Baltimore Washington Medical Center
Women's Center and Inpatient Tower

Glen Burnie, MD

Final Senior Thesis Report

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Baltimore Washington Medical Center
Women's Center and Inpatient Tower Glen Burnie, MD

Project Information

Name: Women's Center and Inpatient Tower
Occupant: Baltimore Washington Medical Center
Size: 310,300 SF, 10 Stories
Dates of Construction: July 2006- March 2009
Cost: Building: $59,386,202; Overall: $68,173,861
Project Delivery Method: CM @ Risk

Project Team

Owner: University of Maryland Medical System
Construction Manager: Whiting-Turner Contracting
Architect: Cannon Design
Structural Engineer: Whitney, Bailey, Cox, & Magnani
Mechanical/Plumbing Engineer: Leach Wallace
Geotechnical Engineer: Marshall Engineering

Architecture

- The façade composed of tan brick veneer, glass curtain-wall, and an EIFS System with ribbon window units.
- Two bridges join the Patient Tower and West Lobby Area to the existing hospital
- Atrium with three angled skylights provides a relaxing space with plenty of natural sunlight .
- Patient rooms, exam rooms, sleep rooms, diagnostic-testing, labor and c-section rooms, and infusion rooms

Structural System

- <u>Foundation:</u> 4000psi Concrete Spread Footings and helical piers supporting existing hospital
- <u>Primary Framing System:</u> 5000psi Cast-in-place concrete slabs with 6 ½" drop panels at each column
- <u>Framing above existing mechanical room:</u> Steel Truss framing with Precast Hollow-core concrete planks and concrete topping
- <u>Bridge Framing:</u> steel framing with 3 ¼" thick concrete slab on composite metal decking.

Mechanical

- Two Air-Handling Units with capacity of 102,000 CFM
- One Air-Handling Unit with a capacity of 45,000 CFM
- One Centrifugal Chiller with a capacity of 1000 Tons
- Two Cooling Towers capacity of 500 Tons serving chiller

Plumbing

- Medical Gas/Vacuum Zone Valve Boxes: vacuum, oxygen, medical air, and high pressure oxygen outlets
- Medical Air Compressor with capacity of 50psi/ 60 SCFM

Electrical

- 13.2KV Primary service distributed
- Secondary service is 480Y/ 277V, 3 Phase, 4 Wire
- One 13.2KV switchgear switches two primary 2000KVA Transformers
- One 13.2KV switchgear switches two primary 3000KVA Transformers
- Thirty-two 480- 208/120V transformers ranging from 30 to 150KVA
- One Emergency Generator Switchgear
- Two 1500KW, 480Y/277V Diesel Engine-Generators
- Two 480V Motors

Megan Wortman | Construction Management
http://www.engr.psu.edu/ae/thesis/portfolios/2008/mlw268/

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF EQUATIONS

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Jason Verhey (PE) -Whiting-Turner
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Mike Sheehan (Architect)- Cannon Design
Chris Miller (Concrete Subcontractor)- Belfast Valley Concrete
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1.0 EXECUTIVE SUMMARY

Presented in my senior thesis report, is an in depth analysis of the Baltimore Washington Medical Center- Women's Center and Inpatient Tower Project in Glen Burnie, MD. The report provides information about the project's background, which provides a description of the architecture and engineering systems involved with the building. An overview of the construction process is also documented in the report. This includes a description of the project team, the owner, existing conditions and site logistics, and an analysis of the project's budget and schedule.

Provided within the report is a background of the project along with an investigation of three topic areas. The report documents the findings from a critical issue research topic relating to the project as well as two technical analyses that focus on some aspect of the building. The breakdown of the report includes project background, construction overview, a critical industry issue (technical analysis #1), and two technical analyses.

The critical industry issue looks at developing a process for comparing two systems using 4D Modeling. The process was used to compare both of the technical analyses, which included a comparison of two façade systems and two structural systems. The 4D Model compared the schedule durations and sequences for the two systems for each technical analysis. The process and results were documented in the report.

The second technical analysis addressed an area of the structural system that was designed differently from the rest of the structure. This area of the building has a different design due to the existing mechanical room that exists below this area. In the analysis, an alternative system is chosen for this area of the structure. The study includes a structural design of the system along with a comparison of the two systems' cost estimates, schedule durations and sequences, and the constructability.

The third technical analysis focuses on the façade system for the building. The original design for the façade was replaced with an alternative system during the value engineering phase of the project. For this analysis, the original design is being compared to the value-engineered solution. The investigation of the two systems deals with a comparison of the thermal quality, structural impact of the systems, initial and life cycle costs, schedule durations and sequencing, and constructability.

2.0 PROJECT BACKGROUND

2.1 Architecture and General Project Information

Located at 301 Hospital Drive, the Women's Center and Inpatient Tower is one of two new additions being built at the Baltimore Washington Medical Center in Glen Burnie, Maryland. The Baltimore Washington Medical Center, which is part of the University of Maryland Medical System, provides medical services for communities located between the Baltimore and Annapolis regions. With the addition of the Women's Center and Inpatient Tower, the Baltimore Washington Medical Center will become an extensive care center for all patients throughout the state of Maryland.

The new Patient Tower, which sits on top of what was an existing parking lot, is located adjacent to the existing six-story hospital and directly behind the main parking garage. Connected to the Patient Tower is the West Lobby Area, which is considered to be the front entrance of the tower. The West Lobby has a curved glass façade, and it is the only section of the tower that is completely visible from the entrance of the Medical Center. The West Lobby provides access to all levels of the new Patient Tower and also to the existing hospital. Figure 1 shows an image of the site model.

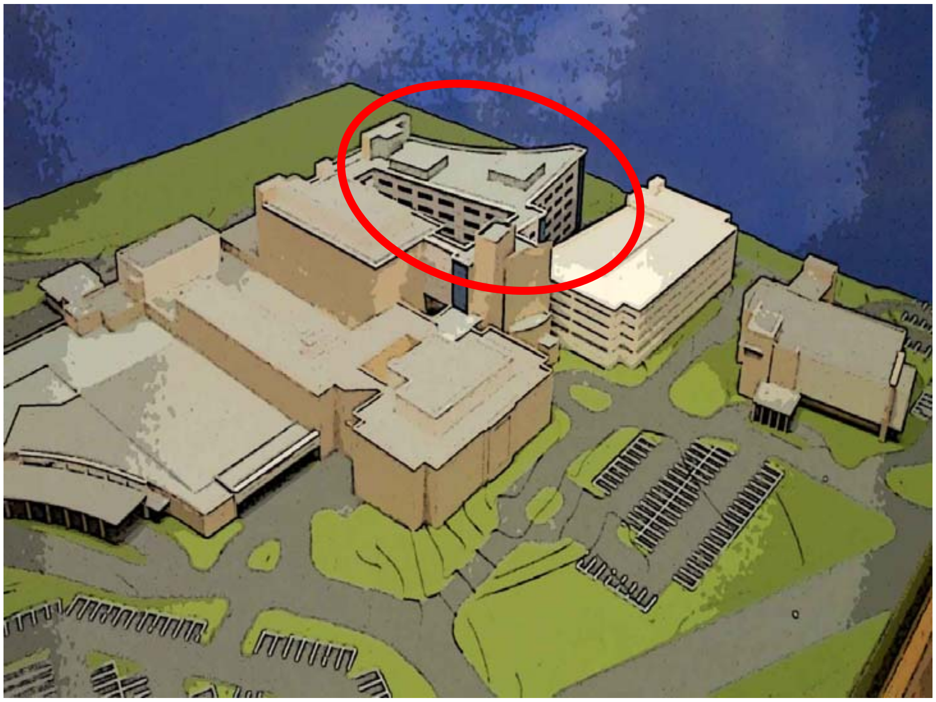


Figure 1: Site Plan Model of Baltimore Washington Medical Center Site

A bridge, which spans from the lobby area to the hospital and extends from level three through six, allows patients and guests to access the existing building using the West Lobby Entrance. Also located between the lobby area and hospital, is a small atrium. The atrium has three angled skylights, which allows plenty of natural light to enter the space. The Patient Tower itself is also connected to the existing hospital by a bridge. The bridge is located at the south edge of the building. This connector bridge joins the new patient rooms to the existing patient rooms for levels two through six.

The Patient Tower consists of a lower level, levels one through eight, and a roof penthouse. The lower level houses some mechanical equipment and most of the electrical equipment such as the generators and switch gear. Levels one through six consist of patient rooms, exam rooms, diagnostic testing rooms, c-section and labor rooms, infusion rooms, and sleep rooms. There are also nurse stations, waiting rooms, work areas, staff locker room and lounge areas, offices, and control stations located throughout these floors. Levels seven and

eight are considered to be core and shell floors that are planned for future fit-out. The roof penthouse contains most of the mechanical equipment including two air handling units, two cooling towers, and one chiller.

2.2 Building Envelope

The building envelope was designed to match the color and style of Baltimore Washington Medical Center's Tate Cancer Center. This style consists of a variety of façade materials including glass curtain wall and windows, tan brick veneer, and EIFS panels. Most of the north, east, and west building façades are made up of the EIFS system with ribbon window units. On the north and west facades, tan brick veneer with ribbon window units extends from the lower level to level two. A glass curtain wall system is used for the West Lobby along with Stair Tower #2, which is located on the northwest corner of the Patient Tower. The façade for Stair Tower #1, which is located at the West Lobby Area, is tan brick veneer. Stair Tower #3, which is located at the southwest corner of the tower, is also tan brick veneer. The Roof Penthouse is composed of a composite metal panel system. The roof system for the Penthouse level is composed of an adhered EPDM sheet roofing with tapered rigid insulation on cast-in-place concrete. The main roof system is consists of an adhered EPDM sheet roofing with tapered rigid insulation on metal decking and structural metal framing. See Figure 2 for an image of the building façade.

<u>EIFS System</u>:
EIFS (Exterior Insulation Finish System) panels on R11 Batt Insulation and 3 5/8" Metal Stud

<u>Brick Veneer System</u>:
Tan Face Brick with 3" Rigid Insulation on either a CIP Concrete Wall or an 8" CMU Block Wall.

<u>Glass Curtain Wall</u>:
¼" Spandrel Glass and 1" Low E Tinted Insulated Glass

<u>Ribbon Window Units</u>:
Aluminum Window: ¼" Spandrel Glass and 1" Low E Tinted Insulated Glass
Accented Metal Panels

<u>Composite Metal Panels</u>:
Aluminum Faced Composite Panels with R19 Batt Insulation on an 8" stud.

Figure 2: Image of Building Facade

2.3 Primary Engineering Systems

2.3.1 Structural System

The primary structural system for the new tower is a cast-in-place concrete system. The patient tower area is composed of 9 ½" thick concrete slabs with 6 ½" drop panels at each square column. The strength of the concrete in this area is 5000psi for the floor slabs, 8000 psi for columns up to level three, and 6000 psi for columns on levels three and above. The west lobby area is composed of 12" thick concrete slabs with no drop panels at each of the circular columns. The strength of the concrete in this area is 6000 psi for the floor slabs, 8000 psi for columns up to level three, and 6000 psi for columns on levels three through nine. Structural steel framing was also used for a portion of the structural system. Structural steel framing is used as the support system for the area above the existing mechanical room. The steel truss system is located at the northeast corner of the new Women's Center and Inpatient Tower. The steel framed truss supports the area above the existing mechanical room for levels three through eight and the penthouse level. The truss system consists of ASTM A-992 wide-flange beams and columns. The wide-flange shapes range in size from W10x45 to W14x283. On level three, ASTM A-36 hollow structural sections are used as bracing for the truss system. The hollow structural sections range in size from HSS10x6x5/16 to HSS16x12x5/8. Precast hollow-core concrete planks are used as the floor system for the area above the existing mechanical room. The precast planks are 8" thick by 48" wide with a 2" concrete topping that is placed over the precast slabs. The structural steel truss supports the concrete planks. The planks have embedded plates with two headed studs, which allow them to connect to the structural steel. These embedded plates are welded to the steel truss using a 1/4" thick, 4" long fillet weld. Structural steel framing is also used for the two bridges that connect the new patient tower to the existing hospital. The structural steel framing used for the bridges consists of ASTM A-992 wide-flange columns and beams. The wide-flange shapes range in size from W14x35 to W14x45. The floor system for these bridges is a 3 ¼" composite concrete slab on 1 ½" thick, 20 gage metal decking. The framing used for the penthouse level is a series of ASTM A-992 wide-flange columns and beams. The wide-flange shapes range in size from W8x13 to W24x62. In Figure 3, an image of the Patient Tower's structure is illustrated.

Figure 3: Image of Patient Tower Structure

2.3.2 Mechanical System

The mechanical system used for the patient tower consists of 3 central air handling units, two of which are located in the penthouse and one that is located on the roof level of the West Lobby. The two units located in the penthouse each have a capacity of 102,000CFM. The third unit, which is located on the roof level of the West Lobby, has a capacity of 45,000CFM. These air handling units serve the individual variable air volume (VAV) supply air terminal units that are located throughout the building. The VAV units, which have hot water heating coils, serve as the distribution system for the building. The penthouse also contains two cooling towers, each with a capacity of 500 Tons. These two cooling towers serve one centrifugal chiller with a capacity of 1000 Tons, which is also located in the penthouse. Figure 4 shows an image of a cooling tower being brought to the site.

Figure 4: Image of Mechanical Cooling Tower

2.3.3 Electrical System

The primary service distributed to the building is 13.2KV. The primary service runs to the main switchgear. The main switchgear then supplies secondary service to the rest of the building. The secondary service is 480Y/ 277V, 3 Phase, 4 Wire. Most of the electrical system for the building is located in the central plant electrical room on the lower level. Some of the equipment is also located in the penthouse electrical room. The central plant electrical room houses the main service switchgear (13.2KV) substation with two 3000KVA transformers. Also located in the central plant, are two 1500KW, 480Y/277V Diesel Engine-Generators. The penthouse electrical room houses another main service switchgear (13.2KV) substation with two 2000KVA transformers and also a switch gear for the emergency generators. The lower level and levels one through six each have an electrical room, which houses three to four 480 to 208/120V transformers and a series of panel boards for each level. See Figure 5 for image of a generator.

Figure 5: Image of Generator

2.3.4 Lighting

The primary system used for the patient tower is fluorescent lighting. The lighting used for the majority of the spaces consists of 2x2 and 2x4 recessed, lensed fluorescent lighting. Patient rooms, reception areas, and nurse stations also utilize 6" downlights as part of the lighting for the areas. The West Lobby Area, which is the main entrance of the tower, is composed of 4" downlights, 2x2 direct/ indirect recessed lights, and 6"x8' narrow recessed lighting.

2.4 Additional Engineering and Engineering Support Systems

2.4.1 Telecommunications

The main telecommunications grounding bus bar is located on the Lower Level of the patient tower. At each level, there is a telecommunications grounding bus bar that connects to the bonding backbone, which runs from the main bus bar to all the levels. Also located on each level is a 19" floor rack, which contains data equipment, television equipment, telephone equipment, monitoring equipment, and security. The data cables run from the main floor rack on the lower level to the floor racks on each level.

2.4.2 Fire Protection System

The primary sprinkler system used for the building is a wet pipe system. The system is used throughout the patient tower excluding the generator and electrical rooms located on the lower level. A pre-action sprinkler system with heat and ionization detectors is used for the generator and electrical rooms.

2.4.3 Transportation

Located throughout the patient tower and west lobby area, there are three stairways, three passenger elevators, and two freight elevators. Stairway one and two of the passenger elevators are located in the west lobby. The stairway runs from the lower level to the roof level, and the two elevators go from the lower level to level eight. Stairway two is located at the north-west corner of the patient tower. This stairway extends from the lower level to level eight. The third stairway and elevator are located at the south end of the patient tower. Both the stairway and elevator start at the lower level and extend to the penthouse level. Along with the three passenger elevators, there are two additional elevators located in the main parking garage. These elevators are also used to transport visitors and employees to the patient tower.

3.0 CONSTRUCTION OVERVIEW

3.1 Project Delivery System

The Baltimore Washington Medical Center: Women's Center and Inpatient Tower is being delivered as a Construction Manager at Risk with a Guaranteed Maximum Price contract with the owner. The building cost is around $59.4 million while the overall project cost is about $68 million. Whiting-Turner was awarded the contract for the construction phase of this project based on the previous relationship held between the owner, University of Maryland Medical System, and Whiting-Turner. The contract for the preconstruction services was awarded to another construction manager at the beginning of the design phase for this project. Even though the contract was only for the preconstruction services, it was understood that if this construction manager could give the owner a reasonable budget at the end of the design, they would be awarded the construction phase of the project. However, at the end of the design, the previous construction manager was unable to lower their budget to the owner's satisfaction, and was not awarded the contract for the construction phase of the project. At this point, the owner turned to Whiting-Turner to complete the construction phase. In the past, Whiting-Turner had completed projects for this owner and was able to maintain a good relationship with them. Whiting-Turner was able to negotiate with the owner to lower the cost of the project, and was therefore given the contract. When the Construction Documents were 50% complete, the project was turned over to Whiting-Turner.

The process for selecting subcontractors for the project varied depending on the scopes of work for these trades. For many of the larger scopes of work such as MEP, concrete, and steel, Whiting-Turner negotiated with large, well-known subcontractors early on in the project. For some of the smaller scopes of work, the work was competitively bid. During this process, Whiting-Turner reviewed many of the lowest bids. To ensure that the lowest bid was actually the best bid, Whiting-Turner held meetings with the subcontractors to discuss the scopes of work and also to get familiar with each of the subcontractors. With this process, Whiting-Turner was able to select the best bid, which was not necessarily the lowest bid. Although most of the work is being performed by subcontractors, Whiting-Turner is self-performing the steel framing and precast concrete planks for the project. The contract held between Whiting-Turner and each of the subcontractors is a Lump Sum Contract. For this project, the owner does not require Whiting-Turner to purchase any bonds. For subcontractors, Whiting-Turner does not require any bid bonds; however, any subcontractor performing over $100,000 of work is required to have payment and performance bonds. Figure 6 shows an image of the organization chart of the primary project team for the project. Also a list of the primary project team and their corresponding websites are listed below the organization chart.

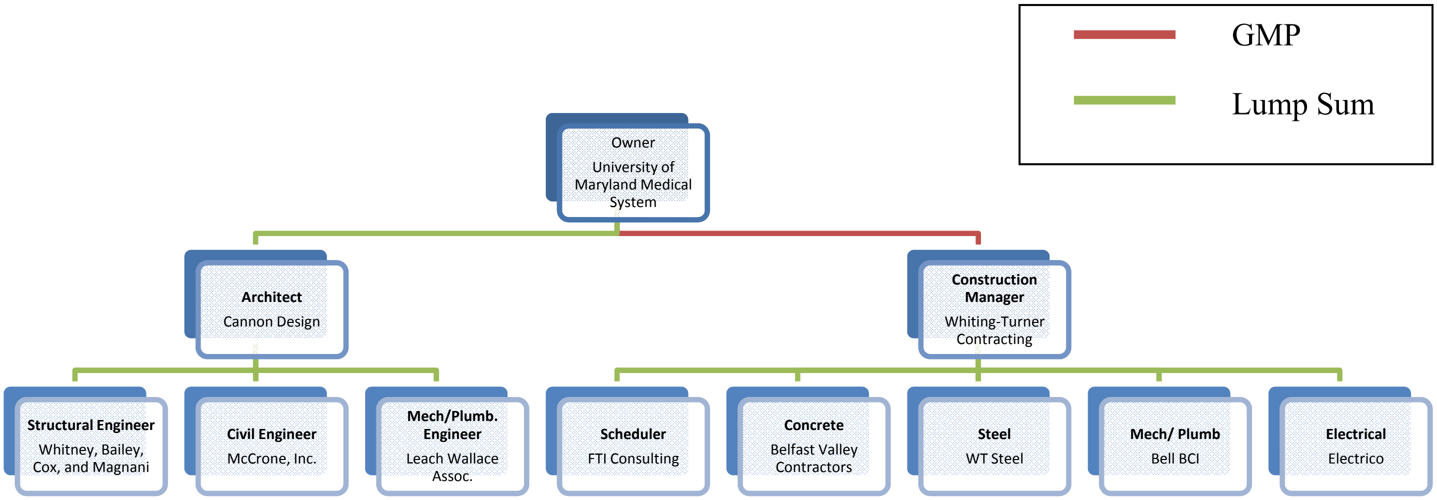


Figure 6: BWMC Project Team Organizational Chart

Primary Project Team:

Owner: University of Maryland Medical System
http://www.umms.org/

Construction Manager: Whiting-Turner Contracting
http://www.whiting-turner.com/

Architect: Cannon Design / CCG Facilities Integration
http://cannondesign.com /
http://www.ccgfacilities.com/capabilities.html

Structural Engineer: Whitney, Bailey, Cox & Magnani
http://www.wbcm.com/

Mechanical / Plumbing Engineer: Leach Wallace Associates, Inc.
http://www.leachwallace.com/

Civil Engineer: McCrone, Inc
http://www.mccrone-inc.com/

Geotechnical Engineer: Marshall Engineering
http://www.marshalleng.com/

3.2 Whiting Turner Staffing

At the beginning of the project, Whiting-Turner had a rather large project team consisting of a project executive, a project manager, an assistant project manager, a superintendent, an assistant superintendent, a MEP coordinator, a MEP engineer, and four project engineers. See Figure 7 for the organizational chart of the Whiting-Turner team.

Bruce DeLawder is the Project Executive for the project. He oversees all of the operations for the project. Due to the young staff and the complexity of the project, Bruce spends the majority of his time in his trailer office located on-site. Albert Marquardt, who was originally the Assistant Project Manager, was recently promoted to Project Manager where he replaced the resigned project manager. Because Albert is new to the project management role, Bruce assists him with many of the management tasks. As the Project Manager, Albert is responsible for managing the project costs and owner invoices. He also tracks overall processes for RFI's, purchase orders, submittals, etc. Along with these tasks, Albert is responsible for a few of the subcontractors where he manages the submittal processes and RFI's for these trades. Below Albert, there are three project engineers: Jason Verhey, Michael Reilly, and Dave Woessner. These project engineers are responsible for a majority of the subcontractors. Each project engineer manages the submittal processes, RFI's, and supplements for their corresponding trades. Ritchie Javier is the MEP Coordinator. He oversees all of the MEP work for the project, and is also responsible for the MEP subcontractors where he manages the submittal process and RFI's for these trades. John Stavros is the Superintendent for this project. Below John, is the Assistant Superintendent, Dan Schindler. John and Dan oversee all work that takes place in the field.

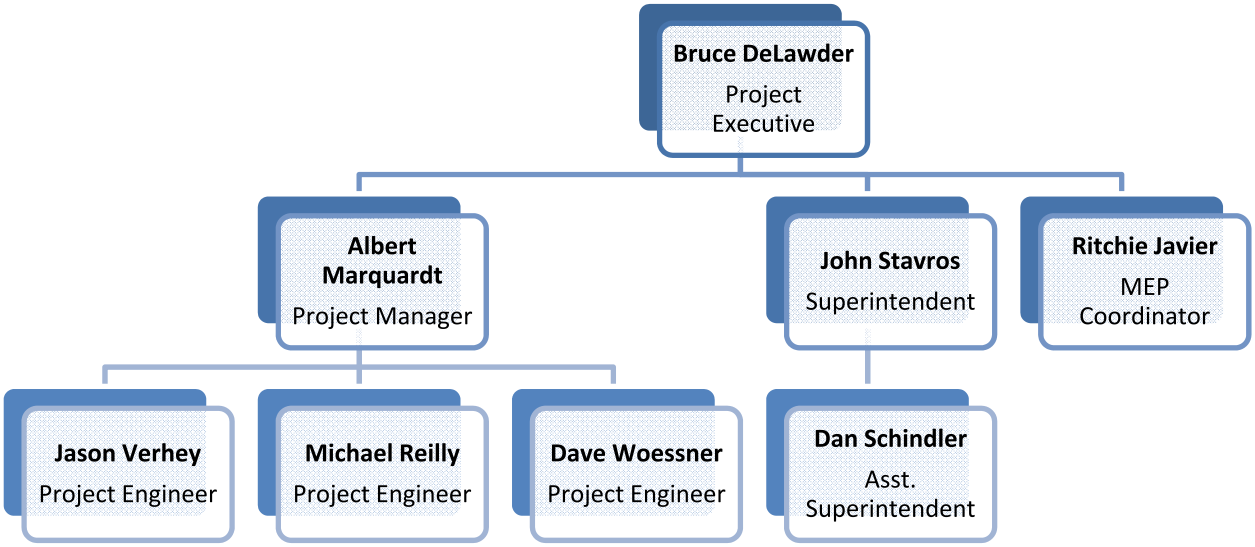


Figure 7: Whiting-Turner's Staffing Plan

3.3 Client Information

The Baltimore Washington Medical Center (BWMC) - Women's Center and Inpatient Tower is owned by the University of Maryland Medical System (UMMS). UMMS recently purchased the existing hospital structure and changed the name from North Arundel Hospital to Baltimore Washington Medical Center. The hospital still remains under the same management; however, the hospital is now corporately owned. The construction for this project is being managed by an owner's representative.

The keys to completing the project to the owner's satisfaction include a high quality project that is on budget and on schedule. The owner holds each of these elements to a very high standard. From the beginning of the project, the owner has held a very stringent budget. In fact, the construction manager who performed the preconstruction services for the project was not awarded the construction phase of the project because they could not lower the budget to the owner's satisfaction. Whiting-Turner was able to present a budget that the owner was satisfied with, and therefore was awarded the construction phase of the project. To ensure that the quality of work is above standards, Whiting-Turner has an incentive program for completing quality control reports. Each employee is required to complete three quality control reports and two safety checklists each week. These quality control items vary each week depending on the activities occurring in the field. For each additional quality control report submitted, the employee receives a chance to win a gift that is awarded at the end of each quarter. The owner is always concerned with the schedule of the project. Owner meetings are held every other Tuesday to discuss whether or not the project is on schedule. For these meetings, the superintendents review the two-week look-ahead schedule to keep the owner up to date with the track of the project. Throughout the project, Whiting-Turner has managed to keep the project on schedule. Safety is always an important issue for the both the owner and Whiting-Turner. In fact, safety is one of Whiting-Turner's biggest priorities. For this project, Whiting-Turner joined in a partnership with MOSH (Maryland Occupational Safety and Health) to ensure a safe environment for all employees on-site.

