**$ 618.84**	**$ 8,835.48**

Third Level Sector A & B										
CSI Number	System	Total Units	Material	Labor	Equipment	Total	Material Cost	Labor Cost	Equipment Cost	Total Cost
05 12 23.17	***Columns, Structural***									
	W14x48: 4	**224**								
3702	W18x50	LF	**62**	**4.2**	**1.9**	**68.1**	**$ 13,888.00**	**$ 940.80**	**$ 425.60**	**$ 15,254.40**
	W14x43: 2	**104**								
3102	W16x40	LF	**49.5**	**3.32**	**2.03**	**54.85**	**$ 5,148.00**	**$ 345.28**	**$ 211.12**	**$ 5,704.40**
05 31 13.50	***Floor Decking***									
	3" 18 Gage Lok-Floor Composite Deck	**396.5**								
5900	Non-cellular composite decking, galvanized, 3" deep, 18 gauge	SF	**2**	**0.55**	**0.04**	**2.59**	**$ 793.00**	**$ 218.08**	**$ 15.86**	**$ 1,026.94**
03 31	***Structural Concrete***									
	Floor: 3 1/4" LW Concrete	**5.8**								
1400	Elevated Slabs, less than 6" thick, pumped	CY	**0**	**16.8**	**5.6**	**22.4**	**$ -**	**$ 97.44**	**$ 32.48**	**$ 129.92**
200	3500 psi	CY	**99.5**	**0**	**0**	**99.5**	**$ 577.10**	**$ -**	**$ -**	**$ 577.10**
03 22 05.50	***Welded Wire Fabric- ASTM A185***									
	W6x6-W2.0xW2.0 WWF	**4.1**								
200	W6x6-W2.1xW2.1 WWF	C-SF	**18.9**	**25**	**0**	**43.9**	**$ 77.49**	**$ 102.50**	**$ -**	**$ 179.99**
05 12 23.40	***Lightweight Framing***									
	ž3x3x5/16	**324**								
476	Angle 3"x3"x3/8"	LF	**4.86**	**20.5**	**1.91**	**27.27**	**$ 6,642.00**	**$ 618.84**	**$ 618.84**	**$ 8,835.48**

Fourth Level Sector A & B										
CSI Number	System	Total Units	Material	Labor	Equipment	Total	Material Cost	Labor Cost	Equipment Cost	Total Cost
05 12 23.17	***Columns, Structural***									
	W14x48: 4	**224**								
3702	W18x50	LF	**62**	**4.2**	**1.9**	**68.1**	**$ 13,888.00**	**$ 940.80**	**$ 425.60**	**$ 15,254.40**
	W14x43: 2	**104**								
3102	W16x40	LF	**49.5**	**3.32**	**2.03**	**54.85**	**$ 5,148.00**	**$ 345.28**	**$ 211.12**	**$ 5,704.40**
05 31 13.50	***Floor Decking***									
	3" 18 Gage Lok-Floor Composite Deck	**396.5**								
5900	Non-cellular composite decking, galvanized, 3" deep, 18 gauge	SF	**2**	**0.55**	**0.04**	**2.59**	**$ 793.00**	**$ 218.08**	**$ 15.86**	**$ 1,026.94**
03 31	***Structural Concrete***									
	Floor: 3 1/4" LW Concrete	**5.8**								
1400	Elevated Slabs, less than 6" thick, pumped	CY	**0**	**16.8**	**5.6**	**22.4**	**$ -**	**$ 97.44**	**$ 32.48**	**$ 129.92**
200	3500 psi	CY	**99.5**	**0**	**0**	**99.5**	**$ 577.10**	**$ -**	**$ -**	**$ 577.10**
03 22 05.50	***Welded Wire Fabric- ASTM A185***									
	W6x6-W2.0xW2.0 WWF	**4.1**								
200	W6x6-W2.1xW2.1 WWF	C-SF	**18.9**	**25**	**0**	**43.9**	**$ 77.49**	**$ 102.50**	**$ -**	**$ 179.99**
05 12 23.40	***Lightweight Framing***									
	ž3x3x5/16	**324**								
476	Angle 3"x3"x3/8"	LF	**4.86**	**20.5**	**1.91**	**27.27**	**$ 6,642.00**	**$ 618.84**	**$ 618.84**	**$ 8,835.48**