Because the new Patient Tower will tie into the existing hospital, there are a number of sequencing issues that are of interest to the owner. Whiting-Turner's scope of work includes both new construction and also renovation of the existing hospital. The areas to be renovated exist on the lower level and level three of the existing hospital. In order to renovate these areas, there must be a space within the new Patient Tower where employees can relocate. In order to provide spaces during the renovation, the patient tower has been split into two phases. The first phase consists of the lower level through level three; therefore, the sequencing of the project is concentrated mostly on these levels. Once this phase is completed and turned over, the renovation can begin in the existing hospital. Before the first phase can be turned over for occupancy, all life safety measures will need to be in place for the entire tower. These safety items include the elevators, fire alarm systems, and sprinkler systems.

3.4 Existing Conditions and Site Plan

*Please see Appendix A for Existing Site Plan

The Baltimore Washington Medical Center is located just south of Baltimore in Glen Burnie, Maryland. The Baltimore Washington Medical Center site consists of an existing hospital, formerly known as the North Arundel Hospital. It also includes the Tate Cancer Center, two parking garages, and a few parking lots. Figure 8 is an image of the BWMC site before the Patient Tower is constructed.

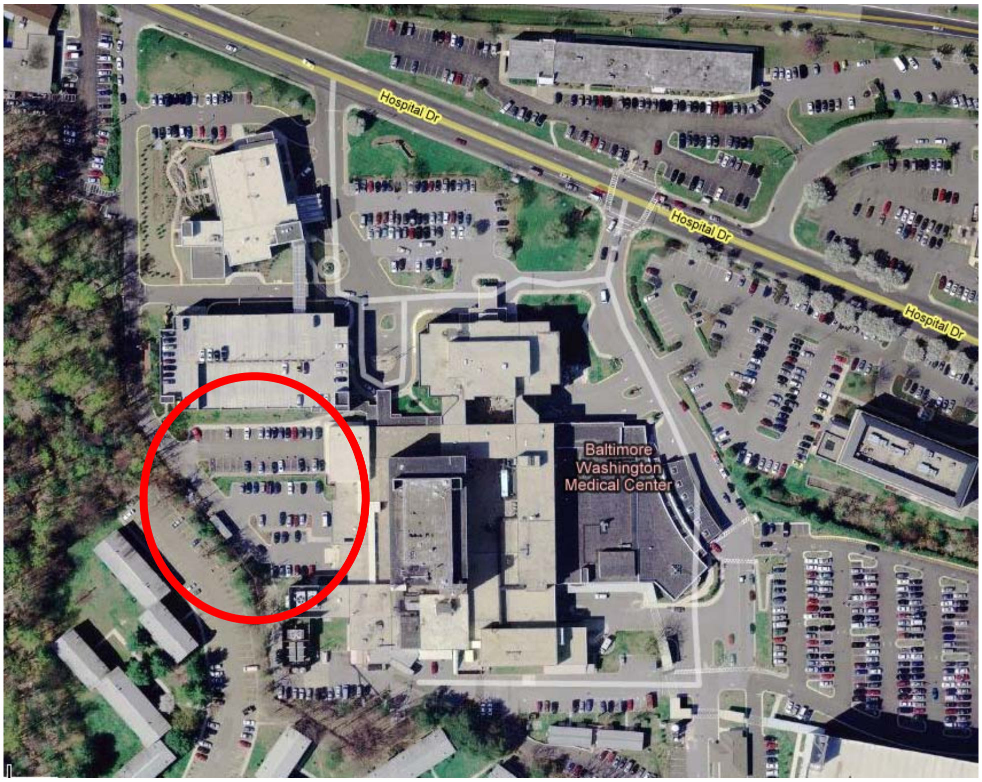


Figure 8: BWMC Site before Patient Tower Construction

On the site, there are currently two new additions to the existing hospital. Along with the addition of the patient tower, the emergency department is also currently under construction. With the large amount of construction currently going on, there is a demand for worker's parking on-site. To accommodate for this demand, the hospital has allocated a section of the back parking garage for construction workers parking. The parking allotted for the workers is sufficient at this time; however, as more trades begin to start up on site, there will need to be more parking available for these extra workers to park. Due to the large volume of construction, there are also a lot of waste products that accumulate on site; therefore, a number of dumpsters have been placed around the entire Baltimore Washington

Medical Center site. The tipping fee for the waste is currently $350/ dumpster. This fee accounts for a certain weight, and for anything that is overweight, there is an additional fee.

The site where the new patient tower is being constructed is a very congested site due to the existing structures that surrounds the construction site. Because the new tower is being built on a busy site where there are many people moving around the area, it is very important to monitor all activities on the construction site. To monitor the area, there are four job trailers located around the site. Most of the project team along with the owner's representative is located in the three of the job trailers set up behind the existing hospital. These trailers were placed in this area to supervise who enters the site and also to check in any new subcontractors entering the site. The fourth trailer is located at the north end of the construction site in order to monitor all material deliveries being made to site.

3.5 Site Logistics

The construction began in July 2006 with the drilling of helical piers below the existing structure and the start of the foundation system. The construction process for the structure started at the south end and moved towards the north end. The concrete structure was poured by floors with 4 phases per floor. The concrete was placed using a combination of two concrete pumps and crane and bucket. However, the majority of concrete was placed using two concrete pumps that run up through the building. The concrete was formed using horizontal and vertical formwork. The horizontal formwork used for the slabs, beams, and drop panels was the conventional metal systems. This system consists of aluminum shores supporting aluminum stringers and joists with plywood sheathing. The vertical formwork used for the columns and stairwells was ganged forms. This system consists of panels that are joined together and supported with steel frames. As the concrete structure was going up, the steel and precast planks were also being erected above the existing mechanical room. Two cranes were used to erect the steel framing and precast panels. Most of the steel was erected using the 150 ton hydraulic truck crane, which is located at the front of the west lobby area. The remaining steel along with the precast planks were erected using the flat top tower crane with a boom length of 246 feet and a capacity of 17,460 lbs, which is located on the west edge of the patient tower. Two material hoists were also used to transport materials. The two material hoists, which are located at the north end of the building, run from the lower level to level six. Because the elevators have not been installed yet, these hoists are critical in the transportation of materials to each level. The construction of the Patient Tower is shown in Figure 9.

Figure 9: Construction of Patient Tower

The following two images in Figures 10 and 11 show different views of the site model developed for the BWMC Women's Center and Inpatient Tower. There are two sections of the new tower. They consist of the Patient Tower and West Lobby Area. As you can see from the model, the site for this new expansion is congested due to the existing hospital and parking garage that surround the construction site.

The site model was designed for the superstructure phase of the building; therefore, it shows the tower crane, mobile crane, concrete pumps and pump trucks, material staging areas, and a material hoist. There are a number of dumpsters and sanitary facilities located around the site. Construction fences also surround the construction areas in order to keep out people around the area

The tower crane is located along the west edge of the Patient Tower. It is placed in the middle area of the tower in order to reach all areas of the Patient Tower. Because the tower crane cannot reach the West Lobby, a hydraulic truck crane is located in front of the West Lobby. Concrete pumps and pump trucks were used to place the concrete structure. One pump truck is usually located at the West Lobby Area. For the Patient Tower, two concrete pumps ran up through the building. A concrete pump truck was also used along the north side of the tower for areas that were often hard to reach by the pumps. As the concrete structure started, a material hoist was erected in the area between the Patient Tower and West Lobby.

In order to avoid people around the area, the material delivery entrance is located on the west edge of the Baltimore Washington Medical Center site. The delivery road to the site, which connects to the main road, Hospital Drive, is used as both an entrance and exit for the delivery trucks.

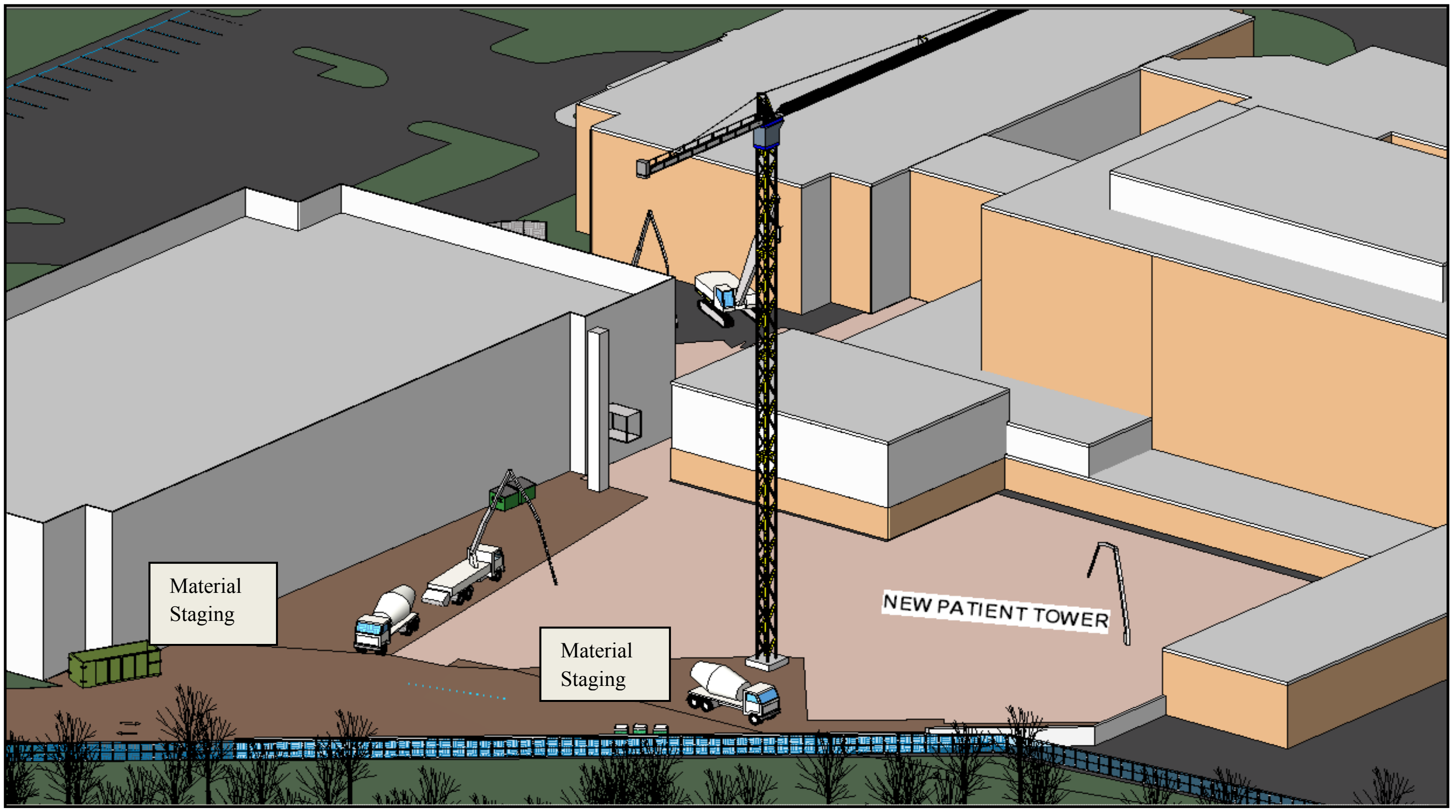


Figure 10: Site Logistics for project- Patient Tower Area

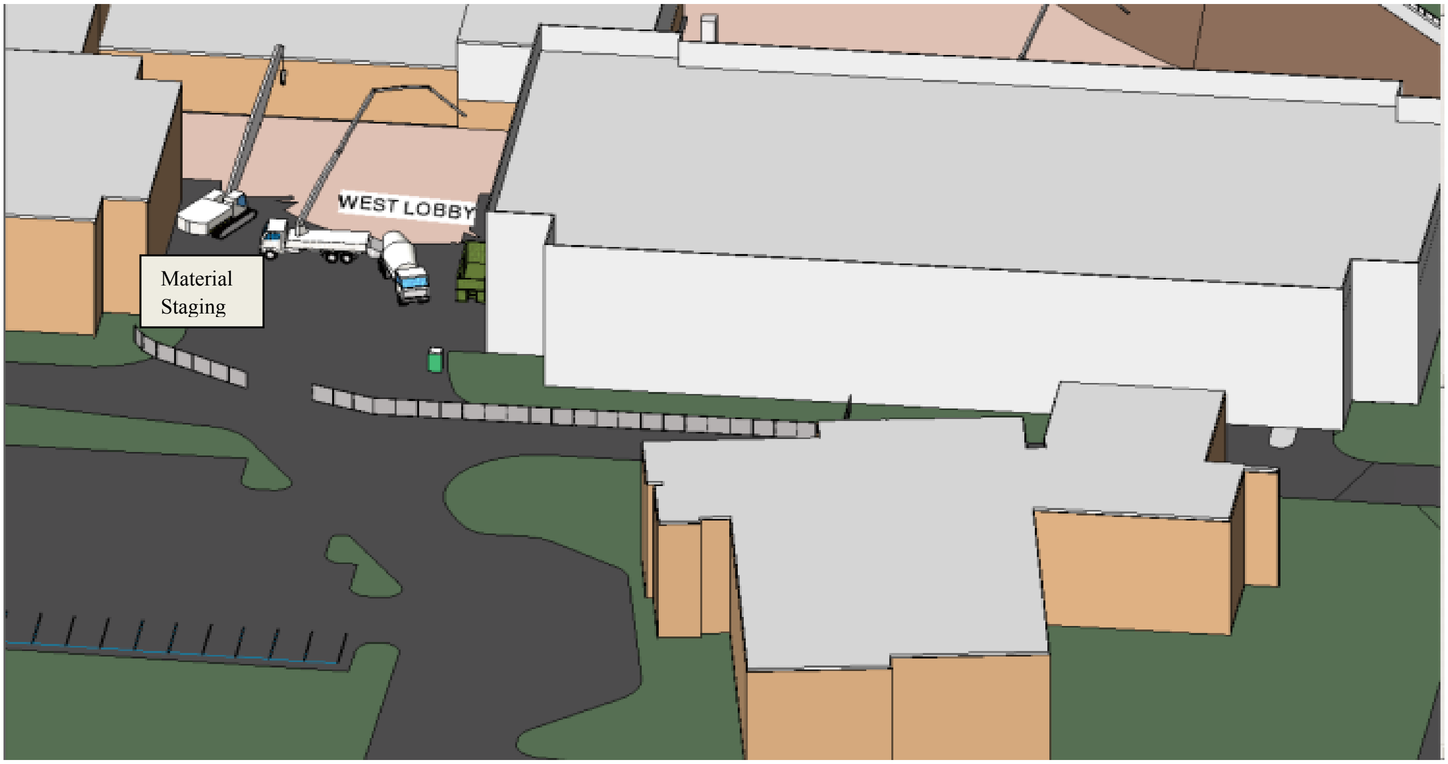


Figure 11: Site Logistics for project- West Lobby Area

3.6 Project Schedule Summary

The design for the BWMC Women's Center and Inpatient Tower Project began in early 2005. Early in the design phase of the project, a construction manager was brought on the project to perform the preconstruction services for the project. This construction manager had a contract with the owner for the preconstruction services only. When the Construction Documents were 50% complete in January 2006, Whiting-Turner was awarded the contract for the construction phase of the project. Whiting-Turner moved onto site in May 2006 and began the subcontractor bidding phase in June 2006. The subcontractor's bids were awarded in mid September 2006, and the final GMP was executed on September 22, 2006. Because the new patient tower was designed to tie into the existing hospital, part of the existing hospital needed to be either demolished or gutted before construction for the new tower could begin.

The construction process for the new tower always moved from south to north. The building construction began with the drilling of helical piers below the existing structure and the start of the foundation system. The concrete structure was poured by floors with 4 phases per floor. The three phases for the Patient Tower began at the south end and moved to the north end. The fourth phase is the West Lobby Area, which is attached to the north-east end of the Patient Tower. The steel truss, which is located above the existing mechanical room, was erected in three sections. Each section was erected

before the concrete structure was placed for those levels. The hollow-core precast planks were placed by level after the steel truss was erected. Once the concrete structure topped out, the penthouse structure was erected.

The MEP equipment was installed at various times depending on the location of the equipment. Once level three of the concrete structure was placed, the MEP rough-ins began on the lower level and worked up the levels as the concrete structure was still being placed. The interior fit-out and finishes followed behind the MEP rough-ins.

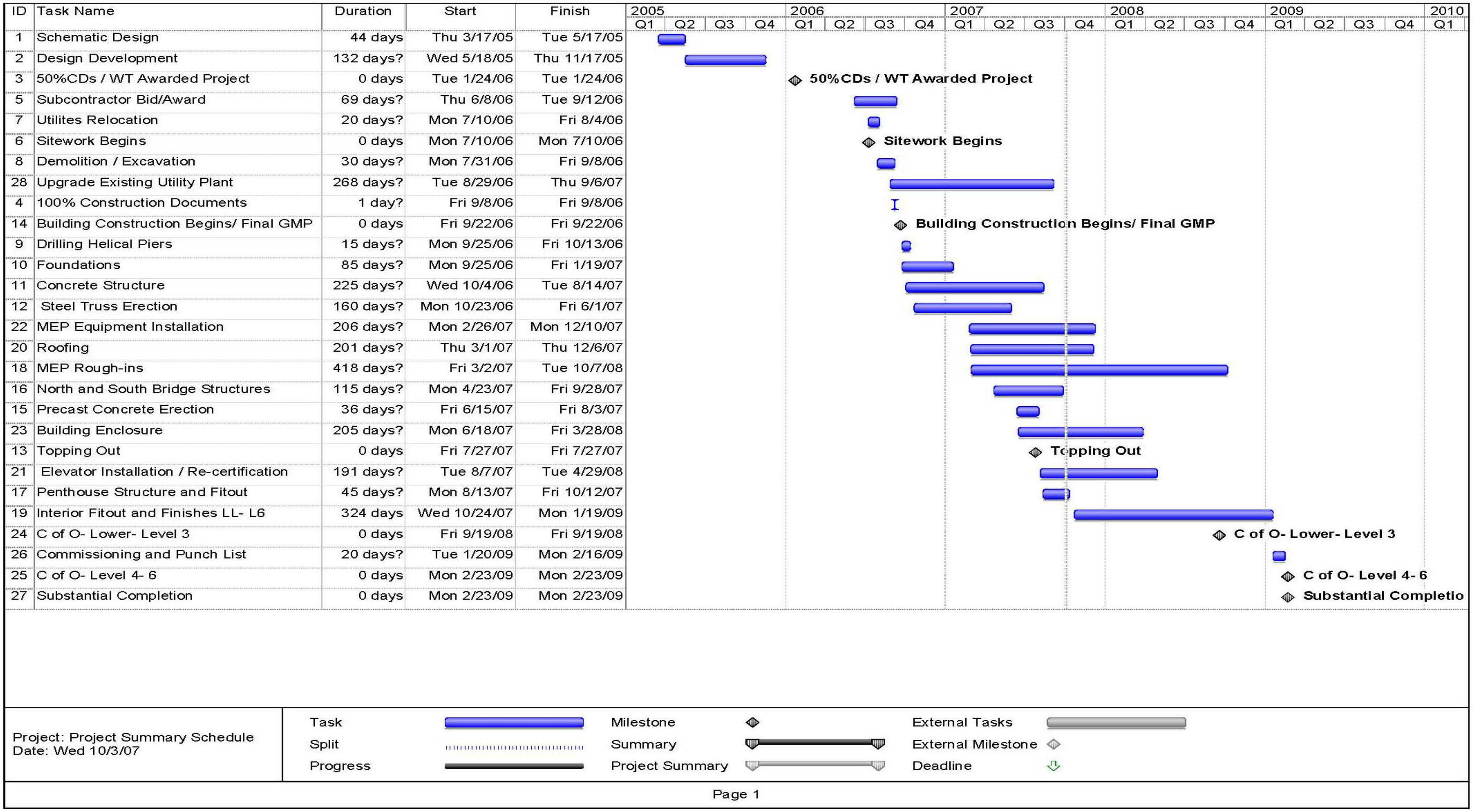
The MEP rough-in sequence:

- Plumbing Mains and Branches
- HVAC Mains and Branches
- Ductwork
- Primary Electrical Feeders
- Plumbing Fixture Carriers
- Plumbing In-Wall Rough-In
- Electrical In-Wall Rough-In
- Duct VAV Boxes
- Medical Gas Rough-In
- Sprinkler Mains and Branches
- Electrical Systems Cable Tray
- HVAC Rough-In
- Plumbing Insulation
- Fire Alarm System Rough-In
- Duct Insulation
- HVAC Insulation
- In-Wall Inspection

The interior fit-out/ finishes sequence:

- Layout Top and Bottom Track and Door Frames
- Interior Wall Framing
- Interior Drywall
- Tape and Mud Drywall
- Prime and 1st Coat Paint
- Ceiling Grid
- Flooring
- Ceramic Tile
- Doors and Hardware
- Millwork/Casework/Cabinetry
- Light Fixtures
- Toilet Accessories
- Miscellaneous Specialties
- Ceiling Tile
- Final Paint

As the concrete structure was finishing, the exterior wall framing and sheathing was started on level 1. The Patient Tower is planned to be turned over in two phases. The first phase consists of the lower level through level two, and the second phase is levels three through six. See Figure 12 for the project summary schedule created in Microsoft Project.



ID	Task Name	Duration	Start	Finish
1	Schematic Design	44 days	Thu 3/17/05	Tue 5/17/05
2	Design Development	132 days?	Wed 5/18/05	Thu 11/17/05
3	50%CDs / WT Awarded Project	0 days	Tue 1/24/06	Tue 1/24/06
5	Subcontractor Bid/Award	69 days?	Thu 6/8/06	Tue 9/12/06
7	Utilites Relocation	20 days?	Mon 7/10/06	Fri 8/4/06
6	Sitework Begins	0 days	Mon 7/10/06	Mon 7/10/06
8	Demolition / Excavation	30 days?	Mon 7/31/06	Fri 9/8/06
28	Upgrade Existing Utility Plant	268 days?	Tue 8/29/06	Thu 9/6/07
4	100% Construction Documents	1 day?	Fri 9/8/06	Fri 9/8/06
14	Building Construction Begins/ Final GMP	0 days	Fri 9/22/06	Fri 9/22/06
9	Drilling Helical Piers	15 days?	Mon 9/25/06	Fri 10/13/06
10	Foundations	85 days?	Mon 9/25/06	Fri 1/19/07
11	Concrete Structure	225 days?	Wed 10/4/06	Tue 8/14/07
12	Steel Truss Erection	160 days?	Mon 10/23/06	Fri 6/1/07
22	MEP Equipment Installation	206 days?	Mon 2/26/07	Mon 12/10/07
20	Roofing	201 days?	Thu 3/1/07	Thu 12/6/07
18	MEP Rough-ins	418 days?	Fri 3/2/07	Tue 10/7/08
16	North and South Bridge Structures	115 days?	Mon 4/23/07	Fri 9/28/07
15	Precast Concrete Erection	36 days?	Fri 6/15/07	Fri 8/3/07
23	Building Enclosure	205 days?	Mon 6/18/07	Fri 3/28/08
13	Topping Out	0 days	Fri 7/27/07	Fri 7/27/07
21	Elevator Installation / Re-certification	191 days?	Tue 8/7/07	Tue 4/29/08
17	Penthouse Structure and Fitout	45 days?	Mon 8/13/07	Fri 10/12/07
19	Interior Fitout and Finishes LL- L6	324 days	Wed 10/24/07	Mon 1/19/09
24	C of O- Lower- Level 3	0 days	Fri 9/19/08	Fri 9/19/08
26	Commissioning and Punch List	20 days?	Tue 1/20/09	Mon 2/16/09
25	C of O- Level 4- 6	0 days	Mon 2/23/09	Mon 2/23/09
27	Substantial Completion	0 days	Mon 2/23/09	Mon 2/23/09

Project: Project Summary Schedule
Date: Wed 10/3/07

Figure 12: Project Summary Schedule

3.7 Project Cost Estimates

3.7.1 Square Foot Cost Evaluation

R.S. Means Square Foot Estimate

The square foot estimate was completed using the R.S. Means reference listed above. The reference used for the square foot estimate was listed under the Commercial/ Industrial/ Institutional Section. The type of building is a 4-8 Story Hospital with the model number M.340. The Exterior Wall was a combination of the Face Brick with Concrete Block Back-up (Reinforced Concrete Frame) and the Precast Concrete Panels with Exposed Aggregate (Steel Frame). Because the S.F. Area of the new patient tower fell between two values, the cost/ square foot was found by interpolating between the S.F. Area values 225,000 SF and 250,000 SF. The building perimeter was also found by interpolating between the L.F. Perimeter values 950 LF and 1033 LF. The Face Brick System makes up about 30% of the Exterior Wall System, and the Precast Concrete System makes up about 70% of the Exterior Wall System. The cost needed to be adjusted for the perimeter, and the basement cost was also added into estimate. To develop a more accurate cost estimate, some of the common additives such as cabinets, closed circuit TVs, nurse call stations, sound system speakers, and sterilizers were included within the estimate.

Square Foot Building Estimate for the BWMC Women's Center and Inpatient Tower

Building Area (SF): 239,088 SF (excluding basement area)

Building Perimeter (LF): 1200 LF

Cost / Square Foot:
- Face Brick with Concrete Block Back-up (Reinforced Concrete Frame): $231.99 / square foot
- Precast Concrete Panels with Exposed Aggregate (Steel Frame): $224.07 / square foot

Base Cost / Square Foot:
- Face Brick: 30% of $231.99 / square foot
- Precast Concrete Panels: 70% of $224.07 / square foot
- Total Base Cost / Square Foot: $ 226.45 / square foot

Cost Adjustment Type:
- Actual Perimeter: 1200 LF
- Interpolated Perimeter: 995 LF
- Adjusted Cost / Square Foot: + $2.05 / square foot
- Adjusted Base Cost / Square Foot: $228.50 / square foot

Building Cost:

- Base Building Cost: $54,631,608
- Basement Cost: $925,230
- Total Cost: $55,556,838

Additions:

- Nurse Call Station (Single Bedside): $42,624
- Nurse Call Station (Emergency Call Station): $49,350
- Nurse Call Station (Duty Station): $9,000
- Nurse Call Station (Master Control Station): $16,650
- Sound System (Speakers): $49,590
- Sterilizers (Single Door, Steam): $161,500
- Closed Circuit TV (station camera and monitor): $61,975
- Cabinets (Base, Door Units): $76,752
- Cabinets (Base, Drawer Units): $50,600
- Cabinets (Wall, Doors): $186,050
- Cabinets (Tall, Storage): $8,100
- Total Cost of Additions: $712,196

Total Cost with Additions: $56,269,029

Multiplier Type:

- Location Multiplier (Baltimore, MD-Commercial): .93

Total Square Foot Estimate for Building: $52,330,200

3.7.2 Building Systems Cost Evaluation

Building Construction Cost:

- Cost: $66,455,588
- Cost/SF: $191.39
    - Note: Building Construction Cost does not include land costs, sitework, permitting, etc.
    - Note: Building Construction Cost does not include the upgrade of the existing utility plant.

Total Project Cost:

- Cost: $75,460,380
- Cost/SF: $219.71

- Note: The sitework for this project is considered to be a separate contract, which includes the sitework for both the new Patient Tower and also for the Emergency Department Expansion; the majority of the sitework is not calculated in this total project cost.

Building Systems Cost:

- See Table 1 for Building Systems Costs

Table 1: Building Systems Costs

Building Systems	Cost	Cost / Square Feet
General Conditions	**$1,386,061**	**$4.47**
Structural System	**$1,2698,671**	**$106.73**
Concrete	$10,329,977	$33.62
Structural Steel	$2,368,694	$73.11
Masonry	**$1,154,148**	**$3.72**
Mechanical System	**$20,486,507**	**$57.62**
Patient Tower	$17,879,997	$57.62
Existing Utility Plant Upgrade	$2,606,510	$0
Electrical System	**$11,151,517**	**$21.56**
Patient Tower	$6,688,641	$21.56
Existing Utility Plant Upgrade	$4,462,876	$0

3.7.3 General Conditions Cost Evaluation

A General Conditions Estimate was developed for the BWMC Women's Center and Inpatient Tower. Table 2 shows the grouping of all the items included for the estimate. For this estimate, both the 2007 R.S. Means Facilities Construction Cost Data and Whiting-Turner's Cost Data were used as cost references. The estimate was performed using the same items listed in Whiting-Turner's General Conditions Budget so that the estimate and budget could be compared. Many of the items listed in the estimate are calculated based on monthly costs. For these items, the project duration is assumed to be thirty-three months (June 2006-Febuary 2009). For the project team, various durations were used for each employee depending on the estimated time that each employee will spend on the job site. The construction fee for this project is assumed to be 1.5% due to the large size of this project. The estimate cost is approximately $2,834,700. The actual budget is $1,541,270. One of the main reasons for the difference in cost could be the project staff estimate. The unit costs were taken from R.S. Means rather than from Whiting-Turner's data. The costs for the employees depend on the company and to some extent, can be difficult to estimate.

Table 2: General Conditions Estimate

General Conditions Estimate									
Item	Unit	Quantity	Mat'l Unit Cost	Mat'l Cost	Labor Unit Cost	Labor Cost	Equipment Unit Cost	Equipment Cost	Total Cost
Project Staff									
(2) Project Engineers	Month	31			1085	134540			$134,540
(1) Assistant Project Manager	Month	31			1250	155000			$155,000
(1) Assistant Superintendent	Month	34			1500	204000			$204,000
(1) Project Manager	Month	33			1550	204600			$204,600
(1) Superintendent	Month	35			1650	231000			$231,000
(1) Senior Project Manager	Month	34			2025	275400			$275,400
(1) MEP Project Manager	Month	34			1775	241400			$241,400
(1) General Laborer	Month	30			1150	138000			$138,000
Project Documentation									
Drawings and Specifications	Sets	120	$700.00	$84,000					$84,000
Engineering Services									
As-Built Surveys	Acres	2.16	$1,160.00	$2,506	$300.00	$648	$20.00	$43	$3,197
Topographic Surveys	Acres	2.16	$17.00	$37	$294.00	$635	$17.60	$38	$710
Temporary Facilities									
50'x10' Job Trailers (Rented/ Month)	Each	2	$330.00	$660					$660
Sanitary Facilities	Each	135	$110.00	$14,850					$14,850
Project Signs	SF	30	$16.55	$497					$497
Field Office Expenses									
Office Equipment	Month	33	$150.00	$4,950					$4,950
Office Supplies	Month	33	$95.00	$3,135					$3,135
Telephone bill	Month	33	$210.00	$6,930					$6,930
Field Office Lights and HVAC	Month	33	$110.00	$3,630					$3,630
Temporary Utilites									
Heat	CSF	3556	$10.35	$36,805	$3.04	$10,810			$47,615
Lighting	CSF	3556	$4.00	$14,224	$15.00	$53,340			$67,564
Power for Lighting	CSF	3556							$5,334
Power for Job Duration	CSF	3556							$266,700
Water Bill	Month	33	$62.00	$2,046					$2,046
Temporary Barricades									
5' Ht. Temporary Fencing	LF.	50	$6.00	$300	$1.15	$58			$358
Guardrail	LF.	6230	$1.14	$7,102	$2.94	$18,316			$25,418
Clean-Up									
Daily Clean-Up	MSF	356	$1.70	$605	$32.50	$11,570	$2.21	$787	$12,962
Final Clean-Up	MSF	450	$2.71	$1,220	$45.00	$20,250	$3.07	$1,382	$22,851
Dumpsters	Pulls	500	$345.00	$172,500					$172,500
Equipment									
Material Hoist	Each	1	$350,000.00	$350,000					$350,000
Small Tools	Total	1	$50,000.00	$50,000					$50,000
								Total Costs:	**$2,729,846**
Insurance									
Builder's Risk Insurance	0.50%								$13,649
Worker's Compensation	18.39%								$50,200
Construction Manager Fee	1.5%								$41,000
								Total Project General Conditions	**$2,834,695**

4.0 TECHNICAL ANALYSIS #1

4D Modeling as a Comparison Tool

4.1 Problem Statement

Even though 4D Modeling is becoming more prevalent in the building industry primarily within the construction aspect, there are still many obstacles for properly using and understanding the 4D Modeling tool. Because 4D Modeling is a fairly new idea used in the construction industry, many are still learning the basics about what can be done with 4D Modeling. As more of the industry becomes familiar with the idea of 4D Modeling, the next step will be how to properly use the tool. Many believe that 4D Models can only be used to show a construction sequence; however, there are many other uses for 4D Modeling. One area that proves to be useful for the BWMC- Women's Center and Inpatient Tower is using 4D Modeling as a comparison tool between two systems. By developing a process that provides a clear description on how to compare systems using 4D Modeling, many project teams will be able to compare alternative systems during the value engineering process.

4.2 Goal

The goal for developing a 4D Modeling process is to show the benefits of using a 4D Model as a comparison tool when looking at alternative systems. The analysis will first look at developing a 3D model of the Women's Center and Inpatient Tower. The 3D Model will be used to compare the other two analysis areas within my thesis project. The process for developing and using a 4D Model as a comparison tool will first be documented and then will be reviewed through my other two analysis areas. The 4D model will be used to review both the structural alternative and façade alternative that were chosen for the two other topics. In order to show the differences in sequencing and durations, the sequencing for the two systems will be illustrated on a single model. By showing the sequencing on a single model, the system that finishes first can easily be determined. If the 4D Model would have been developed and used on the Patient Tower, it would have made the comparison between systems' durations much easier. The use of the 4D Model on the project may have also led to different decisions on the structural system and façade system.

4.3 Analysis Steps

1. The first step to this analysis is to develop a 3D Model.
2. Create a CPM schedule in Microsoft Project.
3. Link 3D Model and CPM schedule in Navisworks Timeliner
4. Simulate the construction sequencing for the two systems using a single model.
5. Review the simulation process and develop conclusions.
6. Repeat steps 2-5 for the second analysis area.

7. In order to develop a clear and concise process for using 4D Modeling as comparison tool, various areas on 4D Modeling where processes have been developed need to be researched. The research will focus on how to develop an effective description of the process used.
8. Document the process of creating and utilizing a 4D Model as a comparison tool.
9. Document the lessons learned with using a 4D Model.
10. Receive feedback on the process and case studies and make any changes necessary.
11. Finalize the analysis area.

4.4 Resources and Tools

1. Architectural Engineering Faculty (Professor Messner, Craig Dubler, Rob Leicht)
2. Revit Architecture
3. Revit Structures
4. Navisworks Timeliner
5. Microsoft Project

4.5 Introduction to 4D Modeling

The term 4D modeling can be defined as the process of attaching the fourth dimension of time to a 3D model. A 4D model is created by linking a construction schedule to a 3D model using a 4D simulation program. The 4D simulation software that was used for the Women’s Center and Inpatient Tower Project was NavisWorks with Timeliner.

4.6 4D Modeling Process

For the Women’s Center and Inpatient Tower Project, a 3D model was first created in Revit Architecture. Figure 13 shows an image of the 3D Model created in Revit Architecture.

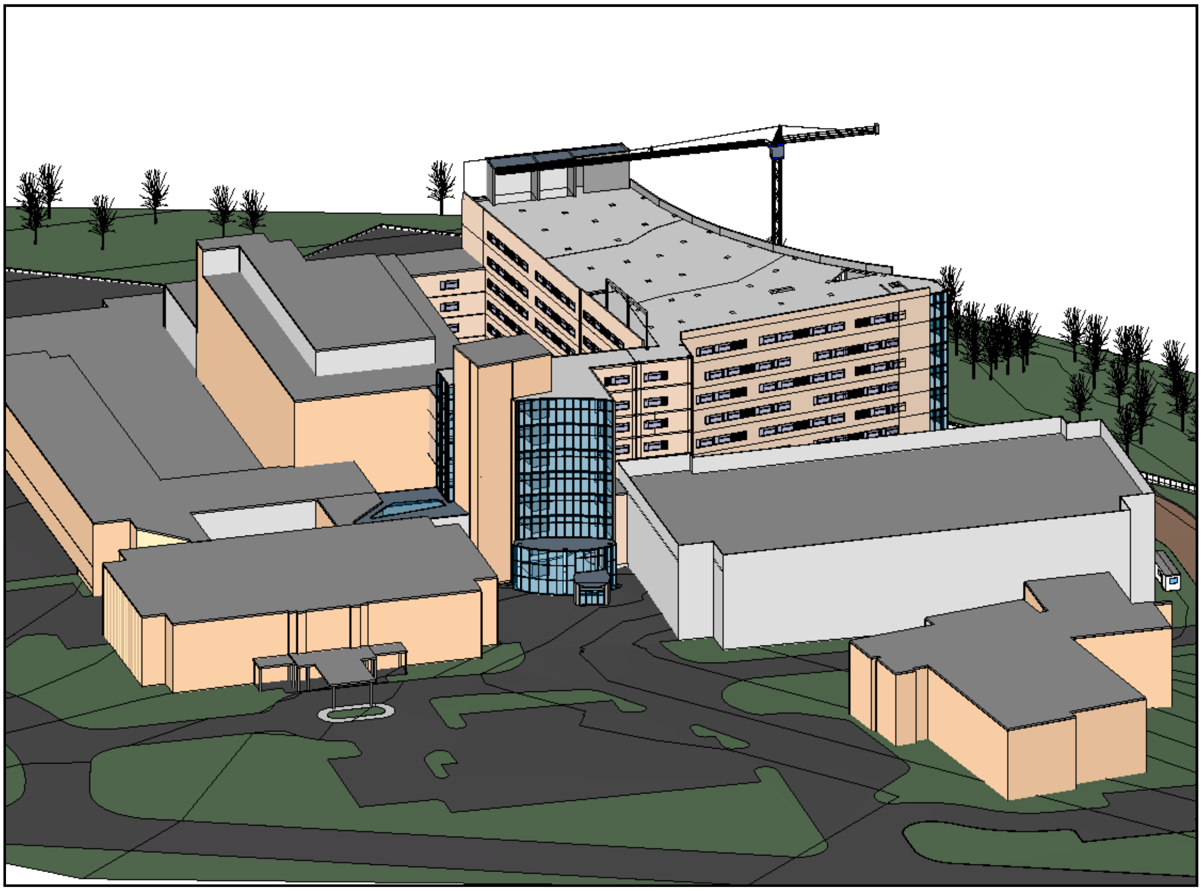
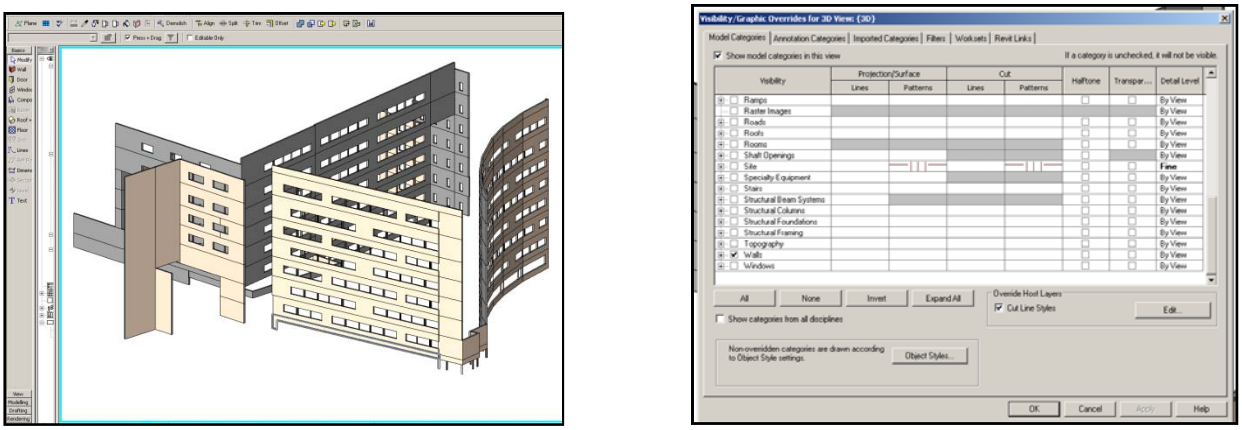


Figure 13: 3D Model of BWMC- Women's Center and Inpatient Tower created in Revit Architecture

Once a 3D model was developed, a construction schedule for each analysis area was created in Microsoft Project. The 3D model was broken up based on the two analysis topics that are being compared. For the structural system comparison, only the structure of the Patient Tower and site plan were used in the 4D Model. With the façade system comparison, the entire model was imported into the 4D Model, but only the façade system was used for the actual 4D Model. The model components for each of the analysis areas were imported into Navisworks. The construction schedule for each analysis was also imported into Navisworks Timeliner. The construction schedules for the two analyses were created using Microsoft Project. The schedule for each analysis area will include both of the systems being compared so that only a single schedule needs to be imported and linked in the 4D Model. Once the schedule and 3D model for the analysis were imported into Navisworks, they were linked together. To make the linking process quicker and easier, model components were created in Revit Architecture first and then imported separately into NavisWorks. By bringing in pieces of the model instead of the entire model, it was easy to isolate each imported model component and link it to the schedule. The model components were created in Revit Architecture by using the visibility settings in the 3D View. In the 3D View, the visibility settings were changed and the views were cropped to show only the necessary elements within the model component. Figure 14 shows an example of a wall component. The first image illustrates a cropped 3D view of the GFRC wall group. The second image shows a visibility settings box for the GFRC walls. As the views were created, they were saved as a NavisWorks file so that they could be directly imported into NavisWorks. Although this process of creating views and importing them separately into NavisWorks was tedious and time consuming, it appeared to be the easiest way to link the 3D model to the schedule. Figure 15 shows the process used for creating a 4D model in Navisworks.



Visibility/Graphic Overrides for 3D View: {3D}

Model Categories | Annotation Categories | Imported Categories | Filters | Worksets | Revit Links

☑ Show model categories in this view

If a category is unchecked, it will not be visible.

Visibility	Projection/Surface		Cut		Halftone	Transpar...	Detail Level
	Lines	Patterns	Lines	Patterns			
☐ Ramps					☐	☐	By View
☐ Raster Images							By View
☐ Roads					☐	☐	By View
☐ Roofs					☐	☐	By View
☐ Rooms					☐	☐	By View
☐ Shaft Openings					☐		By View
☐ Site					☐	☐	Fine
☐ Specialty Equipment					☐	☐	By View
☐ Stairs					☐	☐	By View
☐ Structural Beam Systems					☐	☐	By View
☐ Structural Columns					☐	☐	By View
☐ Structural Foundations					☐	☐	By View
☐ Structural Framing					☐	☐	By View
☐ Topography					☐	☐	By View
☑ Walls					☐	☐	By View
☐ Windows					☐	☐	By View

☐ Show categories from all disciplines

Override Host Layers

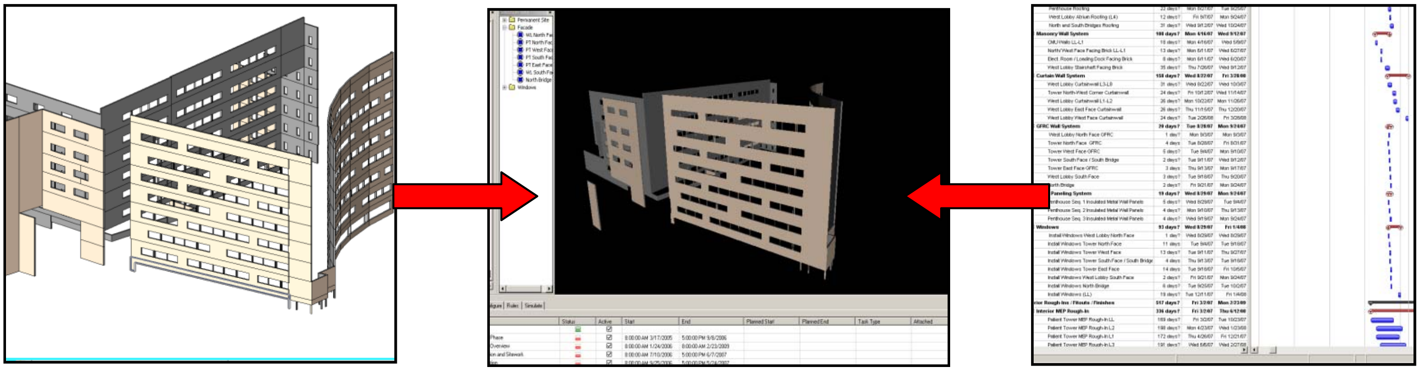
☑ Cut Line Styles

Non-overridden categories are drawn according to Object Style settings.

Cropped 3D View (ex. GFRC Walls)

Visibility Settings Box

Figure 14: 3D View and Visibility Setting Box for GFRC Exterior Wall



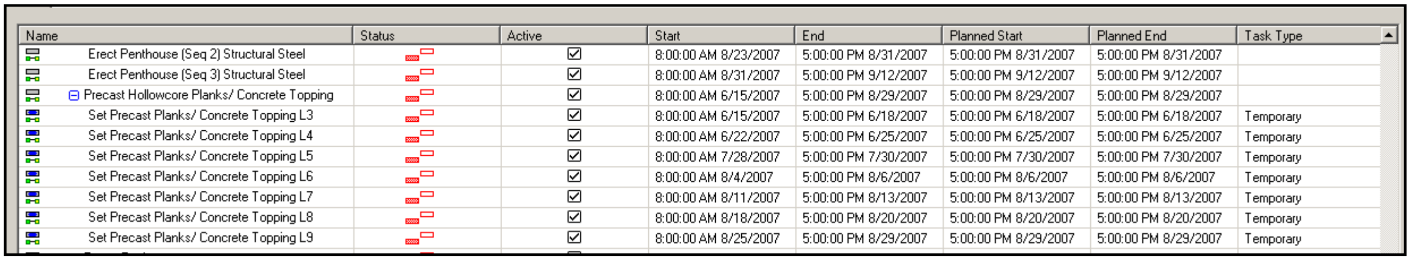
Model Component (ex. GFRC Walls)

Navisworks Jetstream v. 5 TimeLiner

CPM Schedule

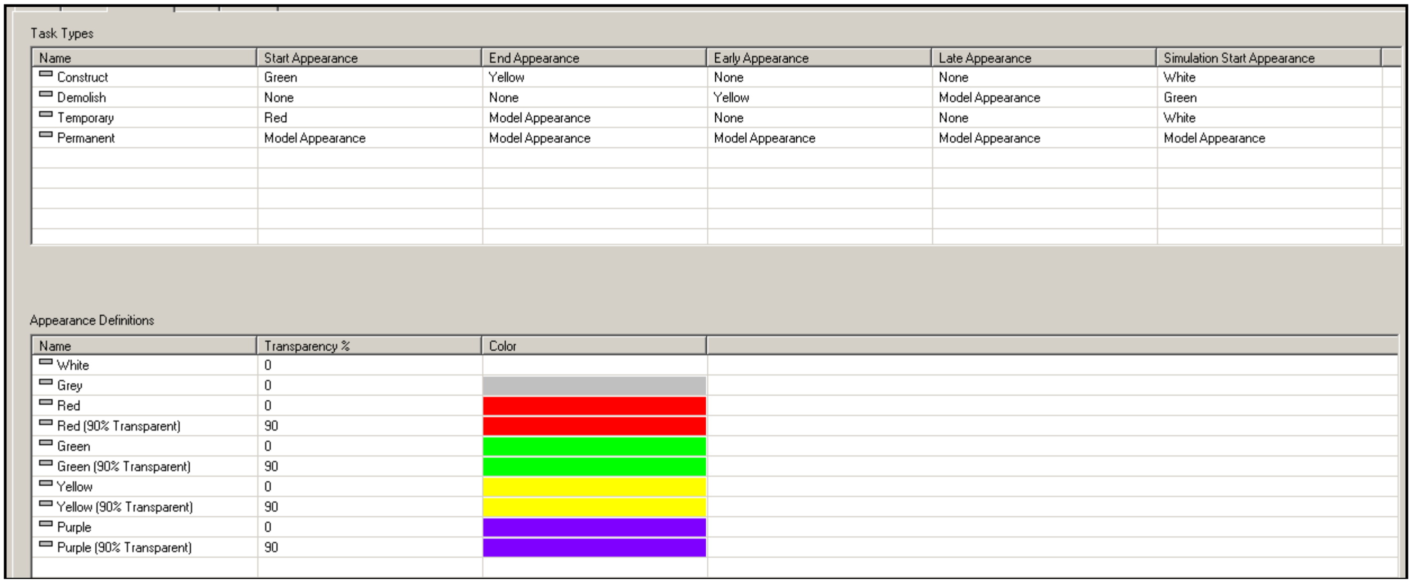
Figure 15: Process for creating 4D Model in Navisworks

In order to show a clear comparison of the two systems for each analysis, only the model components that are being compared within the analysis area are being illustrated in the 4D Model. For example, with the structural system analysis, the only area that is being redesigned is the area above the mechanical room; therefore, this is the only area that is being sequenced in the 4D Model. For the façade comparison, only the façade area where the comparison is being made will be sequenced in the 4D Model. The rest of the model will be used as a background for this area. The goal of this analysis was to include both systems on one 4D Model; however, that proved to be very difficult and confusing for the façade analysis. For the structural analysis, both systems are shown on one 4D Model; therefore, different colors were used to show when each system finishes. The color coding will make it easier to see which system finishes first and which finishes last. In order to use different colors for the two alternatives, two different task types need to be used for the two systems. The purpose of the task type is to show the various processes occurring with the same model components. For example, one task type can be used as a temporary task. This temporary task can be created to show the process of a model component being created and then being taken down later in the construction process. With this analysis, the task types allow the two systems to be linked to the same model pieces. The task types are used to show the difference in durations between two systems on the same model components. For example, with structural analysis, the precast concrete planks were given one task type and the composite slab was given another task type. The rest of the model that is not being sequenced in the 4D Model was given the permanent task type. Each task type used different colors for the start and finish to illustrate the differences in durations. Both systems were then attached to the same model components. Figure 16 shows an example of the linked schedule and the task type associated with the schedule tasks. Figure 17 shows the colors assigned to each task type.