Penthouse Level Sector A & B										
CSI Number	System	Total Units	Material	Labor	Equipment	Total	Material Cost	Labor Cost	Equipment Cost	Total Cost
05 12 23.17	***Columns, Structural***									
	W14x43: 6	**328**								
3102	W16x40	LF	**49.5**	**3.32**	**2.03**	**54.85**	**$ 16,236.00**	**$ 1,088.96**	**$ 665.84**	**$ 17,990.80**
05 31 13.50	***Floor Decking***									
	3" 18 Gage Lok-Floor Composite Deck	**239.25**								
5900	Non-cellular composite decking, galvanized, 3" deep, 18 gauge	SF	**2**	**0.55**	**0.04**	**2.59**	**$ 478.50**	**$ 131.59**	**$ 9.57**	**$ 619.66**
	1 1/2" 22 Gage Type 'B' Metal Roof Deck	**214.65**								
2400	Open Type, 1-1/2" deep, Type B, 22 Ga.	SF	**1.02**	**0.31**	**0.02**	**1.35**	**$ 218.94**	**$ 66.54**	**$ 4.29**	**$ 289.78**
03 31	***Structural Concrete***									
	Floor: 3 1/4" LW Concrete	**2.32**								
1400	Elevated Slabs, less than 6" thick, pumped	CY	**0**	**16.8**	**5.6**	**22.4**	**$ -**	**$ 38.98**	**$ 12.99**	**$ 51.97**
200	3500 psi	CY	**99.5**	**0**	**0**	**99.5**	**$ 230.84**	**$ -**	**$ -**	**$ 230.84**

	Floor: 5" NW Concrete	**3.48**								
1400	Elevated Slabs, less than 6" thick, pumped	CY	**0**	**16.8**	**5.6**	**22.4**	**$ -**	**$ 58.46**	**$ 19.49**	**$ 77.95**
200	3500 psi	CY	**99.5**	**0**	**0**	**99.5**	**$ 346.26**	**$ -**	**$ -**	**$ 346.26**
03 22 05.50	***Welded Wire Fabric- ASTM A185***									
	W6x6-W2.0xW2.0 WWF	**1.64**								
200	W6x6-W2.1xW2.1 WWF	C-SF	**18.9**	**25**	**0**	**43.9**	**$ 31.00**	**$ 41.00**	**$ -**	**$ 72.00**
	W6x6-W2.9xW2.9 WWF	**2.46**								
300	W6x6-W2.9xW2.9 WWF	C-SF	**21.5**	**26.5**	**0**	**48**	**$ 52.89**	**$ 65.19**	**$ -**	**$ 118.08**
05 12 23.40	***Lightweight Framing***									
	ž3x3x5/16	**324**								
476	Angle 3"x3"x3/8"	LF	**4.86**	**20.5**	**1.91**	**27.27**	**$ 6,642.00**	**$ 618.84**	**$ 618.84**	**$ 8,835.48**

Column Systems										
CSI Number	**System**	**Total Units**	**Material**	**Labor**	**Equipment**	**Total**	**Material Cost**	**Labor Cost**	**Equipment Cost**	**Total Cost**
05 12 23.17	***Columns, Structural***									
	W12x50	**296.00**								
902	W10x49	LF	**60.5**	**4.82**	**2.95**	**68.27**	**$ 17,908.00**	**$ 1,426.72**	**$ 873.20**	**$ 20,207.92**
	W12x40	**856**								
2302	W14x34	LF	**42**	**3.27**	**2**	**47.27**	**$ 35,952.00**	**$ 2,799.12**	**$ 1,712.00**	**$ 40,463.12**

Foundation Systems										
CSI Number	**System**	**Total Units**	**Material**	**Labor**	**Equipment**	**Total**	**Material Cost**	**Labor Cost**	**Equipment Cost**	**Total Cost**
03 03 53.40	***Concrete In Place***									
	Footing: 2'-6" Thick Concrete	**130.09**								
3848	Spread Footings (4000psi) over 5 CY	CY	**190**	**61.5**	**0.31**	**251.81**	**$ 24,717.10**	**$ 8,000.54**	**$ 40.33**	**$ 32,757.96**
03 21 05	***Reinforcing Steel***									
	Reinforcing Bars	**416**								
120	#7 Bars	Bars	**7.45**	**9.3**	**0**	**16.75**	**$ 3,099.20**	**$ 3,868.80**	**$ -**	**$ 6,968.00**
	Reinforcing Bars	**12**								
305	#9 Bars	Bars	**14.1**	**25**	**7.15**	**46.25**	**$ 169.20**	**$ 300.00**	**$ 85.80**	**$ 555.00**