Name	Status	Active	Start	End	Planned Start	Planned End	Task Type
Erect Penthouse (Seq 2) Structural Steel		☑	8:00:00 AM 8/23/2007	5:00:00 PM 8/31/2007	5:00:00 PM 8/31/2007	5:00:00 PM 8/31/2007	
Erect Penthouse (Seq 3) Structural Steel		☑	8:00:00 AM 8/31/2007	5:00:00 PM 9/12/2007	5:00:00 PM 9/12/2007	5:00:00 PM 9/12/2007	
⊟ Precast Hollowcore Planks/ Concrete Topping		☑	8:00:00 AM 6/15/2007	5:00:00 PM 8/29/2007	5:00:00 PM 8/29/2007	5:00:00 PM 8/29/2007	
Set Precast Planks/ Concrete Topping L3		☑	8:00:00 AM 6/15/2007	5:00:00 PM 6/18/2007	5:00:00 PM 6/18/2007	5:00:00 PM 6/18/2007	Temporary
Set Precast Planks/ Concrete Topping L4		☑	8:00:00 AM 6/22/2007	5:00:00 PM 6/25/2007	5:00:00 PM 6/25/2007	5:00:00 PM 6/25/2007	Temporary
Set Precast Planks/ Concrete Topping L5		☑	8:00:00 AM 7/28/2007	5:00:00 PM 7/30/2007	5:00:00 PM 7/30/2007	5:00:00 PM 7/30/2007	Temporary
Set Precast Planks/ Concrete Topping L6		☑	8:00:00 AM 8/4/2007	5:00:00 PM 8/6/2007	5:00:00 PM 8/6/2007	5:00:00 PM 8/6/2007	Temporary
Set Precast Planks/ Concrete Topping L7		☑	8:00:00 AM 8/11/2007	5:00:00 PM 8/13/2007	5:00:00 PM 8/13/2007	5:00:00 PM 8/13/2007	Temporary
Set Precast Planks/ Concrete Topping L8		☑	8:00:00 AM 8/18/2007	5:00:00 PM 8/20/2007	5:00:00 PM 8/20/2007	5:00:00 PM 8/20/2007	Temporary
Set Precast Planks/ Concrete Topping L9		☑	8:00:00 AM 8/25/2007	5:00:00 PM 8/29/2007	5:00:00 PM 8/29/2007	5:00:00 PM 8/29/2007	Temporary

Figure 16: Image of Tasks and Task Types in Navisworks Timeliner



Task Types

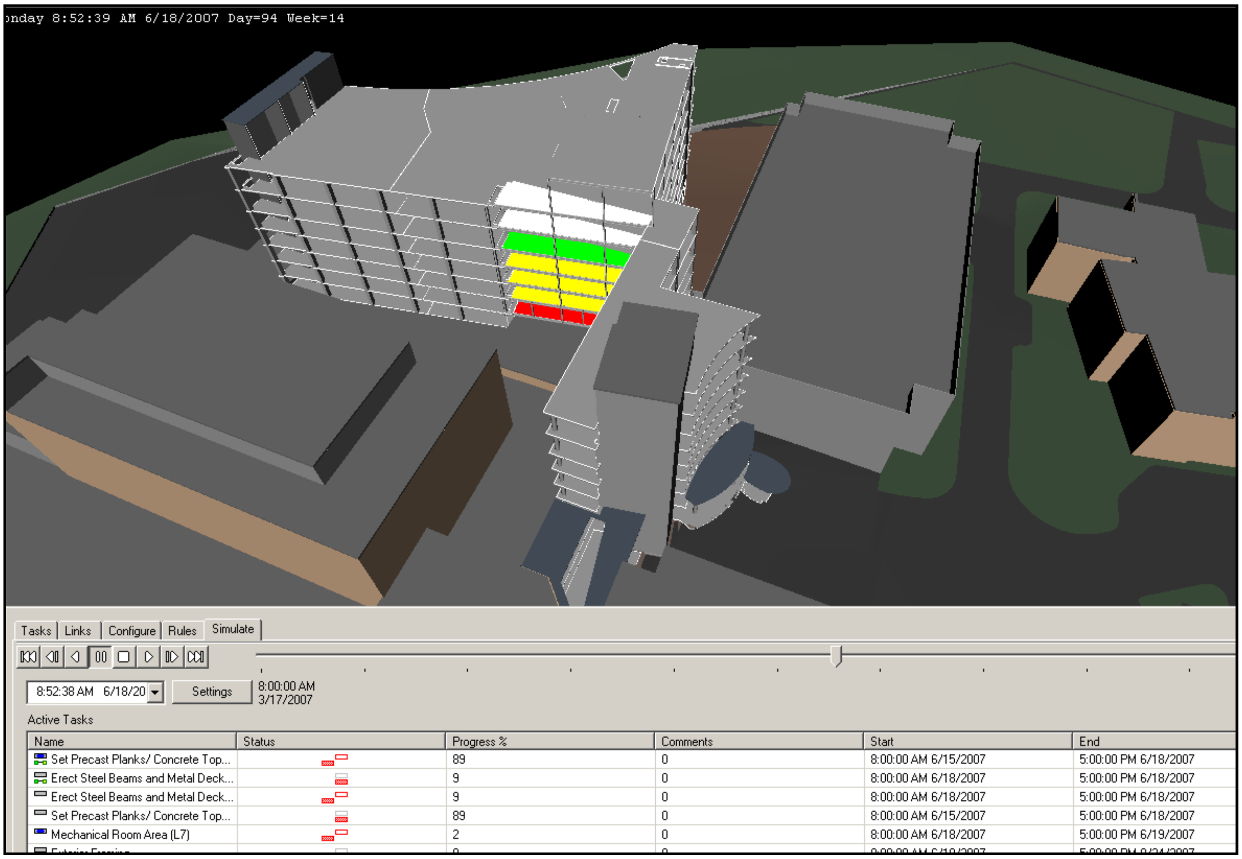
Name	Start Appearance	End Appearance	Early Appearance	Late Appearance	Simulation Start Appearance
Construct	Green	Yellow	None	None	White
Demolish	None	None	Yellow	Model Appearance	Green
Temporary	Red	Model Appearance	None	None	White
Permanent	Model Appearance	Model Appearance	Model Appearance	Model Appearance	Model Appearance

Appearance Definitions

Name	Transparency %	Color
White	0	
Grey	0	▨
Red	0	🟥
Red (90% Transparent)	90	🟥
Green	0	🟩
Green (90% Transparent)	90	🟩
Yellow	0	🟨
Yellow (90% Transparent)	90	🟨
Purple	0	🟪
Purple (90% Transparent)	90	🟪

Figure 17: Image of Colors Assigned to the Task Types in Navisworks Timeliner

For the precast concrete planks, the color used to illustrate the start of construction is red. Because the precast planks finish after the composite slab, the color used for the end of construction is the model appearance. The color used to illustrate the beginning of the composite slab is green and the end of the composite slab is yellow. For the façade analysis, the two systems could not be compared only using one 4D Model. The reason for this is because the sequencing of the EIFS and GFRC would often overlap; therefore, only one color would highlight the walls. It was difficult to show that two systems were being constructed at the same time on the same façade. The sequencing for the two systems was also different. The EIFS would go up by face on two walls at the same time using scaffolding. The GFRC would go by face on one wall at a time using the tower crane. The difference in sequencing adds to the complexity of comparing the two systems using one model. Through trial and error, I found that the easiest way to visually illustrate the difference in durations was to use two separate models for the two façade systems. Because two different models were used to compare the GFRC and EIFS systems, the start color used for both the GFRC façade and the EIFS façade is green. When each system is finished, it will turn to the model appearance. Figure 18 illustrates the two structural systems' sequencing and durations being compared on a single 4D Model. The structural 4D Model in Figure 18 shows the completion of the composite slabs on Levels 3-6 (yellow), the construction of the composite slab on Level 7 (green), and the construction of the precast planks beginning on Level 3 (red). The first model created for the façade comparison is shown in Figure 19. As illustrated in the image, it is difficult to see when the two systems would overlap. The façade model shows the construction of the GFRC and EIFS on the north and south faces. Even though both systems are being constructed, only one of the colors is displayed. The red indicates that the EIFS is being constructed. The color green, which is not shown, should be displayed to show the GFRC being constructed on the same sides as the EIFS. Figure 20 shows the final models used to compare the two façade systems. The two models proved to be the easiest way to compare two different durations. In Figure 20, the two façade systems' sequencing and durations are being compared on two different 4D Models. The facade 4D Model in Figure 20 shows the completion of the GFRC Panels on most of the building facades, the construction of the GFRC Panels on the east façade, and the construction of the EIFS on most sides of the building. Please see Appendix B for more images of the 4D Models.



Active Tasks

Name	Status	Progress %	Comments	Start	End
Set Precast Planks/ Concrete Top...		89	0	8:00:00 AM 6/15/2007	5:00:00 PM 6/18/2007
Erect Steel Beams and Metal Deck...		9	0	8:00:00 AM 6/18/2007	5:00:00 PM 6/18/2007
Erect Steel Beams and Metal Deck...		9	0	8:00:00 AM 6/18/2007	5:00:00 PM 6/18/2007
Set Precast Planks/ Concrete Top...		89	0	8:00:00 AM 6/15/2007	5:00:00 PM 6/18/2007
Mechanical Room Area (L7)		2	0	8:00:00 AM 6/18/2007	5:00:00 PM 6/19/2007

Figure 18: Image of Structural 4D Comparison Model Simulated in Navisworks

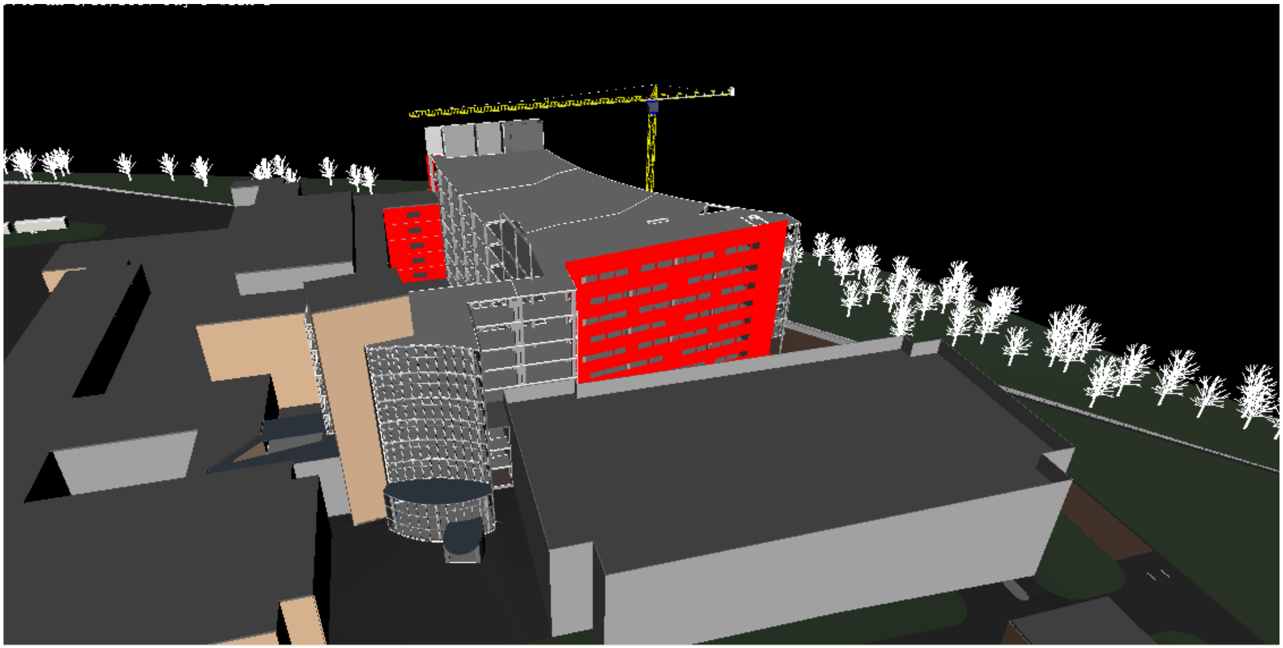
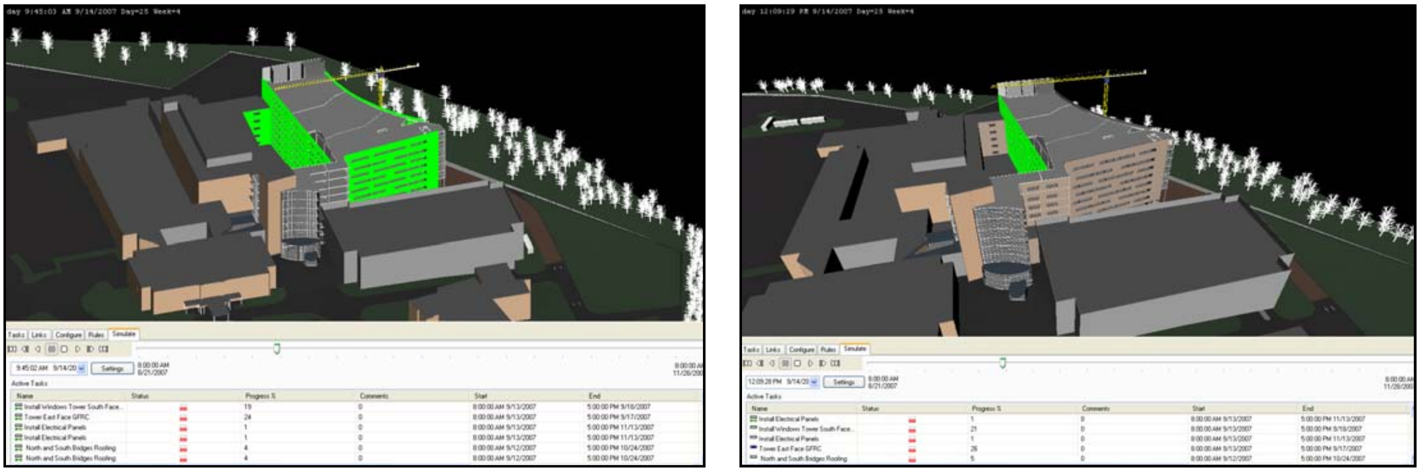


Figure 19: Image of 1st Facade 4D Comparison Model Simulated in Navisworks



EIFS Sequencing

day 9:45:03 AM 9/14/2007 Day=25 Week=4

9:45:02 AM 9/14/20 | 8:00:00 AM 8/21/2007 | 8:00:00 AM 11/28/200

Name	Status	Progress %	Comments	Start	End
Install Windows Tower South Face...	🟥	19	0	8:00:00 AM 9/13/2007	5:00:00 PM 9/18/2007
Tower East Face GFRC	🟥	24	0	8:00:00 AM 9/13/2007	5:00:00 PM 9/17/2007
Install Electrical Panels	🟥	1	0	8:00:00 AM 9/13/2007	5:00:00 PM 11/13/2007
Install Electrical Panels	🟥	1	0	8:00:00 AM 9/13/2007	5:00:00 PM 11/13/2007
North and South Bridges Roofing	🟥	4	0	8:00:00 AM 9/12/2007	5:00:00 PM 10/24/2007
North and South Bridges Roofing	🟥	4	0	8:00:00 AM 9/12/2007	5:00:00 PM 10/24/2007

GFRC Sequencing

day 12:09:29 PM 9/14/2007 Day=25 Week=4

12:09:28 PM 9/14/20 | 8:00:00 AM 8/21/2007 | 8:00:00 AM 11/28/200

Name	Status	Progress %	Comments	Start	End
Install Electrical Panels	🟥	1	0	8:00:00 AM 9/13/2007	5:00:00 PM 11/13/2007
Install Windows Tower South Face...	🟥	21	0	8:00:00 AM 9/13/2007	5:00:00 PM 9/18/2007
Install Electrical Panels	🟥	1	0	8:00:00 AM 9/13/2007	5:00:00 PM 11/13/2007
Tower East Face GFRC	🟥	26	0	8:00:00 AM 9/13/2007	5:00:00 PM 9/17/2007
North and South Bridges Roofing	🟥	5	0	8:00:00 AM 9/12/2007	5:00:00 PM 10/24/2007

Figure 20: Image of Structural 4D Comparison Model Simulated in Navisworks

4.7 Lessons Learned

Through the development of the 4D model, I was able to document some of the lessons learned from creating a 4D comparison model. The following list explains the lessons learned with this analysis:

- The 3D model was difficult and tedious to break up in Navisworks. I found that the best solution is to create the model components in the 3D Revit Model first and then import the components into Navisworks.

- The schedule was somewhat difficult to edit once it was imported into Navisworks. Sometimes the schedule could be edited in the Timeliner and other times the schedule was locked and could not be edited. I found that the schedule needs to be unlinked in the tasks tab within the timeliner tool. In order to unlink a new link, the new link needs to be right-clicked on and unlinked needs to be selected. Once the link is "unlinked", the schedule can be edited.

- The schedules could be edited in Navisworks by unlinking the schedule link. By being able to edit the schedule in Navisworks, there is no time wasted with deleting the link, revising the schedule in Microsoft Project, and relinking the schedule back into Navisworks.

- During the simulation, only some of the walls and windows would highlight to show that they were being constructed. I checked to make sure that all walls and windows were linked to the schedules. I found no problems with the components linking to the schedule so I am unsure why only some of the components are highlighted when being constructed. This problem may be affected by the size of the model that was imported to Navisworks.

- The use of different task types allowed for different colors to be used for each alternative system. The different colors made it very easy to visualize the differences in durations. As discussed above, the use of the different tasks and colors did not help in situations where two systems began at the same time.

- It is difficult to show the construction of two tasks using the same model components at the same time. When the two systems are going up at the same time in the same area, only one of the colors for one of the tasks will show up. Because the second color does not show up, it is unclear that the system is being constructed at the same time as the other system. For example, with the façade analysis, the GFRC system and the EIFS system were going up at the same time on the west side of the building. Because they both started at the same time, only the color for the EIFS system showed up. It was unclear to tell whether the GFRC was going up at the same time; however, once the GFRC was finished on the west side, the walls would turn yellow. The yellow indicated that the GFRC was finished on the walls. The model was very confusing because you didn't see the GFRC starting, but you could see it finish. Because it was difficult to illustrate when the two systems started on one wall, two separate models were used to show the façade systems comparison.

- As found with the façade system comparison, the process for comparing two systems described above does not always work. The process worked well with the structural system comparison because one system started before the other system so you could clearly identify where each structural system was in the simulation. With the façade system, this comparison was difficult because one façade did not go up before the other. Many times, the two systems would start at the same time on the same side or one system would start first and then the second would start on the same wall. During these instances, the second façade system did not appear to be going up on the same wall even though it was. The only way it was apparent that the second façade was going up was when the color changed to indicate the wall was done being constructed. Also, the walls were constructed by face for both the EIFS and GFRC, which made it challenging to show how far along the walls were in the simulation until the entire face would change color. If the two systems are not being sequenced the same, it is hard to illustrate the difference in durations.

- By using different task types and colors, the simulation of the two systems could occur in the same area using the same model components. Once again, the tasks did not help with areas where two façade systems were beginning at the same time.

- The selection sets option in Navisworks made it very easy to combine model components into one item. This item could then easily be linked to the corresponding scheduling task.

4.8 Conclusion and Recommendations

The use of 4D Modeling in the construction industry has become extremely popular over the past few years. For my research, I decided to look into 4D Modeling because I believe that the use of this tool will save money, time, and will also make the visualization process of a construction schedule much easier. I specifically chose to look at 4D Modeling as a comparison tool because my thesis project is based on comparing alternative systems. By creating a process for using a 4D Model as a comparison tool, I could review this process with my two analysis areas that deal with comparing two systems. With the other two analysis areas, I have found that the alternative solutions proposed in my thesis project have proved to be shorter in schedule durations. I believe that if 4D Modeling was used to compare these systems on the Patient Tower project, the project team would have reconsidered the proposed alternative systems. This tool would have been very valuable especially during the value engineering process. The models I have created do not show a lot of detail, but if the models had more detail, the project team could have visualized the actual construction steps with the 4D Model. For example, there are currently some issues with the construction of the EIFS system on the project. The process for constructing the EIFS system is proving to be very labor intensive and tedious. If a model was created in

great detail to illustrate the time consuming installation, the project team may have re-evaluated the decision to use EIFS as a value engineering solution.

Although, the use of 4D Modeling as a comparison tool did not work for all situations as seen with the façade comparison, the 4D Model was effective in showing the differences in durations for the two systems in the structural model. For the façade comparison, two separate models were used to illustrate the durations for the EIFS and GFRC. I believe it would have been able to compare the façade systems using one 4D Model if there was an option that allowed the model component to change colors as the systems are being placed on the building. For example, with the façade model, it was impossible to show the GFRC beginning on a face where the EIFS was still being constructed. The only way the beginning of the GFRC system would appear is if the EIFS was already complete on that specific face. By having an option that allowed the colors to change as systems were still begin simulated on the same side, the beginning of the GFRC could appear even as the EIFS is still being constructed. As the technology advances, there will be ways to better compare durations for the different systems. Within the next few years, I believe this new technology will continue to grow within the construction industry. Even though the 4D Modeling has some flaws, it is still an effective tool to compare various systems. The use of 4D Modeling will not only reduce time and cost on a project but will also aid in a better understanding of the construction sequences and durations.

5.0 TECHNICAL ANALYSIS #2

Precast Hollow Core Concrete Planks vs. Composite Slab

5.1 Problem Statement

The structure for the Women’s Center and Inpatient Tower is primarily a cast-in-place concrete system; however, part of the structural system is composed of structural steel framing with precast hollow core concrete panels. Because part of the new patient tower is being built over-top of an existing mechanical room, a structural steel truss system was used in this area to support the patient tower. The steel framed truss supports the area above the existing mechanical room for levels three through eight and the penthouse level. This area of the building is illustrated in Figure 21. The top right image taken from the patient tower side shows the structural steel truss being erected. The bottom right image taken from the existing hospital side shows the steel beams that will support the precast plank system. For this area, precast hollow core concrete planks were used for the flooring of the structure. The precast planks were chosen because they require no formwork or shoring in the construction process. Because this area of the building is located in a congested area on the inside corner of the tower, the erection of the precast panels was somewhat difficult. The technical analysis will look at eliminating precast hollowcore concrete planks from this area, and using a composite slab system for the flooring system. This analysis will focus on the cost impact, schedule impact, and constructability.

Figure 21: Photos from Patient Tower illustrating the steel truss above the mechanical room

5.2 Goal

The goal of this technical analysis is to demonstrate that a composite slab can be used as a viable option for the area above the existing mechanical room. This analysis will focus on the cost impact, schedule impact, and constructability. By using the composite slab, the precast concrete can be eliminated from the project. The costs of the precast panels will be removed from the project budget, and the costs of the structural steel beams, metal decking and additional concrete will be added to the budget. To determine the cost impact of changing the structural flooring system, the cost of using composite slab will be compared to the cost of precast concrete planks. Along with the cost impact, the constructability of the two systems will be reviewed. The review will consist of an analysis of the structural performance of the composite decking and slab. This analysis will then be compared to the precast concrete planks performance. The review will also look at the various challenges that may exist for constructing each of the structural systems. The change from precast concrete planks to a composite slab may also have an impact on the project schedule. This alternative system may potentially reduce the project schedule duration for the structural system of the patient tower. Because cast-in-place concrete is used for the rest of the tower, the time required to get the concrete is minimum. By using a composite slab, the concrete planks will be eliminated; therefore, the time needed to order and deliver the planks can be reduced. Also, because the concrete slab is placed using a pump, the structure can continue to go up without the use of the crane. With the precast panels, the crane is needed to erect the panels; therefore, the work needed to be completed on specific days when the crane was not in use. Due to this issue, the schedule may be shorter with the composite slab. The schedule and sequencing differences between the two systems will be illustrated using a 4D model. Because this analysis requires design of the composite slab, it will be used for a structural breadth for my thesis research.

5.3 Analysis Steps

1. Compile all information that corresponds to the steel truss and precast concrete panel structural system. This information will include the original budget and the project schedule.
2. Details pertaining to the construction of the precast panels and a description of the precast panels will also be reviewed. This may include any issues that occurred with placing the precast concrete panels.
3. Discuss the structural design with structural professors and students.
4. Design and analyze the composite metal decking and concrete slab system.
5. Create a schedule and budget for the alternate system.
6. Develop a 4D model to illustrate the schedule sequencing.
7. Compare the costs and durations of the alternate system to the original system.

5.4 Resources and Tools

1. Whiting-Turner Team- Bruce DeLawder's Health Group
2. Architectural Engineering Faculty (Professor Parfitt and Professor Hanagan)
3. Belfast Valley Contractors- Chris Miller
4. WT Steel
5. Vulcraft

6. RAM Structural System
7. Steel Construction Manual
8. Microsoft Excel
9. Microsoft Project
10. Whitney, Bailey, Cox, and Magnani- Mike Stasch

5.5 Composite Slab Design

5.5.1 Beam Design in RAM Structures

The design of the composite slab began with the layout of the structural steel beams in RAM Structural System. The area of the building that was being redesigned was set up in RAM Structures. The sizes and layout of the existing structural steel columns and beams remained the same throughout the design. The beams for the composite slab were only pieces being designed in RAM Structural Systems. To design the correct size beams for this area, a composite slab was chosen from the Nucor Vulcraft Group online catalog. The slab that was used for this design has a total slab depth of 6". The concrete used is normal weight concrete (145PCF). The metal decking has a clear span of 12'1" and has a self weight of 2.50PSF. The shear studs used are ¾" in diameter and 4.5" long. Please see Appendix C for an image of the Deck/Slab Property Information window from RAM. The dead and live loads were also applied to the slab before the beams were designed. The live load was taken directly from structural drawings for the BWMC Patient Tower. The dead load was calculated using the composite slab described above and other various dead loads listed in the structural drawings. Equations 1 and 2 show the dead and live loads used for this design.

Eq. 1: Dead Load Equation
DL= 5psf (MEP Equip.) + 2psf (Ceiling Load) + 2psf (Misc.) + 75psf (Comp. Slab)* = 84
*Composite Slab= 6" Concrete Slab (Normal Weight- 145pcf) + Metal Decking (2.5 psf)
= .5' x 145pcf + 2.5psf= 75psf

Eq. 2: Live Load Equation
LL= 80psf + 20psf (partition walls) = 100psf

Please see Appendix C for an image of the Surface Load Properties from RAM. Based on the composite slab and loads used, the beams that were designed in RAM consisted of five 8x10 wide flange beams. In order to be within the metal decking span of 12'1", these 8x10 wide flange beams were spaced 12' apart. The beam and shear stud design is illustrated in Figure 22. Once the beams were designed in RAM, the connections were designed using the Steel Construction Manual.

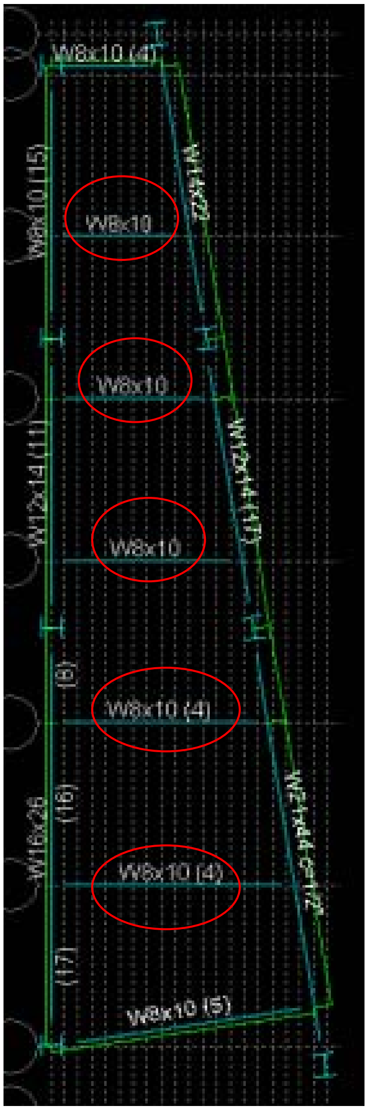


Figure 22: Plan View of 8x10 Beams Designed in RAM Structures

5.5.2 Connection Design

Now that the steel beams have been designed, the connection between the steel beams and concrete slab needs to be designed. The left end of the steel beam is connecting to a 16" concrete beam. The connection was designed using Table 10-9a- Single Plate Connections in the Steel Manual. As stated in Table 10-9. Single-Plate Connections, the single plate connection is welded to the support and bolted to the supported beam. The bolts and plates tabulated in Table 10-9a consider bolt shear, bolt bearing on the plate, shear yielding of the plate, shear rupture of the plate, block shear rupture of the plate, and weld shear. In order to design the connection, the shear force at the end of the beams needs to be calculated. As shown in Equations 1 and 2, the dead load was calculated to be 84psf and the live load was 100psf. Equations 3-5, show the calculations for the

reactions at each end of the beam. Because each beam is a different length, the longest beam length was used to calculate largest reaction on the beam.

Eq. 3: Factored Loads
FL=1.2DL + 1.6LL
FL=1.2 (84psf) + 1.6 (100psf) = 261psf

Eq. 4: Reaction Force
R= (wl)/2= (3132psf x 17’)/2= 26622lbs ~ 26.6kips
w= FL x trib. width of beam
w= 261psf x 12’ = 3132plf
l= length of longest beam
l= 17’

Eq. 5: LFRD
LFRD= ϕ R= (.75) (26.6kips) = 19.95 ~ 20.0kips
Φ= .75

Once the reaction forces were calculated, the single plate connection can be determined in Table 10-9a. Because the beams are only 7.89” deep, the connection needs to have a length smaller than or equal to 7.89”. Based on the LFRD and L≤7.89”, a connection using a ¼” thick plate that is 5 ½” long with (2) ¾” bolts and a 3/16” weld was chosen. The bolts used for the connection are threaded A325 with standard holes. The detailed section of this connection is shown in Figure 23.

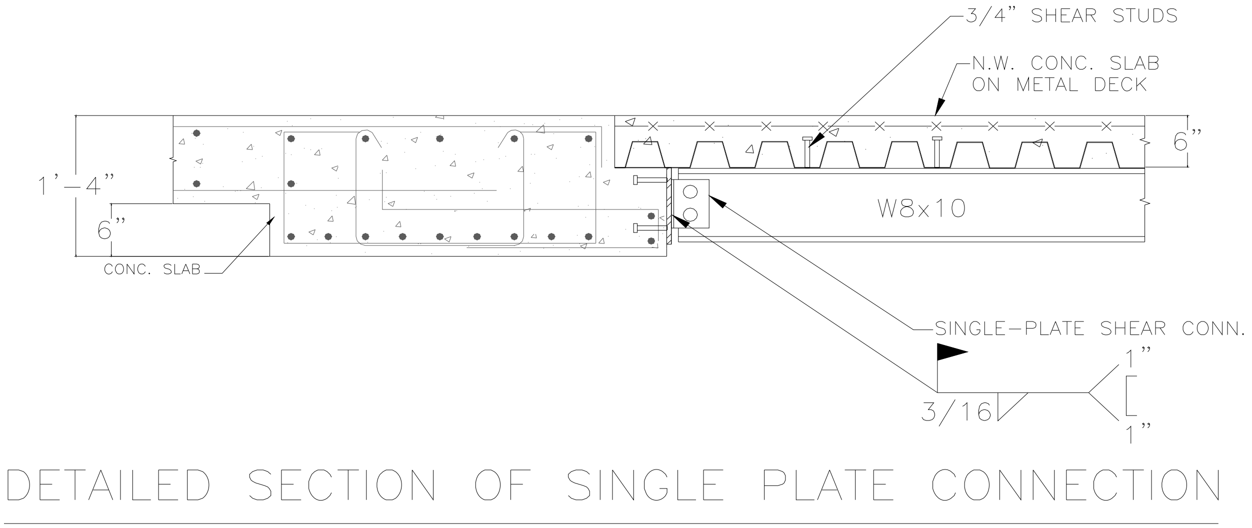


Figure 23: Section View of Connection Detail between cast-in-place beam and composite slab system

5.6 Cost Analysis

*Please see Appendix D for material quantity takeoffs

The cost estimates for the two systems were calculated using primarily estimates provided by the actual subcontractors who worked on the BWMC Patient Tower. The cost for the W8x10 beams is the only item where R.S Means was used. The precast system as shown in Table 3, includes the precast hollow core planks and a 2”concrete topping with 6”x6” W.14xW1.4 W.W.F. The composite slab alternative system in Table 4, includes W8x10 beams, a 6” concrete slab with 6”x6” W.14xW1.4 W.W.F., and metal decking. The equipment cost for the precast concrete planks was taken from the tower crane rental cost for the project. The equipment costs for the concrete and metal decking is included within the material or labor cost. For the concrete, the equipment used is a concrete pump. The equipment used to erect the metal decking is a mobile crane.

Table 3: Precast Planks Cost Estimate

Precast Concrete Hollow Core Planks Estimate										
Item	Units	Quantity	Unit Mat'l	Mat'l Cost	Unit Labor	Labor Cost	Unit Equip.	Quantity	Equip. Cost	Total Item Cost
8" Hollow Planks	planks	70	$1,500.00	$105,000	$200.00	$14,000	$974/Day	10 days	$9,740	$128,740
2" Concrete Topping w/ 6"x 6" W1.4 x W1.4 W.W.F	sf	7252	$5.00	$36,260	$0.00	$0	$0.00	-	$0	$36,260
Total Precast Concrete Planks Estimate:										**$165,000**

Table 4: Composite Slab Cost Estimate

Composite Slab Estimate									
Item	Units	Quantity	Unit Mat'l	Mat'l Cost	Unit Labor	Labor Cost	Unit Equip.	Equip. Cost	Total Item Cost
W 8x10 Beams	lf	469	$11.30	$5,300	$3.77	$1,768	$2.58	$1,210	$8,278
6" Concrete Slab w/ 6"x 6" W1.4 x W1.4 W.W.F	sf	7252	$6.00	$108,968	$0.00	$0	$0.00	$0	$108,968
3" 20 Gauge Metal Decking	sf	7252	$2.10	$15,229	$0.90	$6,527	$0.00	$0	$21,756
Total Composite Slab Estimate:									**$139,002**

Table 5: Cost Comparison of Structural Systems

Cost Comparison of Structural Systems	
Item	Cost
Precast Hollow Core Planks	$165,000
Composite Slab	$139,000
Difference in Cost :	**$26,000**

Based on the cost comparison in Table 5, the cost of the composite slab system is somewhat less than the precast system. The difference between the two systems is about $26,000. The cost of the tower crane added a large cost to the precast system whereas the composite slab only required a mobile crane so the cost was not nearly as high.

5.7 Schedule

*Please see Appendix B for more images of the Structural 4D Model.
*Please see Appendix E for project schedules of the two different systems created in Microsoft Project

The schedule durations were calculated using actual data from the concrete and steel subcontractors on the project and also R.S. Means. The durations for each item within the two systems are shown in Tables 6 through 9. Because many of the durations only took an hour or two, some items were combined so that they could be completed on the same day. As shown in Tables 5 and 7, the placing of the wire mesh and concrete can be completed on the same day for both the precast planks system and the composite slab system. The concrete can also be finished on the same day that the wire mesh and concrete is placed. With the composite slab, the metal decking can be placed the same day as the W8x10 beams. See Tables 6 through 9 for the durations of both structural systems in hours and days.

Table 6: Precast Plank Durations in Hours

Precast Concrete Panels Schedule Durataions				
Items per Level	Units	Quantity	Daily Output	Durations (Hours)
Precast Concrete Panels	planks	10	10	8
Place Wire Mesh	csf	10.36	35	2
Place 2" Concrete Topping with Pump	cy	7	160	1

Table 7: Precast Plank Durations in Days

Precast Concrete Panels Schedule Durations	
Levels 3-9	Duration (Days)
Precast Concrete Panels	1
Place Wire Mesh and Concrete	1
Total Duration (Levels 3-9) :	**14**

Table 8: Precast Plank Durations in Hours

Composite Slab Schedule Durataions				
Items per Level	Units	Quantity	Daily Output	Duration (Hours)
Erect Structural Steel (8x10)	lf	70	600	1
Erect Metal Decking	sf	1036	3200	3
Place Wire Mesh	csf	10.36	35	2
Place Concrete by Pump	cy	20	160	1

Table 9: Precast Plank Durations in Days

Composite Slab Schedule Durations	
Levels 3-9	Duration (Days)
Erect Steel Beams and Metal Decking	1
Place Wire Mesh and Concrete	1
Total Duration (Levels 3-9) :	**14**

Because the precast planks can be placed in the same amount of time as the steel beams and decking, the schedule durations for the two systems will take about the same amount of time. The estimated duration for the two systems as illustrated in Table 10 is about 14 days.

Table 10: Schedule Duration Comparison of Structural Systems

Schedule Duration Comparison for Structural Systems	
	Duration (Days)
Precast Planks	14
Composite Slab	14
Difference (Days) :	**0**

Even though the durations are about the same, the sequencing for these two systems is considerably different. The precast planks are erected using the tower crane whereas the steel beams and metal decking are erected using a mobile crane. Because the concrete subcontractor had rented the tower crane, the precast planks needed to be erected on an off-day when the crane was not utilized by the concrete subcontractor. The precast planks were typically placed on a Saturday, and the concrete topping was placed in the following week. With the composite slab, the cast-in-place concrete for the surrounding structure would need to be placed and cured first before the steel beams could be erected. Because the conventional 28-day strength needs seven days before it can support any load, the steel beams can be erected seven days after the surrounding concrete is poured. Once the steel beams and metal decking are erected, the wire mesh and concrete could be placed the following day.

5.8 Constructability

Even though the schedule durations for the two systems proved to be about the same, the alternative system using a composite slab is the best system in terms of constructability. The precast plank system was chosen based on the fact that there is no need for formwork and shoring. However, with the composite slab system, minimal formwork will be needed seeing as though the metal decking replaces much of the formwork and shoring if needed will be minimal. Even though there is no need for shoring and formwork with the precast system, there are still other constructability issues with the precast planks. As illustrated in Figure 9, this area of the building is located on the inside corner of the Patient Tower; therefore, it is difficult to reach the area using a tower crane. The placing of the planks on the bottom floors within this area are especially hard to reach. With the composite slab, the metal decking is considerably lighter than the precast planks; therefore, a mobile crane can be used instead of the tower crane to place the metal decking. Because this mobile crane has some flexibility with where it is placed, it is much easier to place the metal decking. In order for the mobile crane to reach this area, it would be placed at the north edge of the tower. Because there is already a mobile crane on site, there will be no additional cost for renting an additional mobile crane. Figure 24 shows an image of the site layout for the construction of this redesigned area.

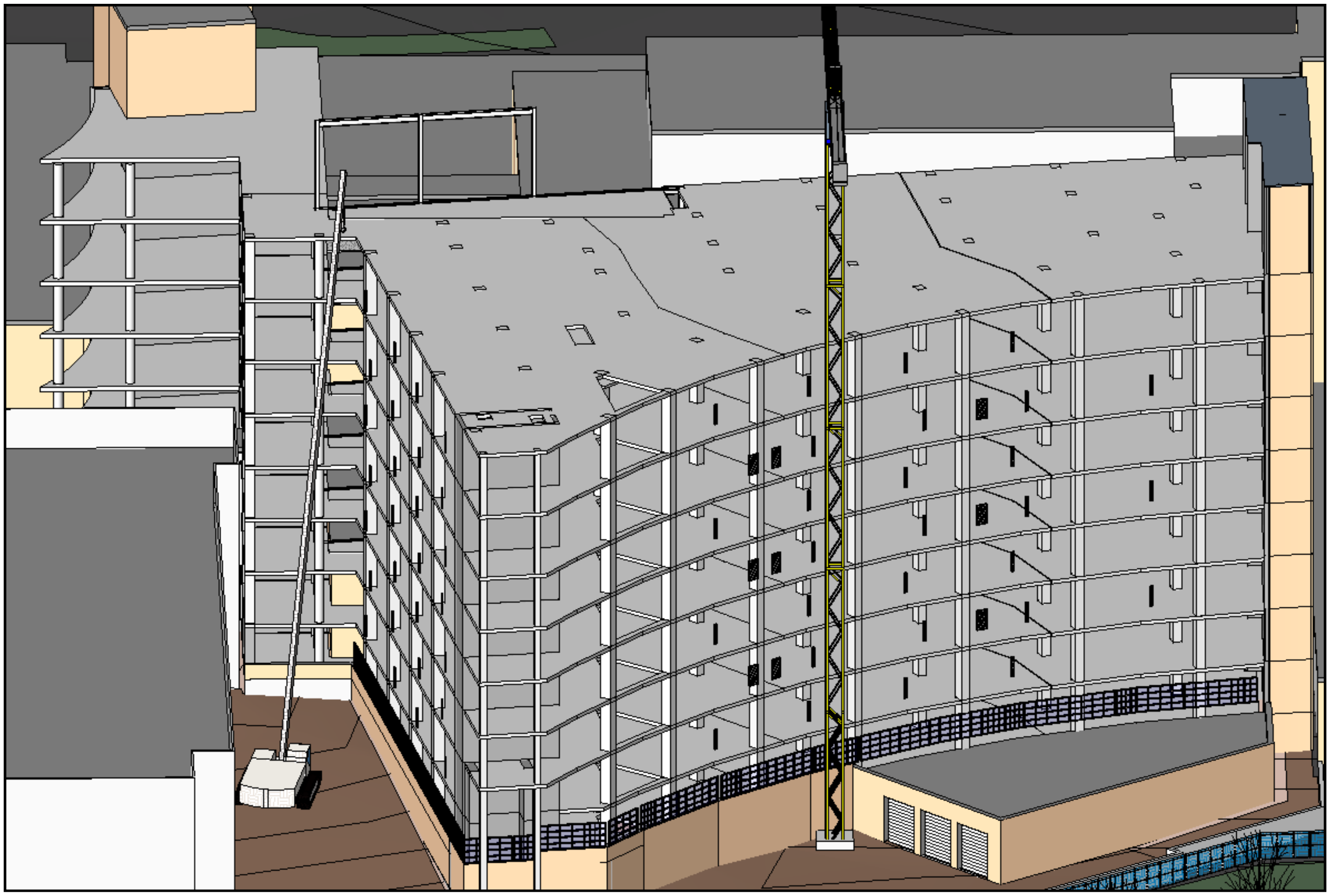


Figure 24: Site Logistics of Mobile Crane for Area above Ex. Mechanical Room

5.9 Conclusion and Recommendations

Based on my analysis of the precast concrete planks versus the composite slab, I conclude that the alternate design using the composite slab system is the best option for this area of the Patient Tower. The idea for this analysis area arose when I talked to a project engineer from the project team. We discussed that it made little sense to use precast planks when the rest of the structural system was designed using cast-in-place concrete. After further investigation with this area, the precast planks did not appear to be the best solution. When the precast planks were compared to the composite slab, the composite slab proved to be the best option in terms of cost and constructability. Using the composite slab system, an estimated $26,000 would be saved in cost. Because a mobile crane can be used to place the metal decking, the placement of the metal decking would be much easier than the precast concrete planks. The concrete slab for the composite slab and the concrete topping for the precast planks would both be pumped using a pump truck so the constructability of the concrete appears to be the same. As far as the schedule durations, the two systems would take about the same time to complete. For BWMC-Women’s Center and Inpatient Tower, it is recommended to use the composite slab in place of the precast hollow core concrete planks.

6.0 TECHNICAL ANALYSIS #3
EIFS Panels vs. GFRC Panels

6.1 Problem Statement

The original design of the Women's Center and Inpatient Tower included Glass-Fiber Reinforced Concrete (GFRC) Panels for the majority of the façade. During the value engineering process, these GFRC panels were replaced with Exterior Insulation Finishing System (EIFS) Panels. As the EIFS was being installed, there were some issues with the termination of EIFS around the windows. This issue is very important because if the EIFS is not properly installed and sealed, water is able to seep into the building. These issues with the EIFS will most likely delay the project schedule, which may also have an impact on the project cost. Another concern with installation of EIFS is that it is labor intensive. EIFS is composed of many layers, and each of the layers is installed separately on site. The only layer of the EIFS Panel that can be prefabricated offsite is the EPS Insulation. This insulation board can be cut to size before it reaches the construction site. Because the EIFS Panels are not prefabricated, the process of installing each layer is very tedious. A third issue with EIFS involves the quality of the system. If EIFS is not properly installed, there is the potential that water will seep into the building, and there will be mold issues. Because this building is a hospital, it is crucial that the building is of the highest quality; therefore, any health issues such as mold need to be avoided at all costs.

6.2 Goal

The goal of this technical analysis is to prove that the original design using GFRC is best design option for the building. In order to prove that GFRC is the best option, this analysis will focus on comparing the thermal quality, life cycle cost, and constructability of the two systems. Because the highest quality needs to be maintained for hospitals, the thermal quality of the building is a critical issue. Because the initial cost of EIFS proves to be less than the initial cost of GFRC, a life cycle cost will be determined for the two systems to illustrate a more accurate cost analysis for the two systems. A constructability analysis will be used to focus on the constructability of the two systems, which may affect the schedule durations. The advantages of the GFRC Panels will be demonstrated by improving the installation process and decreasing the schedule duration, using the life cycle cost as an accurate cost analysis, and also by improving the thermal quality of the hospital.

6.3 Analysis Techniques:

1. Determine the square footage of the EIFS Façade that will be replaced by GFRC.
2. Use the same GFRC design that is shown in the original construction documents. Compile all information for the original GFRC panels.
3. Select the EIFS Panels from StoCorp Website that match the design used on the building.

4. Find the R-values for all of the building components for both façade systems. Calculate the U-value of the two systems using the R-Values from each material component. Calculate and compare the heat loss and gain for the two systems.
5. Analyze the structural impact of the GFRC Panels.
6. Contact various manufacturers to determine the initial costs and installation durations for the GFRC and EIFS Panels.
7. Compare the initial costs of the two systems.
8. Determine the life cycle costs of the two systems by obtaining information from various manufacturers about the maintenance of GFRC and EIFS Panels.
9. Use Engineering Economic equations and Microsoft Excel to determine the future value of the maintenance costs. Include the initial costs in the total cash outflow.
10. Compare the life cycle costs of the two systems. Relate the life cycle costs to the initial costs.
11. Create a schedule for the GFRC using the installation durations provided by manufacturers.
12. Create a schedule for the EIFS using the actual project schedule
13. Compare schedule durations of the two systems.
14. Create 4D Models of the two façade systems to show the difference in installation durations.
15. Compile and compare all the information for the two systems.

6.4 Resources and Tools

1. Whiting-Turner Team- Bruce DeLawder's Health Group
2. Clark Pacific- Sales/Technical Representative
3. Eagle Precast Company- Lynn Fred (Sales/ Project Manager)
4. Architectural Engineering Faculty (Andreas Phelps)
5. Whitney, Bailey, Cox, and Magnani- Mike Stasch
6. Dryvit- John Roam (Sales Rep.)
7. Mechanical and Electrical Equipment for Buildings 9th Ed.
8. Engineering Economics Analysis Book
9. Georgia- Pacific Building Products
10. Precast Concrete Institute (PCI) GFRC- Recommended Practice- MNl-128-01:Recommended Practice for Glass Fiber Reinforced Concrete
11. StoCorp
12. R.S. Means
13. ASHRAE Handbook of Fundamentals
14. Trace 700 (Trane)
15. Microsoft Excel
16. Microsoft Project
17. Revit Architecture
18. Navisworks- Timeliner

6.5 Existing Conditions

The alternative system chosen to replace the existing façade is Glass Fiber Reinforced Concrete (GFRC). This alternative was selected because it was the original design for the façade. The original design included the GFRC Panels with 2 ½" Spray Polyurethane Foam Insulation. The GFRC Facade consisted of a GFRC Panel that was attached to 3 5/8" metal studs. These panels were replaced with the EIFS Panels in order to save money. EIFS was chosen because its initial cost is much less than the cost of GFRC. EIFS is also known for its thermal quality because it uses Expanded Polystyrene Foam for the insulation component. The EIFS seemed to be the best solution initially. Because various colors can be selected for the EIFS and GFRC panels, the architectural appearance of the building will only slightly change. Some of the advantages of using the GFRC (original) design may include better thermal quality, cheaper lifecycle cost, quicker installation, and less waste material. The Figures 25 and 26 illustrate the building sections for the existing design using EIFS and the alternative (original) design using GFRC.

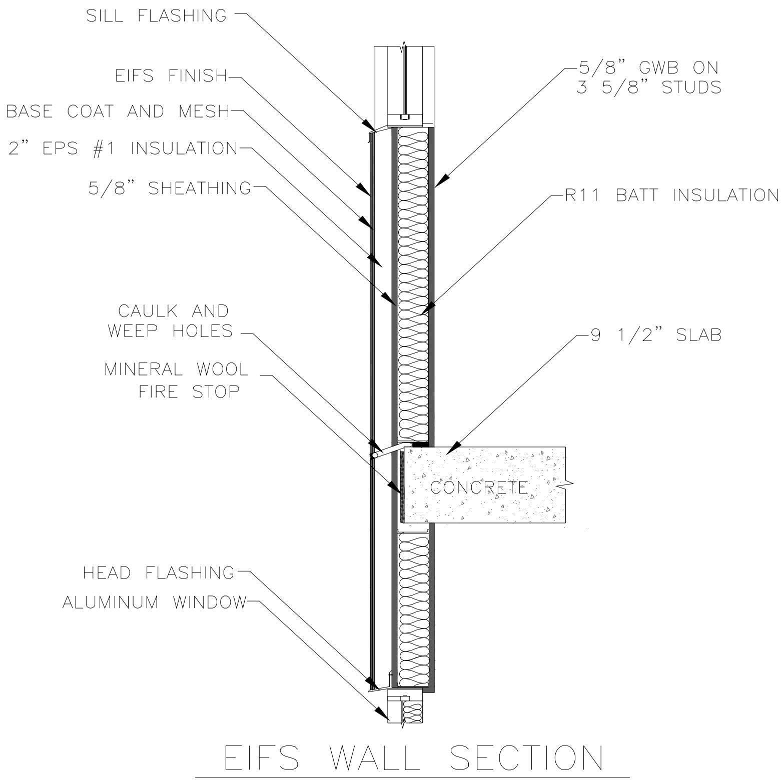


Figure 25: EIFS Wall Section

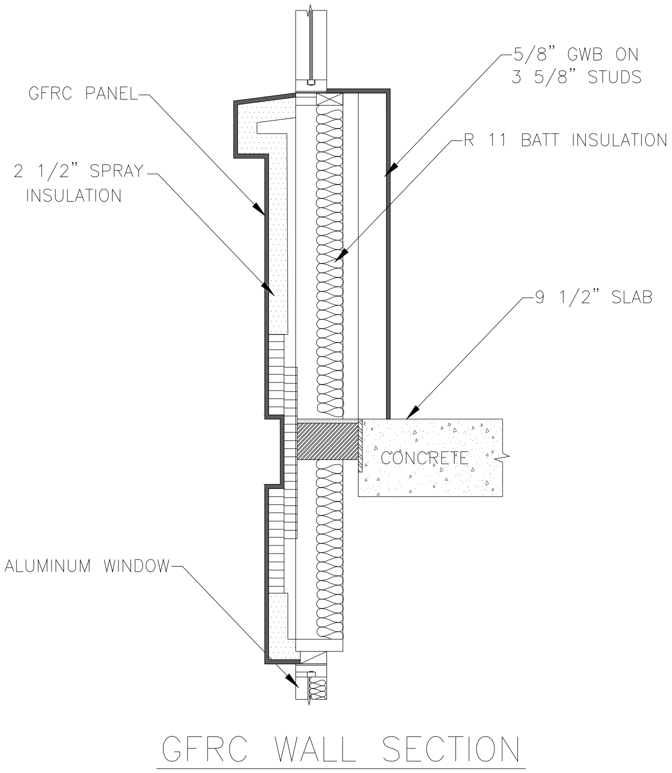


Figure 26: GFRC Wall Section

6.6 Thermal Quality Impact

The thermal quality of a building façade can vary greatly depending on the type and thickness of the materials used for a system. The R-Values of each material are used to determine the thermal impact that a façade has on the building. The R-Values are then used to calculate the U-Value for the entire façade system. The lower the U-Value, the better it is at insulating. Tables 11 and 12 show the R-Values for each component within a wall system and the U-Value for each system.

Table 11: R-Values and U-Values for EIFS

R-Values and U-Values for Exterior Insulation Finishing System (EIFS)			
Components	Thickness (in.)	R-Value / Thickness (in)	R-Value (hr ft^2 °F/BTU)
Sto Essence DPR Finish	-	-	-
Sto Primer/Adhesive-B	-	-	-
Sto Reinforcing Mesh	-	-	-
2" Sto #1 EPS Insulation	2	4.00	8
Sto Primer/Adhesive-B	-	-	-
Sto Guard Moisture Protection	-	-	-
5/8" DensGlass Gold Sheating	0.625	-	0.67
3 5/8" Metal Studs	-	-	-
R11 Batt Insulation	3.5	-	11
5/8" GWB	0.625	-	0.67
	Total R-Value	**hr ft2 °F/ BTU**	**20.34**
	U-Value (∑ 1/R)	**BTU/ hr ft2 °F**	**0.0492**

Table 12: R-Values and U-Values for GFRC

R-Values and U-Values for Glass Fiber Reinforced Concrete (GFRC)			
Components	Thickness (in)	R-Value / Thickness (in)	R-Value (hr ft^2 °F/BTU)
GFRC Skin	0.50	0.14	0.07
2 1/2" Spray Insulation	2.5	6	15
3 5/8" Metal Studs	-	-	-
R 11 Batt Insulation	3.5	-	11
5/8" GWB	0.625	-	0.67
	Total R-Value	**hr ft2 °F/ BTU**	**26.74**
	U-Value (∑ 1/R)	**BTU/ hr ft2 °F**	**0.0374**

Based on the two U-Values shown in Table 11 and 12, the GFRC seems to be the best insulating system. These two U-Values calculated above along with the outside and inside dry bulb temperatures are used to determine the heat gain in the summer and heat loss in the winter for the two façade systems. The outside and inside temperatures for Baltimore, MD shown below were determined using Trane Software.

Fig. 27: Summer Cooling Loads for Baltimore, MD

Outside Dry Bulb Design Temperature (To)	91°F
Inside Dry Bulb Design Temperature (Ti)	75°F
Change in Temperature (ΔT)	16°F

Fig. 28: Winter Heating Loads for Baltimore, MD

Outside Dry Bulb Design Temperature (To)	13°F
Inside Dry Bulb Design Temperature (Ti)	70°F
Change in Temperature (ΔT)	57°F

Using the Heat Transfer Equation, the total summer heat gain and winter heat loss from the façade systems can be determined. The heat transfer equation shown as Eq. 6 was given in the ASHRAE Handbook of Fundamentals.

Eq. 6: Heat Transfer Equation

$$q_x = \Delta T * A * U$$

Table 13: Summer Heat Gain

Summer Heat Gain					
Façade System	Area (SF)	U-Value (BTU/hr ft2 °F)	ΔT (°F)	Heat Gain (BTU/hr)	Heat Gain (Tons=12,000 BTU/hr)
EIFS	45690	0.0492	16	35967	3.0
GFRC	45690	0.0374	16	27341	2.3
				Difference (Tons) :	**0.7**

Table 14: Winter Heat Loss

Winter Heat Loss					
Façade System	Area (SF)	U-Value (BTU/hr ft2 °F)	ΔT (°F)	Heat Loss (BTU/hr)	Heat Loss (Tons=12,000 BTU/hr
EIFS	45690	0.0492	57	128133	10.7
GFRC	45690	0.0374	57	97402	8.1
				Difference (Tons) :	**2.6**

Based on the summer heat gain and winter heat loss shown in Table 13 and 14, the GFRC Façade proved to be the better system in terms of thermal quality. For the summer heat gain, the difference between the two systems was 0.7 tons, which is considered to be minimal. However, for the

winter heat loss, the difference between the systems was 2.6, which is considered to be somewhat significant. Initially, the EIFS System seems to be the best option; however, the GFRC turned out to be the better alternative overall. The GFRC System itself did not have the best thermal quality; however, the 2 ½" spray polyurethane foam insulation that was used in the original design greatly increased the thermal quality of the façade system. Without this additional spray insulation, the EIFS System would have been the better thermal system. Based on the two systems used, the original design using GFRC is the best thermal option for this building.