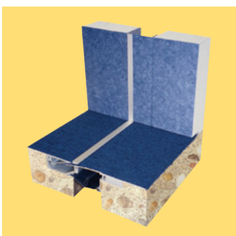
Foundation Systems										
CSI Number	**System**	**Total Units**	**Material**	**Labor**	**Equipment**	**Total**	**Material Cost**	**Labor Cost**	**Equipment Cost**	**Total Cost**
07 95 13	***Expansion Joint Cover Assemblies***									
	Floor Plate Cover Track	**648**								
	Nystrom EJ-TMM-200W	LF	**21.5**	**9.05**	**0**	**30.55**	**$ 13,932.00**	**$ 5,864.40**	**$ -**	**$ 19,796.40**
	Wall Plate Cover Track	**480**								
	Nystrom EJ-TMM-200w-W	LF	**18.1**	**9.05**	**0**	**27.15**	**$ 8,688.00**	**$ 4,344.00**	**$ -**	**$ 13,032.00**
	Roof Plate Cover Track	**162**								
	Nystrom EJ-RJ-200	LF	**40**	**6.05**	**0**	**46.05**	**$ 6,480.00**	**$ 980.10**	**$ -**	**$ 7,460.10**

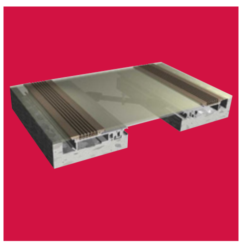
Expansion Joint System Total Cost	**$ 297,569.99**

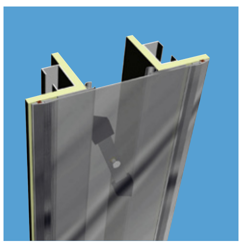
APPENDIX N | NYSTROM EXPANSION JOINT PRODUCT GUIDE

Expansion Joint Systems

Complementary Building Products





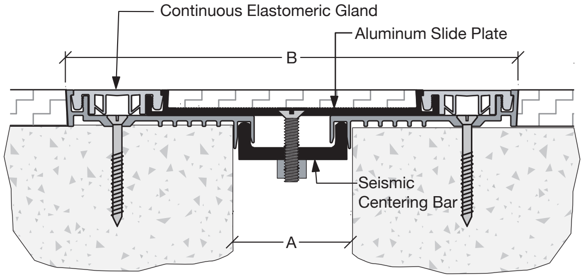


NYSTROM®

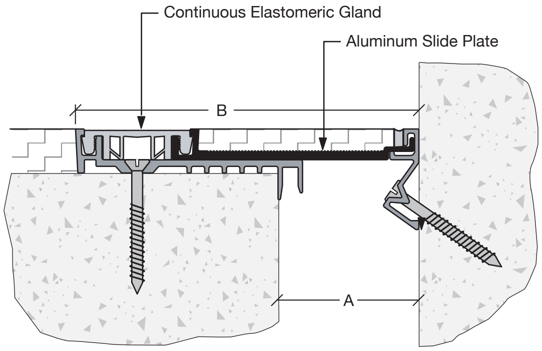
Right to site.

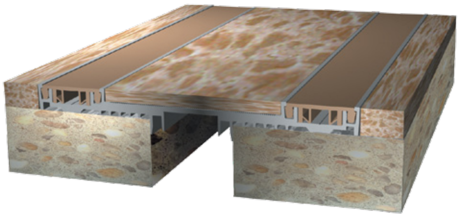
Double Seam

TMM



TMMw





- No visible hardware for extra aesthetic appeal
- Flat seal design
- No block-outs required
- Accepts most finished flooring
- Suggested for vertical gyp. board applications

EXPANSION & CONTRACTION
FIRE RATED
VERTICAL DISPLACEMENT
ADA GUIDELINE COMPLIANT
LATERAL SHEAR

Standard Colors

Black (-B) Gray (-G) White (-W) Beige (-E)