6.7 Structural Impact

The GFRC Panels used as the alternative system are considered to be lightweight precast panels compared to other precast concrete panels. After speaking with the Structural Engineer for the Patient Tower project, I was informed that the difference in weight between the GFRC and EIFS is minimal. In fact, when the system was changed from GFRC to EIFS in the value engineering process, the structure remained the same. Because the weights are about the same for the two façade systems and the structure did not change, there will be no structural impact from using the alternative facade.

6.8 Initial Cost Analysis

One of the main reasons that the GFRC was replaced with EIFS is due to the huge difference in initial cost. The EIFS is considerably cheaper than the GFRC when looking at the initial cost. In order to have the most accurate costs for the two systems, most of the cost data was obtained from various subcontractors and manufacturers. The price of the EIFS Panels shown in Table 15 was provided by the same subcontractor that is installing the EIFS System on the Patient Tower. Because the GFRC price varied significantly depending on the location, the estimate shown in Table 16 was calculated using the average cost of three estimates provided by various subcontractors. None of the estimates for the GFRC included the additional spray insulation that was used in the original design so this cost needed to be added to the GFRC estimate. The other costs were found using cost data from R.S. Means.

Table 15: EIFS Cost Estimate

EIFS Estimate									
Item	Units	Quantity	Unit Mat'l	Mat'l Cost	Unit Labor	Labor Cost	Unit Equip.	Equip. Cost	Total Item Cost
EIFS	sf	45690	$10.00	$456,900	$1.00	$45,690	$1.50	$68,535	$571,125
Non-Structural Metal Framing	sf	45690	$0.34	$15,535	$0.76	$34,724	$0.00	$0	$50,259
Exterior Sheathing (1/2")	sf	45690	$0.52	$23,759	$0.55	$25,130	$0.00	$0	$48,888
								Total Cost :	**$670,272**

Table 16: GFRC Cost Estimate

GFRC Estimate									
Item	Units	Quantity	Unit Mat'l	Mat'l Cost	Unit Labor	Labor Cost	Unit Equip.	Equip. Cost	Total Item Cost
GFRC Panels	sf	45690	$45.00	$2,056,050	$0.00	$0	$0.00	$0	$2,056,050
2 1/2" Spray Polyurethane Foan	sf	45690	$1.03	$47,061	$1.48	$67,621	$1.27	$58,026	$172,708
								Total Cost :	**$2,228,758**

When comparing the initial costs of the two systems as shown in Table 17, the cost of the EIFS System is significantly lower than the GFRC System. In fact, the GFRC is more than three times the cost of the EIFS System. In terms of initial cost, the EIFS proved to be the best value engineering solution. However, the initial cost does not include any maintenance costs; therefore, the best way to compare the two systems in terms of cost is a life cycle cost.

Table 17: Cost Comparison of Façade Systems

Cost Comparison of Façade Systems	
Item	Cost
Exterior Insulation Finishing System	$670,272
Glass Fiber Reinforced Concrete	$2,228,758
Difference in Cost=	**$1,558,486**

6.9 Life Cycle Cost Analysis

*Please see Appendix F for Life Cycle Costs of EIFS and GFRC

As shown above, the EIFS System appeared to be the best solution when comparing the initial costs of the two. This initial cost does not provide an accurate estimate over the life time of these two systems. The life cycle costs are shown for a duration of 25 years. The costs that are shown in Table 18 and 19 include all types of maintenance and the cost estimates associated with each type of maintenance. The various types of maintenance and costs were also obtained from various subcontractors in order to have accurate life cycle costs. In order to calculate the future value of all maintenance, the future value equation was used. This equation shown as Eq. 7 was taken from the Engineering Economic Analysis Book. The interest rate (r, rate) that is assumed for this calculation is 3.0%. After comparing the life cycle costs, the EIFS System proved to still be the cheapest system overall.

Eq. 7: Future Value Equation by Hand

$F = P\,(1+r)^n$

F = Future sum of money
P = Present sum of money
r = Nominal rate of interest
n = number of interest periods

Eq. 8: Future Value Equation by Excel

FV(rate,nper,pmt,pv) in Microsoft Excel

FV= Future sum of money
Rate= interest rate per period
Nper= number of interest periods
Pmt= payment made each period
PV= Present sum of money

Table 18: Life Cycle Cost for EIFS

Life Cycle Cost for EIFS							
EIFS	Year 0	Year 5	Year 10	Year 15	Year 20	Year 25	Cash Outflow
Initial Cost of System	-$670,272						-$670,272
Description of Maintenance							
Cleaning		-$15,890	-$18,421	-$21,355	-$24,756	-$28,699	-$109,122
Re-coat Panels					-$165,042		-$165,042
Replace Joint Sealant			-$16,127		-$21,673		-$37,800
						Total Cost :	**($982,237)**

Table 19: Life Cycle Cost for GFRC

Life Cycle Cost for GFRC							
GFRC	Year 0	Year 5	Year 10	Year 15	Year 20	Year 25	Cash Outflow
Initial Cost of System	-$2,228,758						-$2,228,758
Description of Maintenance							
Replace Joint Sealant					-$21,673		-$21,673
Cleaning						-$68,879	-$68,879
						Total Cost :	**($2,319,310)**

6.10 Schedule Durations

*Please see Appendix B for more images of the Facade 4D Models.
*Please see Appendix E for project schedules of the two different systems created in Microsoft Project
*Please see Appendix G for Façade Duration Calculations

When comparing the two systems in terms of schedule durations, the GFRC Panels can be installed much faster than the EIFS Panels. Because the GFRC Panels, which include metal studs, are prefabricated in a factory, the duration for erecting these panels is very short. In order to receive these panels on time, there is a lead time of around 8 months. The EIFS Panels cannot be fabricated in a factory; therefore, each layer of the panel needs to be installed onsite. This process of installing each layer onsite is considered to be very tedious and labor intensive. Due to this onsite installation, the durations are considerably longer than the GFRC Panels. In Table 20, the schedule durations are compared for the two systems. The schedule durations for the EIFS Panels were taken directly from the project schedule. In order to have accurate schedule durations for the GFRC Panels, a few durations were obtained from various subcontractors and were averaged together. Both façade systems were sequenced by face of the building. The window installation began as soon as the façade was finished on that particular face of the building.

Table 20: Façade Schedule Duration Comparison

Façade Schedule Duration Comparison	
	Duration (Days)
EIFS	122
GFRC	29
Difference (Days)=	**93**

As shown in Table 20, the EIFS will take an additional 93 days to install when compared to the GFRC System. This significant difference between the duration can have a huge impact on the overall project duration. This duration is very important because it dictates how quickly the building can be enclosed. This is a huge milestone on the project schedule because the chance of mold and other issues is greatly reduced once the building is enclosed. With the GFRC System, the building can be enclosed much faster than the EIFS. Along with the building being enclosed early, change in duration may also have an impact on the overall project completion date. If the project schedule can be reduced, the cost of the project can potentially be reduced. In terms of schedule duration, the GFRC System is the best solution.

6.11 Conclusion and Recommendations

From the facade analysis on EIFS versus GFRC, I have found advantages and disadvantages for both systems. The advantages found with using EIFS are a lower initial cost and also a life cycle cost. I expected to find the initial cost to be significantly lower for the EIFS since this was the main reason for switching to the EIFS system; however, I was surprised by the huge difference in costs for the life cycle costs. I had expected to find that the life cycle costs of the two systems were not as drastic as the initial costs. The cost is the major advantage for the EIFS system. Even though this is a huge advantage for using EIFS, it is really the only advantage found. Some of the disadvantages found with using EIFS are the amount of time it takes to place the façade system, and also the labor intensity involved with placing the system. Also with EIFS, there is a greater potential for water problems if the system is not properly installed. Any problems with water damage or mold issues could have a huge impact on the project. Another disadvantage was found on the actual project. There were problems with the installation process, which may affect the overall project duration. If the project is delayed, there may be extra costs incurred from the delay. These are some of the advantages and disadvantages found with using EIFS.

The advantages found with GFRC mostly involved the construction process for installing the façade. The GFRC proved to go up much faster than the EIFS system, and also the constructability of the GFRC was better than the EIFS. The fact that the GFRC panels were already prefabricated when they reached the site allowed the GFRC to go up rapidly and easily. With the EIFS, the various layers are installed directly on the faces of the building; therefore, it takes longer and is considered more tedious. With a quicker schedule, the building may be enclosed much faster than with the EIFS system. If this is the case, the potential for weathering damage will be greatly reduced. Also, if the façade schedule affects the overall project schedule in the fact that the project can finish earlier, there may also be a potential for cost savings. The GFRC also proved to be the best insulated system. In most cases, EIFS proves to be the best system because it is mostly composed of insulation; however, the original design of the GFRC used an additional 2 ½" spray insulation. The difference in the summer heat gain was minimal; however, the winter heat loss between the two systems was somewhat significant. With the GFRC being the better thermal system, there may also be energy savings. The major disadvantage for the GFRC was the initial and life cycle costs that were calculated. The GFRC costs were significantly higher the EIFS; however, there may be some cost savings with the other advantages of the GFRC.

Based on the advantages and disadvantages of the two systems, I find the GFRC system to be the best in quality; however, the EIFS system is the best for this project considering the budget that is required for the project. In most circumstances, I would recommend the GFRC because I believe it is a better quality system. The EIFS is being recommended for this project based on the huge cost savings that it provides.

7.0 FINAL SUMMARY AND CONCLUSIONS

The first analysis, which looked at a critical industry issue, examines the use of 4D Modeling as a comparison tool for the Baltimore Washington Medical Center- Women's Center and Inpatient Tower. The study involved the development of a 4D Modeling process, which could be used to compare scheduling and sequencing for two systems. The process was reviewed on the structural and façade analyses where the process proved to be somewhat effective in comparing the alternatives. It was discovered that the 4D Model could be used as a comparison is some instances, but not all instances. For the structural analysis, the 4D tool proved to be effective in showing the different timing between the two structural systems. However, with the façade analysis, it was difficult to clearly show the scheduling and sequencing of the façade systems using the 4D Model. Even though there are some improvements that need to be made with the program, the 4D comparison tool would still have been useful on the BWMC-Women's Center and Inpatient Tower.

The second analysis looked a small portion of the structural system for the Patient Tower. The investigation focused on replacing the precast hollow core planks with a composite slab for the area above the existing mechanical room. The study included a structural design of the composite slab and an analysis on the cost, schedule, and constructability of the alternative system. The alternative system proved to be the best system in terms of cost and also constructability. The schedule durations for the two systems were the same, but the alternative system had no restrictions on when it could be placed whereas the precast planks could only be placed on the weekend when the tower crane was free to use. It is recommended that the composite slab be used in place of the precast hollow core concrete planks.

The third analysis focuses on the changing the façade system from EIFS to GFRC. The original design for the project was GFRC; however, EIFS replaced it as a value engineering option. For the analysis, the two systems were compared based on their thermal quality, their impact on the structural system, initial and life cycle cost over 25 years, schedule duration and sequencing, and constructability. From the investigation, there were advantages and disadvantages for both systems. The biggest advantage for the EIFS is the initial and life cycle cost. The EIFS proved to be much cheaper than the GFRC. The advantages of the GFRC included thermal quality, schedule durations, and constructability. Even though I believe the GFRC is the best system in terms of quality, the huge cost savings associated with the EIFS system make it the best system for this project.

8.0 REFERENCES

American Institute of Steel Construction. Steel construction manual, American Institute of Steel Construction 2005.

ASHRAE, 2005 ASHRAE – Fundamentals. American Society of Heating Refrigeration and Air Conditioning Engineers, Inc., Atlanta, GA. 2001.

Lindeburg, Michael R, Engineering Economics Analysis- An Introduction. Professional Publications, Inc., Belmont, CA 2001.

PCI Committee on Glass Fiber Reinforced Concrete Panels. GFRC- Recommended Practice- MNl-128-01:Recommended Practice for Glass Fiber Reinforced Concrete. Chicago, IL: Precast/Prestressed Concrete Institute ,2001.

Products/ Gypsum Boards and Drywall. Georgia-Pacific- Building Products. March 2008. http://www.gp.com/build/product.aspx?pid=4674

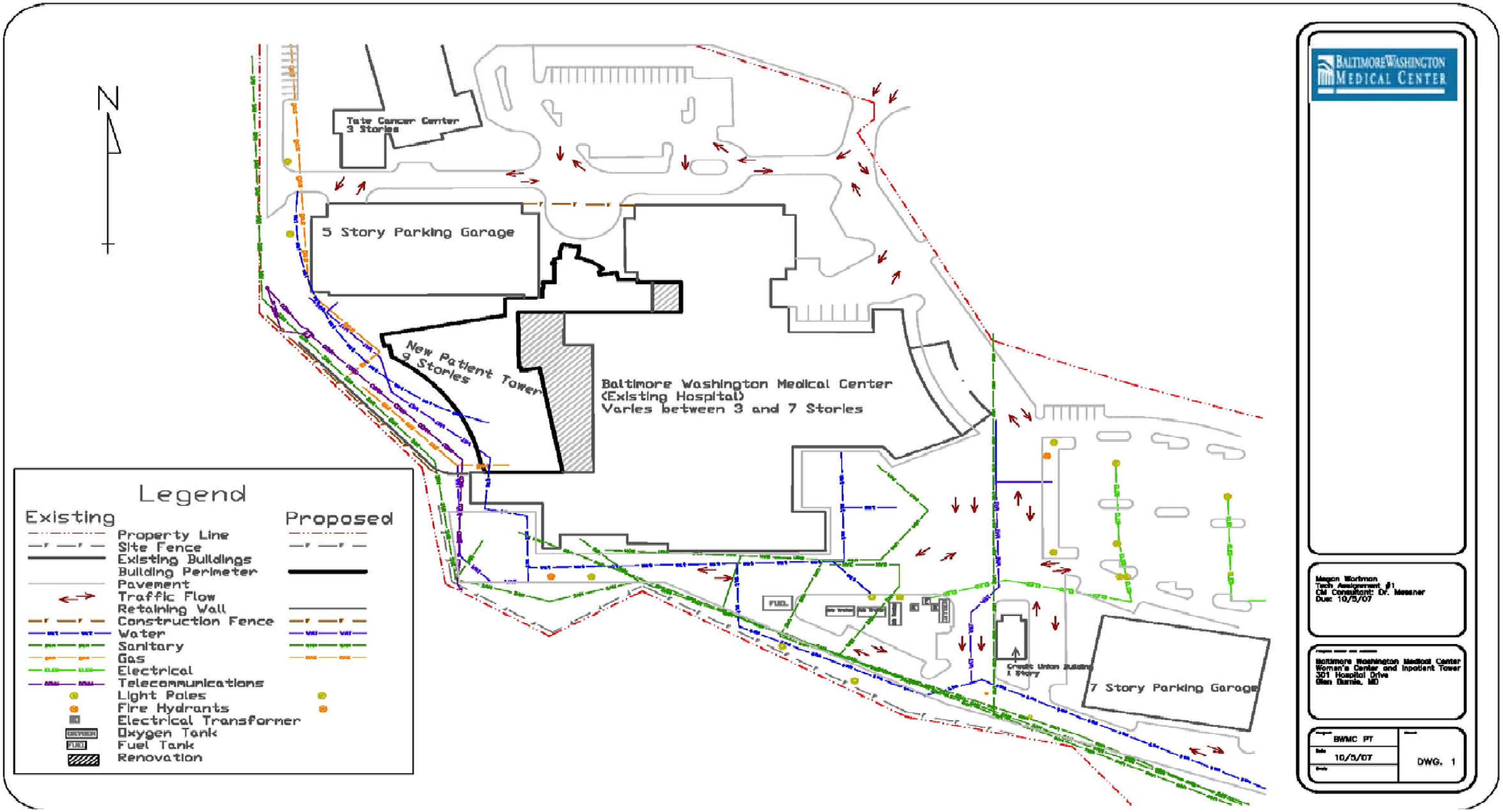
RS Means, Repair & Remodeling Cost Data, R.S. Means Company. Kingston, MA 1996.

Stein, Benjamin. Mechanical and Electrical Equipment for Buildings *9th ed*. Wiley 2000.

"Vulcraft Steel Roof and Floor Deck," Nucor Corp- Vulcraft Group 2007, March 2008. http://www.vulcraft.com/downlds/catalogs/deckcat.pdf

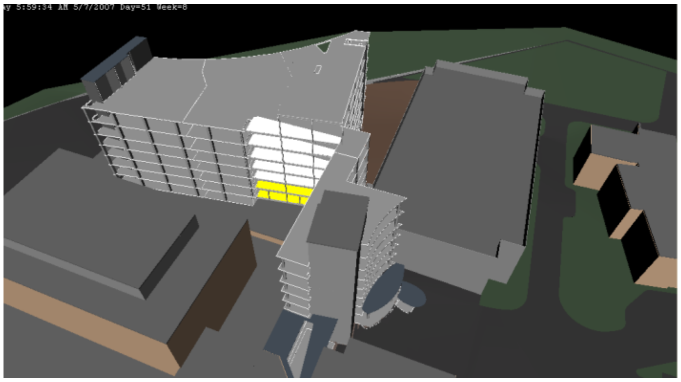
Waier, Phillip R., RS Means Building Construction Cost Data, 21st ED Western Edition. 2008.

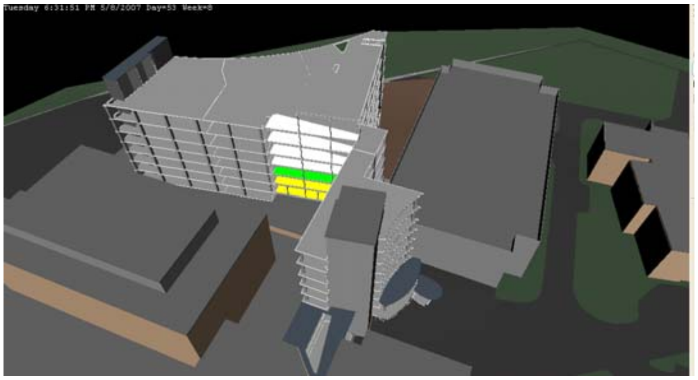
APPENDIX A: EXISTING SITE PLAN

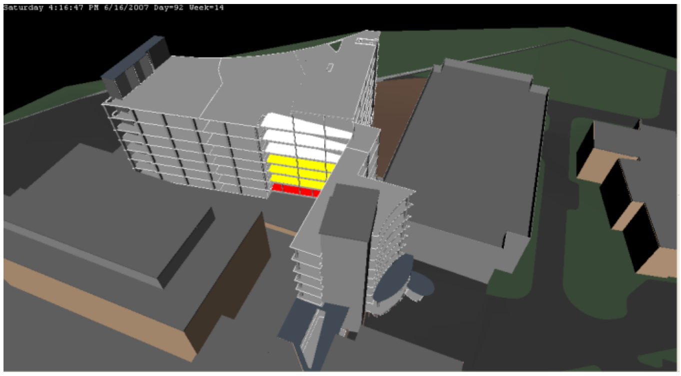


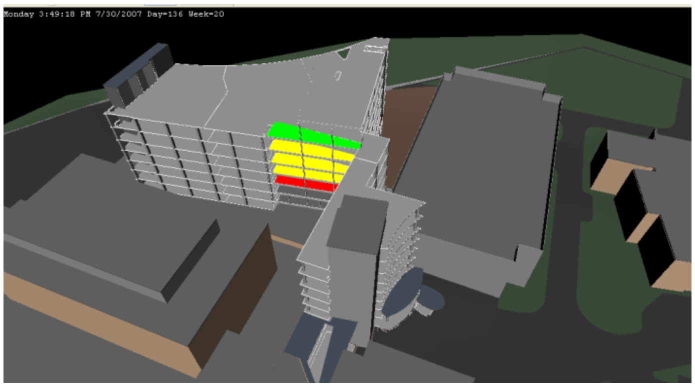
APPENDIX B: 4D MODEL IMAGES

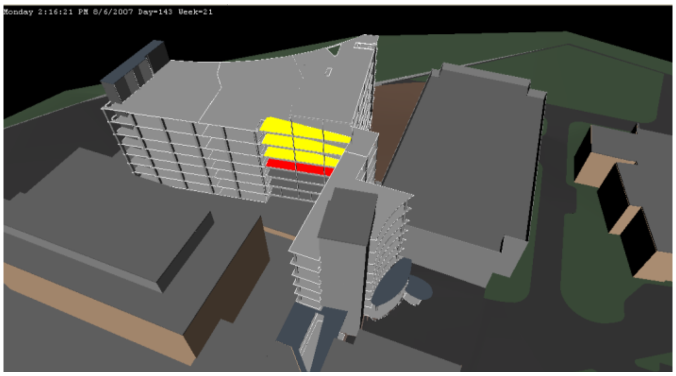
Structural 4D Model











Color Legend

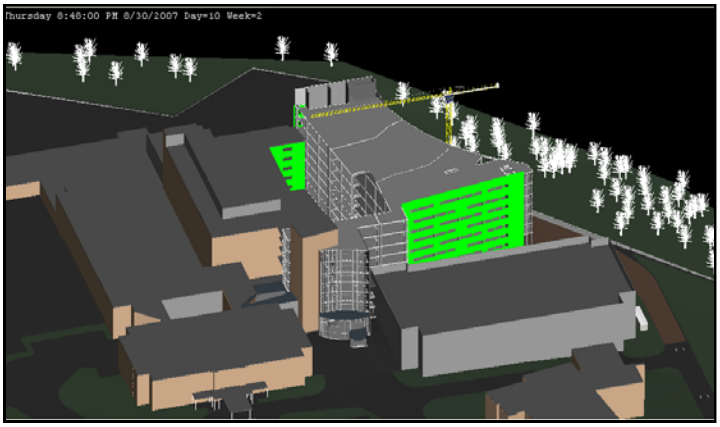
Green- Composite Slab is being constructed

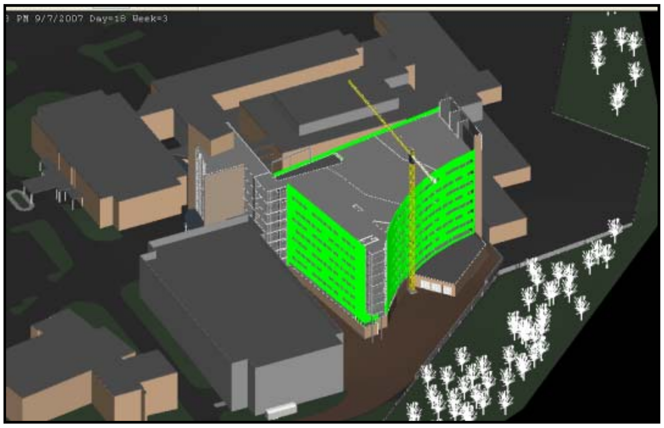
Yellow-Composite Slab is completed

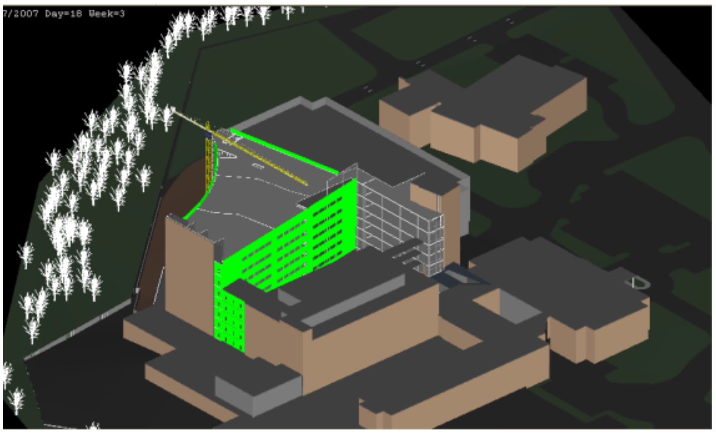
Red- Precast Planks are being constructed

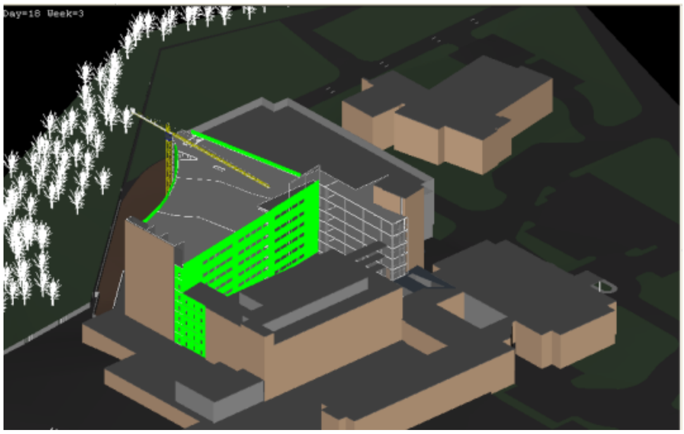
Model Appearance- Precast Planks are completed

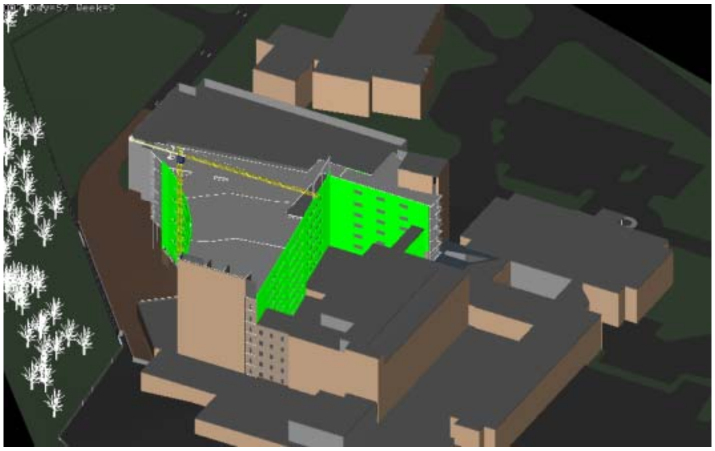
Façade 4D Model- EIFS









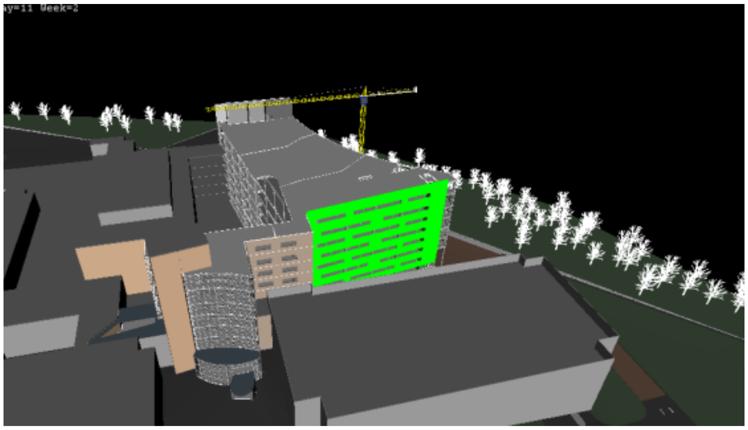


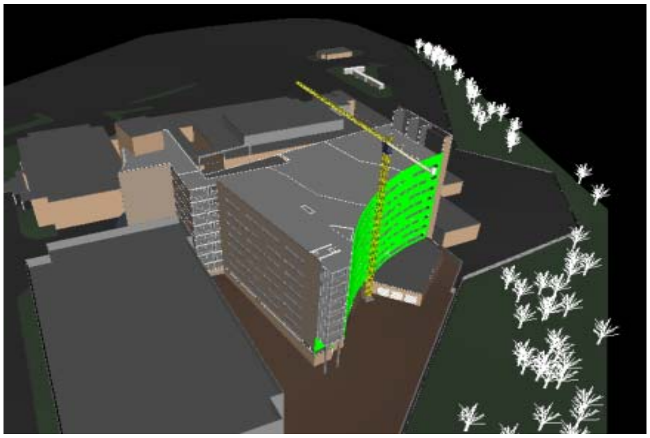
Color Legend

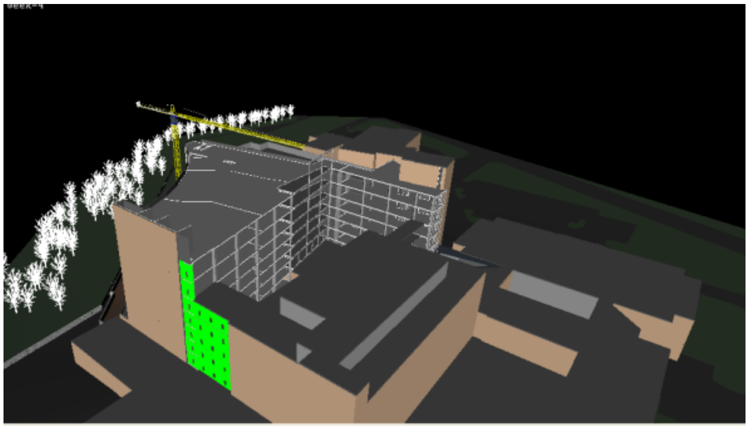
🟩 Green- EIFS is being constructed

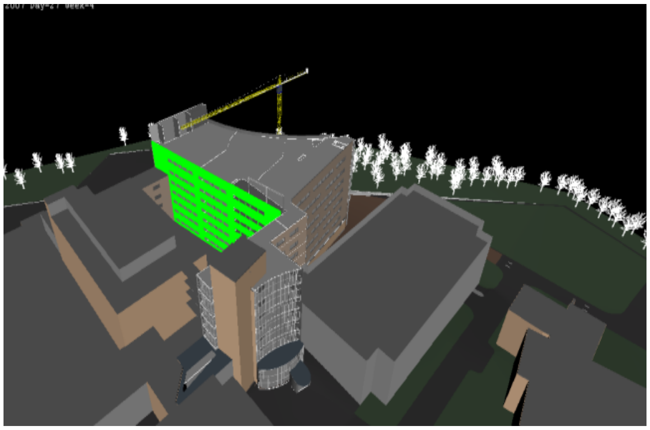
Model Appearance- EIFS is completed

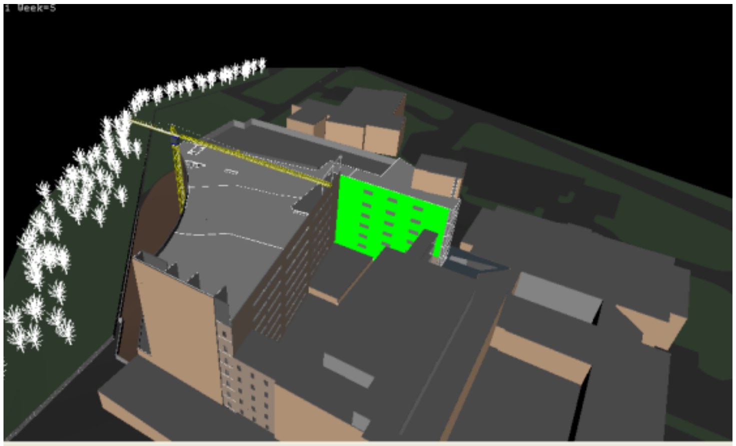
Façade 4D Model- GFRC











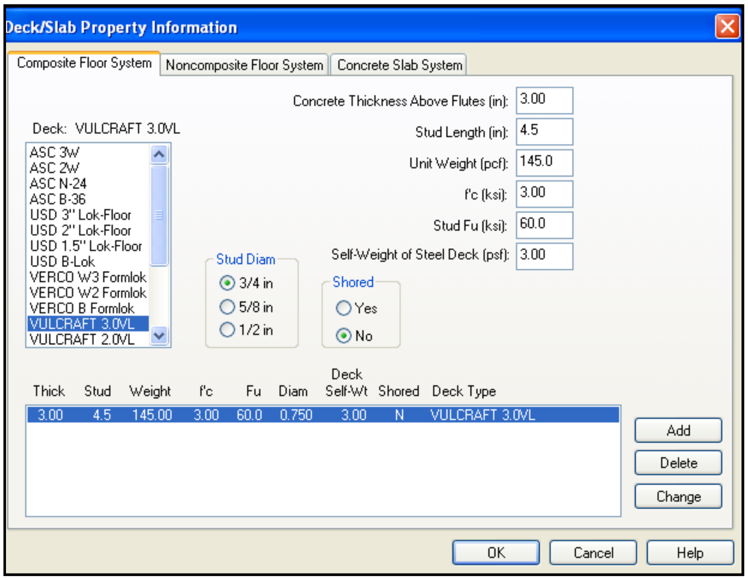
Color Legend

Green- GFRC is being constructed

Model Appearance- GFRC is completed

APPENDIX C: PROPRERY WINDOWS

Windows from RAM Structures



Concrete Thickness Above Flutes (in): 3.00
Stud Length (in): 4.5
Unit Weight (pcf): 145.0
f'c (ksi): 3.00
Stud Fu (ksi): 60.0
Self-Weight of Steel Deck (psf): 3.00

Deck: VULCRAFT 3.0VL

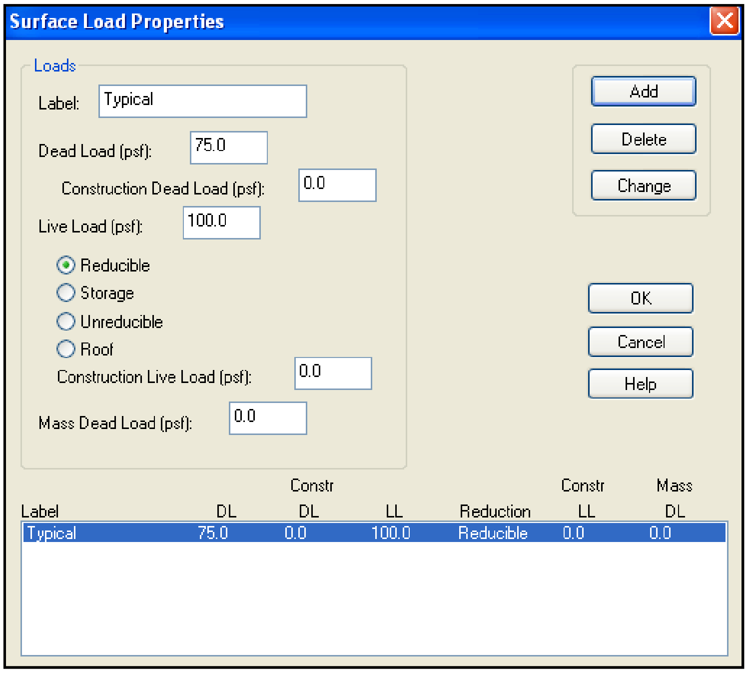
- ASC 3W
- ASC 2W
- ASC N-24
- ASC B-36
- USD 3" Lok-Floor
- USD 2" Lok-Floor
- USD 1.5" Lok-Floor
- USD B-Lok
- VERCO W3 Formlok
- VERCO W2 Formlok
- VERCO B Formlok
- VULCRAFT 3.0VL
- VULCRAFT 2.0VL

Stud Diam
● 3/4 in
○ 5/8 in
○ 1/2 in

Shored
○ Yes
● No

Thick	Stud	Weight	f'c	Fu	Diam	Deck Self-Wt	Shored	Deck Type
3.00	4.5	145.00	3.00	60.0	0.750	3.00	N	VULCRAFT 3.0VL

Figure 29. Deck/Slab Property Information from RAM Structures



Loads
Label: Typical
Dead Load (psf): 75.0
Construction Dead Load (psf): 0.0
Live Load (psf): 100.0
● Reducible
○ Storage
○ Unreducible
○ Roof
Construction Live Load (psf): 0.0
Mass Dead Load (psf): 0.0

Label	DL	Constr DL	LL	Reduction	Constr LL	Mass DL
Typical	75.0	0.0	100.0	Reducible	0.0	0.0

Figure 30. Surface Load Properties from RAM Structures

APPENDIX D: MATERIAL QUANTITY TAKEOFFS

Table 21: Precast Plank System Takeoff

Precast Concrete Hollow Core Planks Takeoff		
Item	Units	Quantity
8" Hollow Planks	sf	7252
2" Concrete Topping	sf	7252
6"x 6" W1.4 x W1.4 W.W.F	sf	7252

Table 22: Structural Steel Takeoff

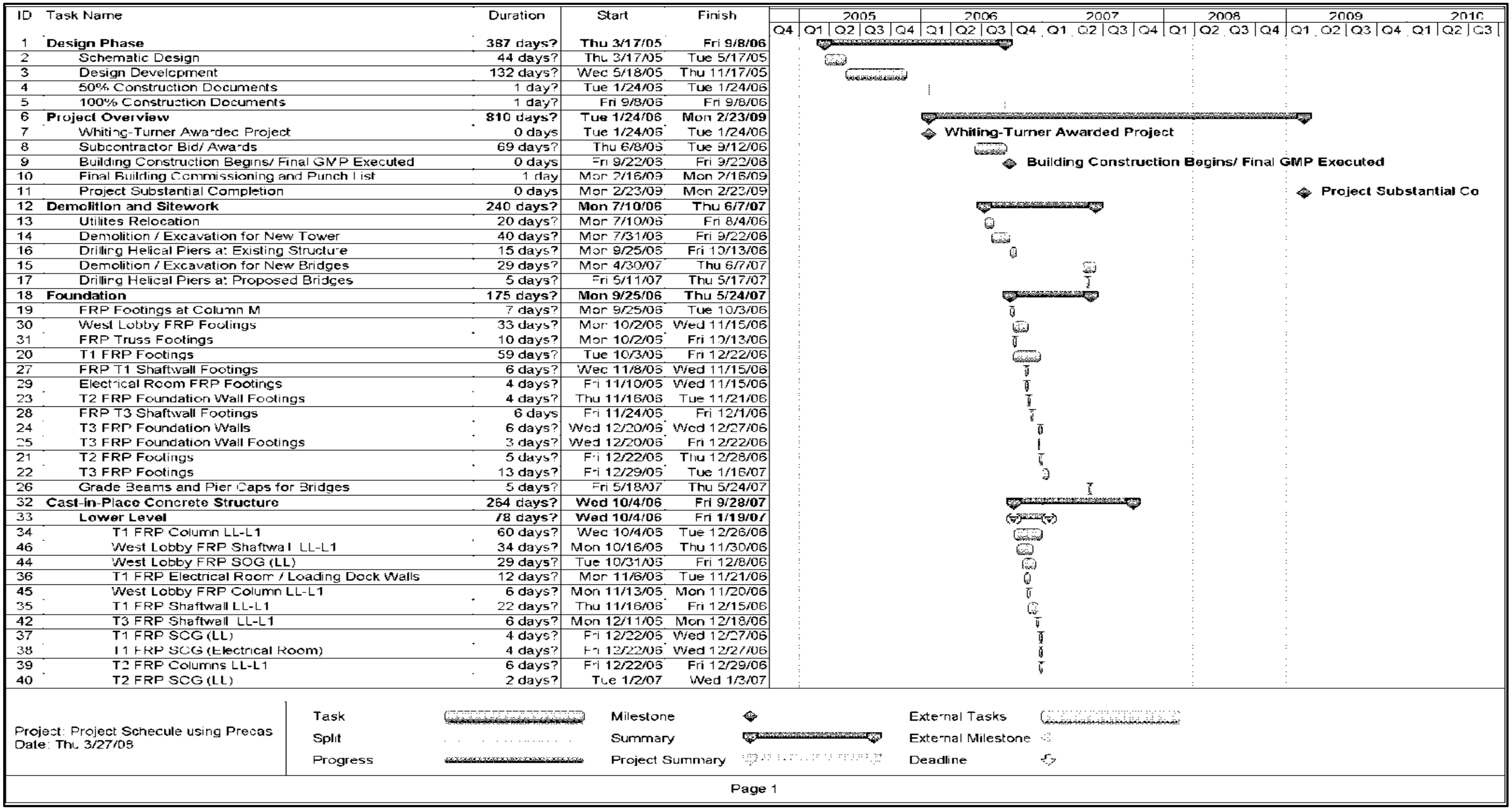
Structural Steel Takeoff			
Member Size	Quantity	At Length (LF)	Tot Length (LF)
W8x10	7	17	119
W8x10	7	15	105
W8x10	7	13	91
W8x10	7	12	84
W8x10	7	10	70
Total Beam Length (LF)=			**469**

Table 23: Composite Slab System Takeoff

Composite Slab Takeoff		
Item	Units	Quantity
6" Concrete Slab	sf	7252
6"x 6" W1.4 x W1.4 W.W.F	sf	7252
3" 20 Gauge Metal Decking	sf	7252

APPENDIX E: STRUCTURAL SYSTEMS SCHEDULES

Composite Slab Structural Schedule



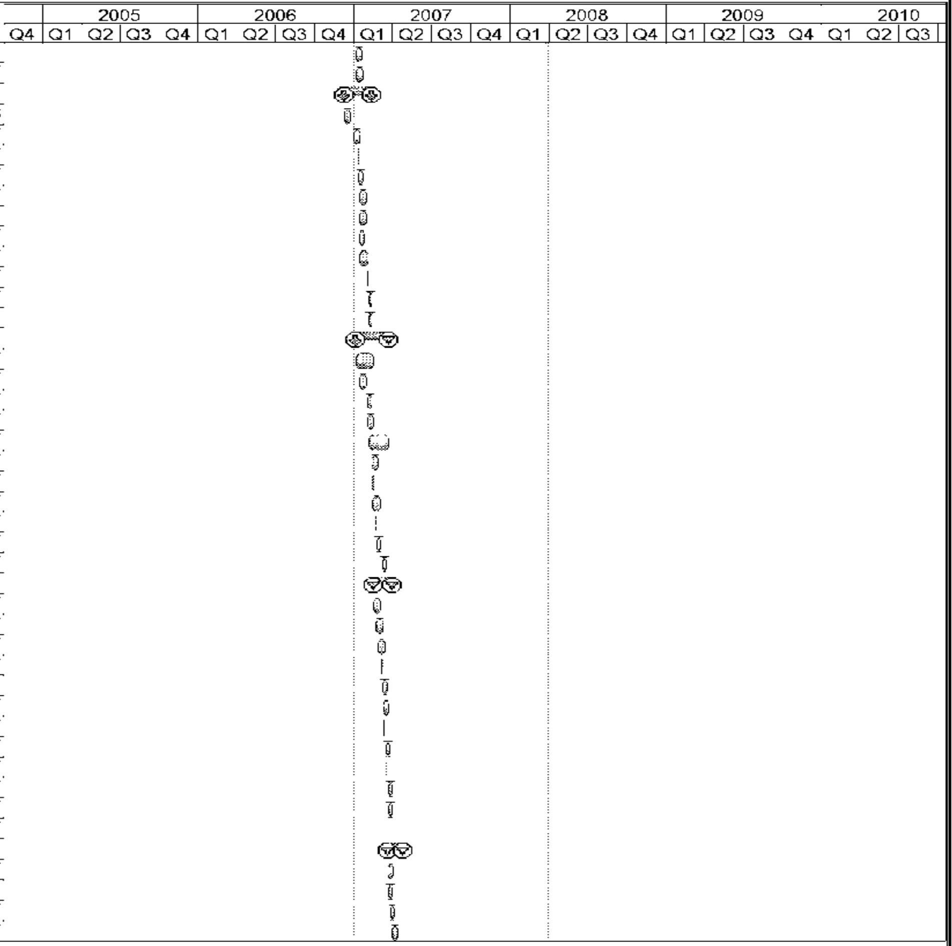
ID	Task Name	Duration	Start	Finish
1	**Design Phase**	**387 days?**	**Thu 3/17/05**	**Fri 9/8/06**
2	Schematic Design	44 days?	Thu 3/17/05	Tue 5/17/05
3	Design Development	132 days?	Wed 5/18/05	Thu 11/17/05
4	50% Construction Documents	1 day?	Tue 1/24/06	Tue 1/24/06
5	100% Construction Documents	1 day?	Fri 9/8/06	Fri 9/8/06
6	**Project Overview**	**810 days?**	**Tue 1/24/06**	**Mon 2/23/09**
7	Whiting-Turner Awarded Project	0 days	Tue 1/24/06	Tue 1/24/06
8	Subcontractor Bid/ Awards	69 days?	Thu 6/8/06	Tue 9/12/06
9	Building Construction Begins/ Final GMP Executed	0 days	Fri 9/22/06	Fri 9/22/06
10	Final Building Commissioning and Punch List	1 day	Mon 2/16/09	Mon 2/16/09
11	Project Substantial Completion	0 days	Mon 2/23/09	Mon 2/23/09
12	**Demolition and Sitework**	**240 days?**	**Mon 7/10/06**	**Thu 6/7/07**
13	Utilites Relocation	20 days?	Mon 7/10/06	Fri 8/4/06
14	Demolition / Excavation for New Tower	40 days?	Mon 7/31/06	Fri 9/22/06
16	Drilling Helical Piers at Existing Structure	15 days?	Mon 9/25/06	Fri 10/13/06
15	Demolition / Excavation for New Bridges	29 days?	Mon 4/30/07	Thu 6/7/07
17	Drilling Helical Piers at Proposed Bridges	5 days?	Fri 5/11/07	Thu 5/17/07
18	**Foundation**	**175 days?**	**Mon 9/25/06**	**Thu 5/24/07**
19	FRP Footings at Column M	7 days?	Mon 9/25/06	Tue 10/3/06
30	West Lobby FRP Footings	33 days?	Mon 10/2/06	Wed 11/15/06
31	FRP Truss Footings	10 days?	Mon 10/2/06	Fri 10/13/06
20	T1 FRP Footings	59 days?	Tue 10/3/06	Fri 12/22/06
27	FRP T1 Shaftwall Footings	6 days?	Wed 11/8/06	Wed 11/15/06
29	Electrical Room FRP Footings	4 days?	Fri 11/10/06	Wed 11/15/06
23	T2 FRP Foundation Wall Footings	4 days?	Thu 11/16/06	Tue 11/21/06
28	FRP T3 Shaftwall Footings	6 days	Fri 11/24/06	Fri 12/1/06
24	T3 FRP Foundation Walls	6 days?	Wed 12/20/06	Wed 12/27/06
25	T3 FRP Foundation Wall Footings	3 days?	Wed 12/20/06	Fri 12/22/06
21	T2 FRP Footings	5 days?	Fri 12/22/06	Thu 12/28/06
22	T3 FRP Footings	13 days?	Fri 12/29/06	Tue 1/16/07
26	Grade Beams and Pier Caps for Bridges	5 days?	Fri 5/18/07	Thu 5/24/07
32	**Cast-in-Place Concrete Structure**	**264 days?**	**Wed 10/4/06**	**Fri 9/28/07**
33	**Lower Level**	**78 days?**	**Wed 10/4/06**	**Fri 1/19/07**
34	T1 FRP Column LL-L1	60 days?	Wed 10/4/06	Tue 12/26/06
46	West Lobby FRP Shaftwall LL-L1	34 days?	Mon 10/16/06	Thu 11/30/06
44	West Lobby FRP SOG (LL)	29 days?	Tue 10/31/06	Fri 12/8/06
36	T1 FRP Electrical Room / Loading Dock Walls	12 days?	Mon 11/6/06	Tue 11/21/06
45	West Lobby FRP Column LL-L1	6 days?	Mon 11/13/06	Mon 11/20/06
35	T1 FRP Shaftwall LL-L1	22 days?	Thu 11/16/06	Fri 12/15/06
42	T3 FRP Shaftwall LL-L1	6 days?	Mon 12/11/06	Mon 12/18/06
37	T1 FRP SOG (LL)	4 days?	Fri 12/22/06	Wed 12/27/06
38	T1 FRP SOG (Electrical Room)	4 days?	Fri 12/22/06	Wed 12/27/06
39	T2 FRP Columns LL-L1	6 days?	Fri 12/22/06	Fri 12/29/06
40	T2 FRP SOG (LL)	2 days?	Tue 1/2/07	Wed 1/3/07

Project: Project Schecule using Precas
Date: Thu 3/27/08

Task	▭	Milestone	◆	External Tasks	▭
Split	………	Summary	▬	External Milestone	◆
Progress	▬	Project Summary	▬	Deadline	⇩

Page 1

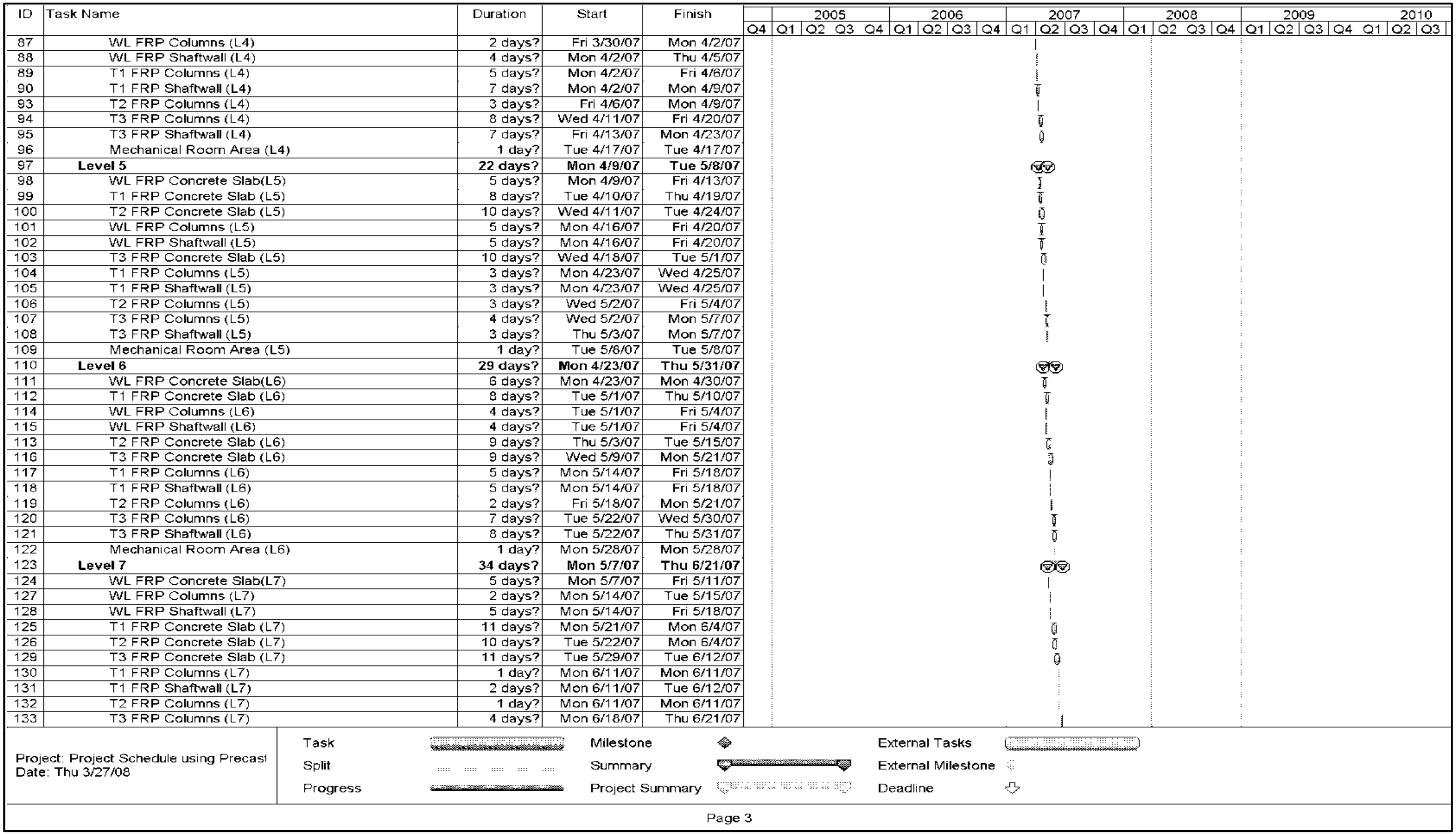
ID	Task Name	Duration	Start	Finish
41	T3 FRP Columnl LL-L1	12 days?	Tue 1/2/07	Wed 1/17/07
43	T3 FRP SOG (LL)	13 days?	Wed 1/3/07	Fri 1/19/07
47	**Level 1**	**48 days?**	**Wed 12/6/06**	**Fri 2/9/07**
56	WL FRP Concrete Slab(L1)	11 days?	Wed 12/6/06	Wed 12/20/06
48	T1 FRP Concrete Slab (L1)	11 days?	Fri 12/29/06	Fri 1/12/07
57	WL FRP Columns (L1)	3 days?	Wed 1/10/07	Fri 1/12/07
58	WL FRP Shaftwall (L1)	7 days?	Wed 1/10/07	Thu 1/18/07
49	T1 FRP Columns (L1)	11 days?	Fri 1/12/07	Fri 1/26/07
50	T1 FRP Shaftwall (L1)	11 days?	Fri 1/12/07	Fri 1/26/07
51	T2 FRP Concrete Slab (L1)	7 days?	Fri 1/12/07	Mon 1/22/07
53	T3 FRP Concrete Slab (L1)	13 days?	Fri 1/12/07	Tue 1/30/07
52	T2 FRP Columns (L1)	2 days?	Mon 1/29/07	Tue 1/30/07
54	T3 FRP Columns (L1)	6 days?	Fri 2/2/07	Fri 2/9/07
55	T3 FRP Shaftwall (L1)	6 days?	Fri 2/2/07	Fri 2/9/07
59	**Level 2**	**54 days?**	**Wed 1/3/07**	**Mon 3/19/07**
61	T1 FRP Concrete Slab (L2)	29 days?	Wed 1/3/07	Mon 2/12/07
60	WL FRP Concrete Slab(L2)	11 days?	Fri 1/12/07	Fri 1/26/07
62	WL FRP Columns (L2)	10 days?	Mon 1/29/07	Fri 2/9/07
63	WL FRP Shaftwall (L2)	11 days?	Mon 1/29/07	Mon 2/12/07
66	T2 FRP Concrete Slab (L2)	32 days?	Fri 2/2/07	Mon 3/19/07
67	T3 FRP Concrete Slab (L2)	11 days?	Fri 2/9/07	Fri 2/23/07
64	T1 FRP Columns (L2)	4 days?	Mon 2/12/07	Thu 2/15/07
65	T1 FRP Shaftwall (L2)	14 days?	Mon 2/12/07	Thu 3/1/07
68	T2 FRP Columns (L2)	2 days?	Tue 2/20/07	Wed 2/21/07
69	T3 FRP Columns (L2)	7 days?	Thu 2/22/07	Fri 3/2/07
70	T3 FRP Shaftwall (L2)	6 days?	Wed 3/7/07	Wed 3/14/07
71	**Level 3**	**33 days?**	**Tue 2/13/07**	**Thu 3/29/07**
72	WL FRP Concrete Slab(L3)	13 days?	Tue 2/13/07	Thu 3/1/07
73	T1 FRP Concrete Slab (L3)	14 days?	Mon 2/19/07	Thu 3/8/07
78	T2 FRP Concrete Slab (L3)	12 days?	Fri 2/23/07	Mon 3/12/07
74	WL FRP Columns (L3)	3 days?	Mon 3/5/07	Wed 3/7/07
75	WL FRP Shaftwall (L3)	9 days?	Tue 3/6/07	Fri 3/16/07
79	T3 FRP Concrete Slab (L3)	9 days?	Thu 3/8/07	Tue 3/20/07
76	T1 FRP Columns (L3)	2 days?	Fri 3/9/07	Mon 3/12/07
77	T1 FRP Shaftwall (L3)	8 days?	Wed 3/14/07	Fri 3/23/07
80	T2 FRP Columns (L3)	2 days?	Wed 3/14/07	Thu 3/15/07
81	T3 FRP Columns (L3)	7 days?	Wed 3/21/07	Thu 3/29/07
82	T3 FRP Shaftwall (L3)	7 days?	Wed 3/21/07	Thu 3/29/07
83	Mechanical Room Area (L3)	1 day?	Tue 3/27/07	Tue 3/27/07
84	**Level 4**	**27 days?**	**Mon 3/19/07**	**Mon 4/23/07**
86	T1 FRP Concrete Slab (L4)	10 days?	Mon 3/19/07	Fri 3/30/07
85	WL FRP Concrete Slab(L4)	8 days?	Tue 3/20/07	Thu 3/29/07
91	T2 FRP Concrete Slab (L4)	6 days?	Mon 3/26/07	Mon 4/2/07
92	T3 FRP Concrete Slab (L4)	10 days?	Thu 3/29/07	Tue 4/10/07