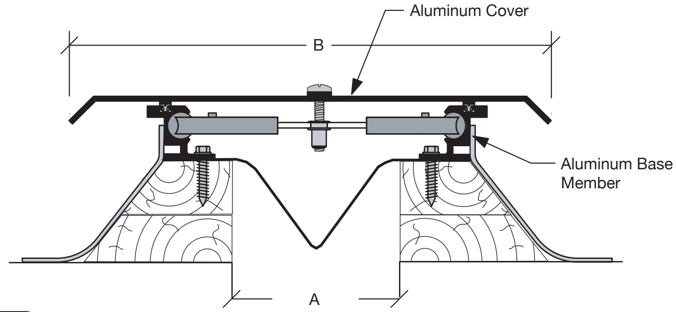
Add the hyphen and color code at the end of the model number to specify color. Ex: EJ-TMF-300-G

Floor to Floor	Joint Opening (A)		System Width (B)		Total Movement	
Model #	in	mm	in	mm	in	mm
EJ-TMM-200	2.0	51	7.75	197	4.25	108
EJ-TMM-400	4.0	102	9.75	248	6.25	159
EJ-TMM-600	6.0	152	11.75	298	8.25	210

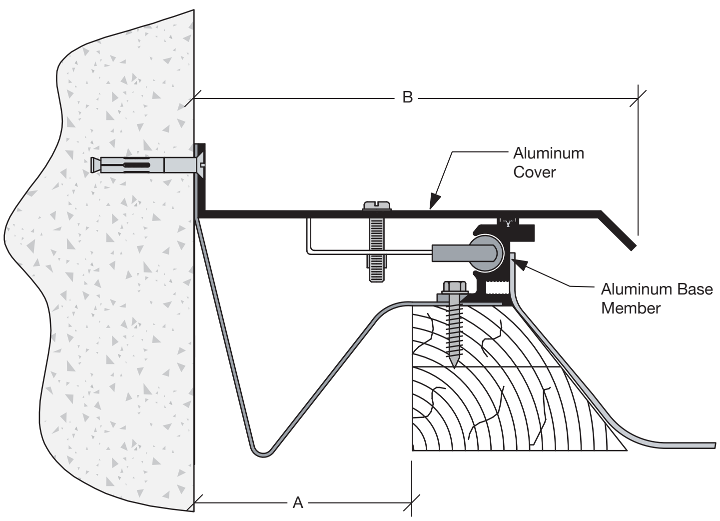
Floor to Wall	Joint Opening (A)		System Width (B)		Total Movement	
Model #	in	mm	in	mm	in	mm
EJ-TMM-200w	2.0	51	4.88	124	2.5	64
EJ-TMM-400w	4.0	102	6.88	175	4.5	114
EJ-TMM-600w	6.0	152	8.88	225	6.5	165

Roof Cover

RJS



RJSw



- Flat or sloped roofs
- Engineered for snow and ice loads
- Puncture proof

EXPANSION & CONTRACTION
FIRE RATED
VERTICAL DISPLACEMENT
WATER PROOF
LATERAL SHEAR

Roof to Roof	Joint Opening (A)		System Width (B)		Total Movement	
Model #	in	mm	in	mm	in	mm
EJ-RJS-200	2.0	51	8.0	203	3.0	76
EJ-RJS-400	4.0	102	11.0	279	6.0	152
EJ-RJS-600	6.0	152	14.0	356	9.0	229
EJ-RJS-800	8.0	203	17.0	432	12.0	305
EJ-RJS-1000	10.0	254	20.0	508	15.0	381
EJ-RJS-1200	12.0	305	23.0	584	18.0	457
EJ-RJS-1800	18.0	457	32.0	813	27.0	686
EJ-RJS-2400	24.0	610	41.0	1041	36.0	914

Roof to Corner	Joint Opening (A)		System Width (B)		Total Movement	
Model #	in	mm	in	mm	in	mm
EJ-RJS-200w	2.0	51	5.5	140	3.00	76
EJ-RJS-400w	4.0	102	8.5	216	6.00	152
EJ-RJS-600w	6.0	152	11.5	292	9.00	229
EJ-RJS-800w	8.0	203	14.5	368	12.00	305
EJ-RJS-1000w	10.0	254	17.5	445	9.75	248
EJ-RJS-1200w	12.0	305	20.5	521	11.75	298
EJ-RJS-1800w	18.0	457	29.5	749	17.75	451
EJ-RJS-2400w	24.0	610	38.5	978	23.75	603

For the latest CAD, BIM, Spec, LEED, and general product information, please visit NYSTROM.com