Project: Project Schedule using Precas
Date: Thu 3/27/08

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

Page 2

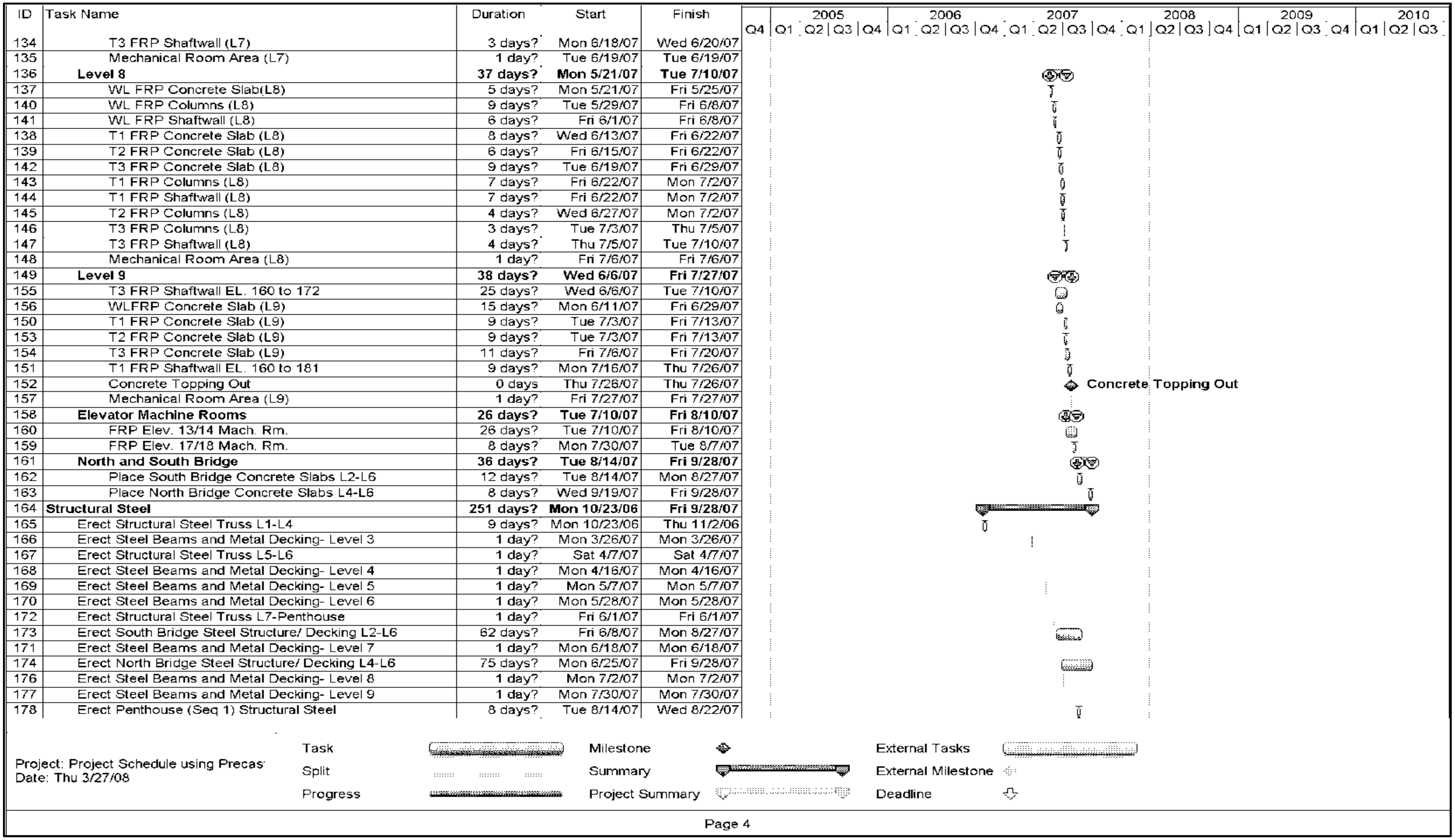


ID	Task Name	Duration	Start	Finish
87	WL FRP Columns (L4)	2 days?	Fri 3/30/07	Mon 4/2/07
88	WL FRP Shaftwall (L4)	4 days?	Mon 4/2/07	Thu 4/5/07
89	T1 FRP Columns (L4)	5 days?	Mon 4/2/07	Fri 4/6/07
90	T1 FRP Shaftwall (L4)	7 days?	Mon 4/2/07	Mon 4/9/07
93	T2 FRP Columns (L4)	3 days?	Fri 4/6/07	Mon 4/9/07
94	T3 FRP Columns (L4)	8 days?	Wed 4/11/07	Fri 4/20/07
95	T3 FRP Shaftwall (L4)	7 days?	Fri 4/13/07	Mon 4/23/07
96	Mechanical Room Area (L4)	1 day?	Tue 4/17/07	Tue 4/17/07
97	**Level 5**	**22 days?**	**Mon 4/9/07**	**Tue 5/8/07**
98	WL FRP Concrete Slab(L5)	5 days?	Mon 4/9/07	Fri 4/13/07
99	T1 FRP Concrete Slab (L5)	8 days?	Tue 4/10/07	Thu 4/19/07
100	T2 FRP Concrete Slab (L5)	10 days?	Wed 4/11/07	Tue 4/24/07
101	WL FRP Columns (L5)	5 days?	Mon 4/16/07	Fri 4/20/07
102	WL FRP Shaftwall (L5)	5 days?	Mon 4/16/07	Fri 4/20/07
103	T3 FRP Concrete Slab (L5)	10 days?	Wed 4/18/07	Tue 5/1/07
104	T1 FRP Columns (L5)	3 days?	Mon 4/23/07	Wed 4/25/07
105	T1 FRP Shaftwall (L5)	3 days?	Mon 4/23/07	Wed 4/25/07
106	T2 FRP Columns (L5)	3 days?	Wed 5/2/07	Fri 5/4/07
107	T3 FRP Columns (L5)	4 days?	Wed 5/2/07	Mon 5/7/07
108	T3 FRP Shaftwall (L5)	3 days?	Thu 5/3/07	Mon 5/7/07
109	Mechanical Room Area (L5)	1 day?	Tue 5/8/07	Tue 5/8/07
110	**Level 6**	**29 days?**	**Mon 4/23/07**	**Thu 5/31/07**
111	WL FRP Concrete Slab(L6)	6 days?	Mon 4/23/07	Mon 4/30/07
112	T1 FRP Concrete Slab (L6)	8 days?	Tue 5/1/07	Thu 5/10/07
114	WL FRP Columns (L6)	4 days?	Tue 5/1/07	Fri 5/4/07
115	WL FRP Shaftwall (L6)	4 days?	Tue 5/1/07	Fri 5/4/07
113	T2 FRP Concrete Slab (L6)	9 days?	Thu 5/3/07	Tue 5/15/07
116	T3 FRP Concrete Slab (L6)	9 days?	Wed 5/9/07	Mon 5/21/07
117	T1 FRP Columns (L6)	5 days?	Mon 5/14/07	Fri 5/18/07
118	T1 FRP Shaftwall (L6)	5 days?	Mon 5/14/07	Fri 5/18/07
119	T2 FRP Columns (L6)	2 days?	Fri 5/18/07	Mon 5/21/07
120	T3 FRP Columns (L6)	7 days?	Tue 5/22/07	Wed 5/30/07
121	T3 FRP Shaftwall (L6)	8 days?	Tue 5/22/07	Thu 5/31/07
122	Mechanical Room Area (L6)	1 day?	Mon 5/28/07	Mon 5/28/07
123	**Level 7**	**34 days?**	**Mon 5/7/07**	**Thu 6/21/07**
124	WL FRP Concrete Slab(L7)	5 days?	Mon 5/7/07	Fri 5/11/07
127	WL FRP Columns (L7)	2 days?	Mon 5/14/07	Tue 5/15/07
128	WL FRP Shaftwall (L7)	5 days?	Mon 5/14/07	Fri 5/18/07
125	T1 FRP Concrete Slab (L7)	11 days?	Mon 5/21/07	Mon 6/4/07
126	T2 FRP Concrete Slab (L7)	10 days?	Tue 5/22/07	Mon 6/4/07
129	T3 FRP Concrete Slab (L7)	11 days?	Tue 5/29/07	Tue 6/12/07
130	T1 FRP Columns (L7)	1 day?	Mon 6/11/07	Mon 6/11/07
131	T1 FRP Shaftwall (L7)	2 days?	Mon 6/11/07	Tue 6/12/07
132	T2 FRP Columns (L7)	1 day?	Mon 6/11/07	Mon 6/11/07
133	T3 FRP Columns (L7)	4 days?	Mon 6/18/07	Thu 6/21/07

Project: Project Schedule using Precast
Date: Thu 3/27/08

Task	▬	Milestone	◆	External Tasks	▭
Split	┈	Summary	▬	External Milestone	◆
Progress	▬	Project Summary	▬	Deadline	⇩

Page 3

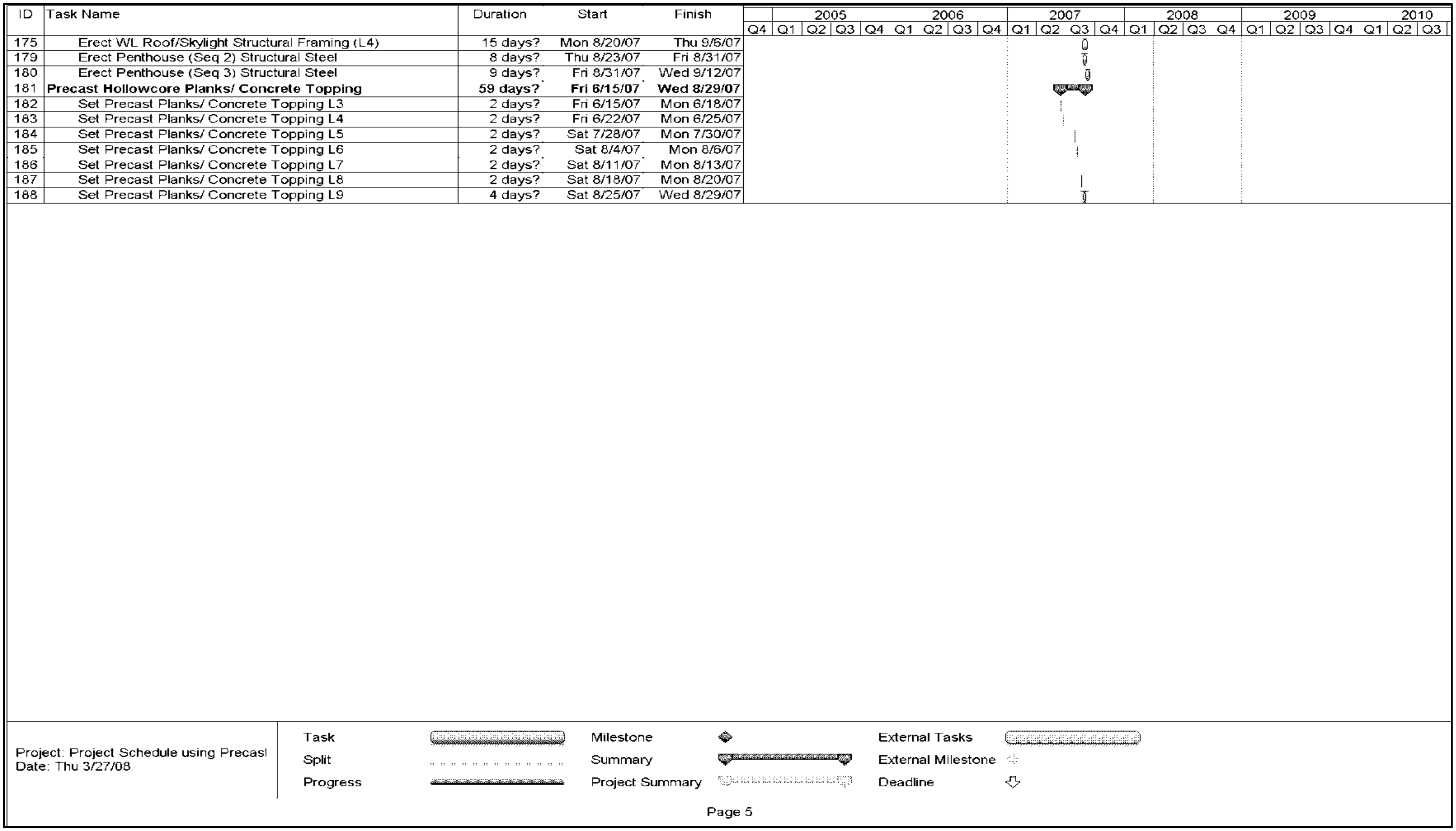


ID	Task Name	Duration	Start	Finish
134	T3 FRP Shaftwall (L7)	3 days?	Mon 6/18/07	Wed 6/20/07
135	Mechanical Room Area (L7)	1 day?	Tue 6/19/07	Tue 6/19/07
136	**Level 8**	**37 days?**	**Mon 5/21/07**	**Tue 7/10/07**
137	WL FRP Concrete Slab(L8)	5 days?	Mon 5/21/07	Fri 5/25/07
140	WL FRP Columns (L8)	9 days?	Tue 5/29/07	Fri 6/8/07
141	WL FRP Shaftwall (L8)	6 days?	Fri 6/1/07	Fri 6/8/07
138	T1 FRP Concrete Slab (L8)	8 days?	Wed 6/13/07	Fri 6/22/07
139	T2 FRP Concrete Slab (L8)	6 days?	Fri 6/15/07	Fri 6/22/07
142	T3 FRP Concrete Slab (L8)	9 days?	Tue 6/19/07	Fri 6/29/07
143	T1 FRP Columns (L8)	7 days?	Fri 6/22/07	Mon 7/2/07
144	T1 FRP Shaftwall (L8)	7 days?	Fri 6/22/07	Mon 7/2/07
145	T2 FRP Columns (L8)	4 days?	Wed 6/27/07	Mon 7/2/07
146	T3 FRP Columns (L8)	3 days?	Tue 7/3/07	Thu 7/5/07
147	T3 FRP Shaftwall (L8)	4 days?	Thu 7/5/07	Tue 7/10/07
148	Mechanical Room Area (L8)	1 day?	Fri 7/6/07	Fri 7/6/07
149	**Level 9**	**38 days?**	**Wed 6/6/07**	**Fri 7/27/07**
155	T3 FRP Shaftwall EL. 160 to 172	25 days?	Wed 6/6/07	Tue 7/10/07
156	WLFRP Concrete Slab (L9)	15 days?	Mon 6/11/07	Fri 6/29/07
150	T1 FRP Concrete Slab (L9)	9 days?	Tue 7/3/07	Fri 7/13/07
153	T2 FRP Concrete Slab (L9)	9 days?	Tue 7/3/07	Fri 7/13/07
154	T3 FRP Concrete Slab (L9)	11 days?	Fri 7/6/07	Fri 7/20/07
151	T1 FRP Shaftwall EL. 160 to 181	9 days?	Mon 7/16/07	Thu 7/26/07
152	Concrete Topping Out	0 days	Thu 7/26/07	Thu 7/26/07
157	Mechanical Room Area (L9)	1 day?	Fri 7/27/07	Fri 7/27/07
158	**Elevator Machine Rooms**	**26 days?**	**Tue 7/10/07**	**Fri 8/10/07**
160	FRP Elev. 13/14 Mach. Rm.	26 days?	Tue 7/10/07	Fri 8/10/07
159	FRP Elev. 17/18 Mach. Rm.	8 days?	Mon 7/30/07	Tue 8/7/07
161	**North and South Bridge**	**36 days?**	**Tue 8/14/07**	**Fri 9/28/07**
162	Place South Bridge Concrete Slabs L2-L6	12 days?	Tue 8/14/07	Mon 8/27/07
163	Place North Bridge Concrete Slabs L4-L6	8 days?	Wed 9/19/07	Fri 9/28/07
164	**Structural Steel**	**251 days?**	**Mon 10/23/06**	**Fri 9/28/07**
165	Erect Structural Steel Truss L1-L4	9 days?	Mon 10/23/06	Thu 11/2/06
166	Erect Steel Beams and Metal Decking- Level 3	1 day?	Mon 3/26/07	Mon 3/26/07
167	Erect Structural Steel Truss L5-L6	1 day?	Sat 4/7/07	Sat 4/7/07
168	Erect Steel Beams and Metal Decking- Level 4	1 day?	Mon 4/16/07	Mon 4/16/07
169	Erect Steel Beams and Metal Decking- Level 5	1 day?	Mon 5/7/07	Mon 5/7/07
170	Erect Steel Beams and Metal Decking- Level 6	1 day?	Mon 5/28/07	Mon 5/28/07
172	Erect Structural Steel Truss L7-Penthouse	1 day?	Fri 6/1/07	Fri 6/1/07
173	Erect South Bridge Steel Structure/ Decking L2-L6	62 days?	Fri 6/8/07	Mon 8/27/07
171	Erect Steel Beams and Metal Decking- Level 7	1 day?	Mon 6/18/07	Mon 6/18/07
174	Erect North Bridge Steel Structure/ Decking L4-L6	75 days?	Mon 6/25/07	Fri 9/28/07
176	Erect Steel Beams and Metal Decking- Level 8	1 day?	Mon 7/2/07	Mon 7/2/07
177	Erect Steel Beams and Metal Decking- Level 9	1 day?	Mon 7/30/07	Mon 7/30/07
178	Erect Penthouse (Seq 1) Structural Steel	8 days?	Tue 8/14/07	Wed 8/22/07

Project: Project Schedule using Precas
Date: Thu 3/27/08

Task	▨	Milestone	◆	External Tasks	▨
Split	┈	Summary	▬	External Milestone	◆
Progress	▬	Project Summary	▬	Deadline	⇩

Page 4



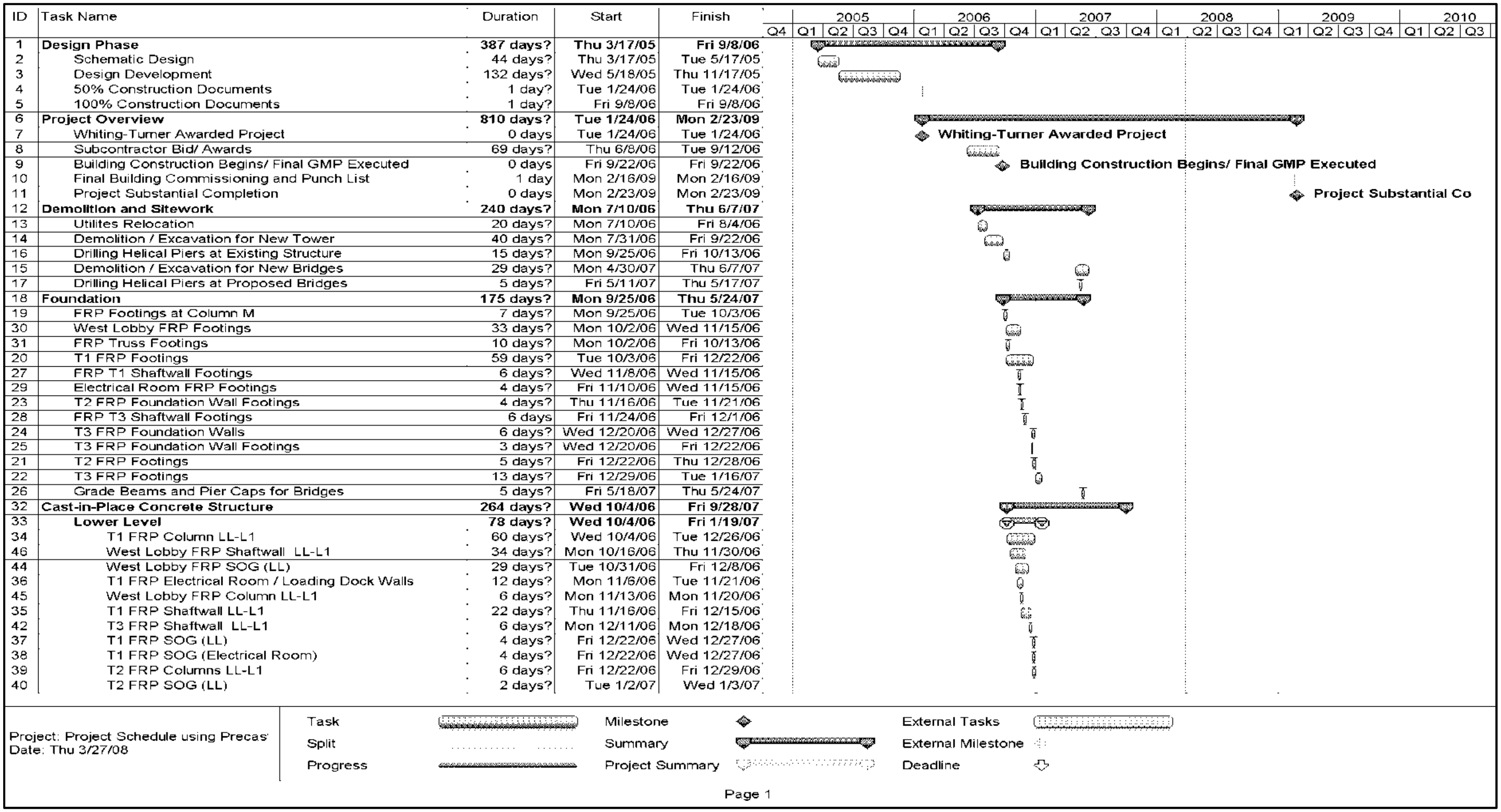
ID	Task Name	Duration	Start	Finish
175	Erect WL Roof/Skylight Structural Framing (L4)	15 days?	Mon 8/20/07	Thu 9/6/07
179	Erect Penthouse (Seq 2) Structural Steel	8 days?	Thu 8/23/07	Fri 8/31/07
180	Erect Penthouse (Seq 3) Structural Steel	9 days?	Fri 8/31/07	Wed 9/12/07
181	**Precast Hollowcore Planks/ Concrete Topping**	**59 days?**	**Fri 6/15/07**	**Wed 8/29/07**
182	Set Precast Planks/ Concrete Topping L3	2 days?	Fri 6/15/07	Mon 6/18/07
183	Set Precast Planks/ Concrete Topping L4	2 days?	Fri 6/22/07	Mon 6/25/07
184	Set Precast Planks/ Concrete Topping L5	2 days?	Sat 7/28/07	Mon 7/30/07
185	Set Precast Planks/ Concrete Topping L6	2 days?	Sat 8/4/07	Mon 8/6/07
186	Set Precast Planks/ Concrete Topping L7	2 days?	Sat 8/11/07	Mon 8/13/07
187	Set Precast Planks/ Concrete Topping L8	2 days?	Sat 8/18/07	Mon 8/20/07
188	Set Precast Planks/ Concrete Topping L9	4 days?	Sat 8/25/07	Wed 8/29/07

Project: Project Schedule using Precast
Date: Thu 3/27/08

Task	▭	Milestone	◆	External Tasks	▭
Split	········	Summary	▬	External Milestone	◆
Progress	▬	Project Summary	▬	Deadline	⇩

Page 5

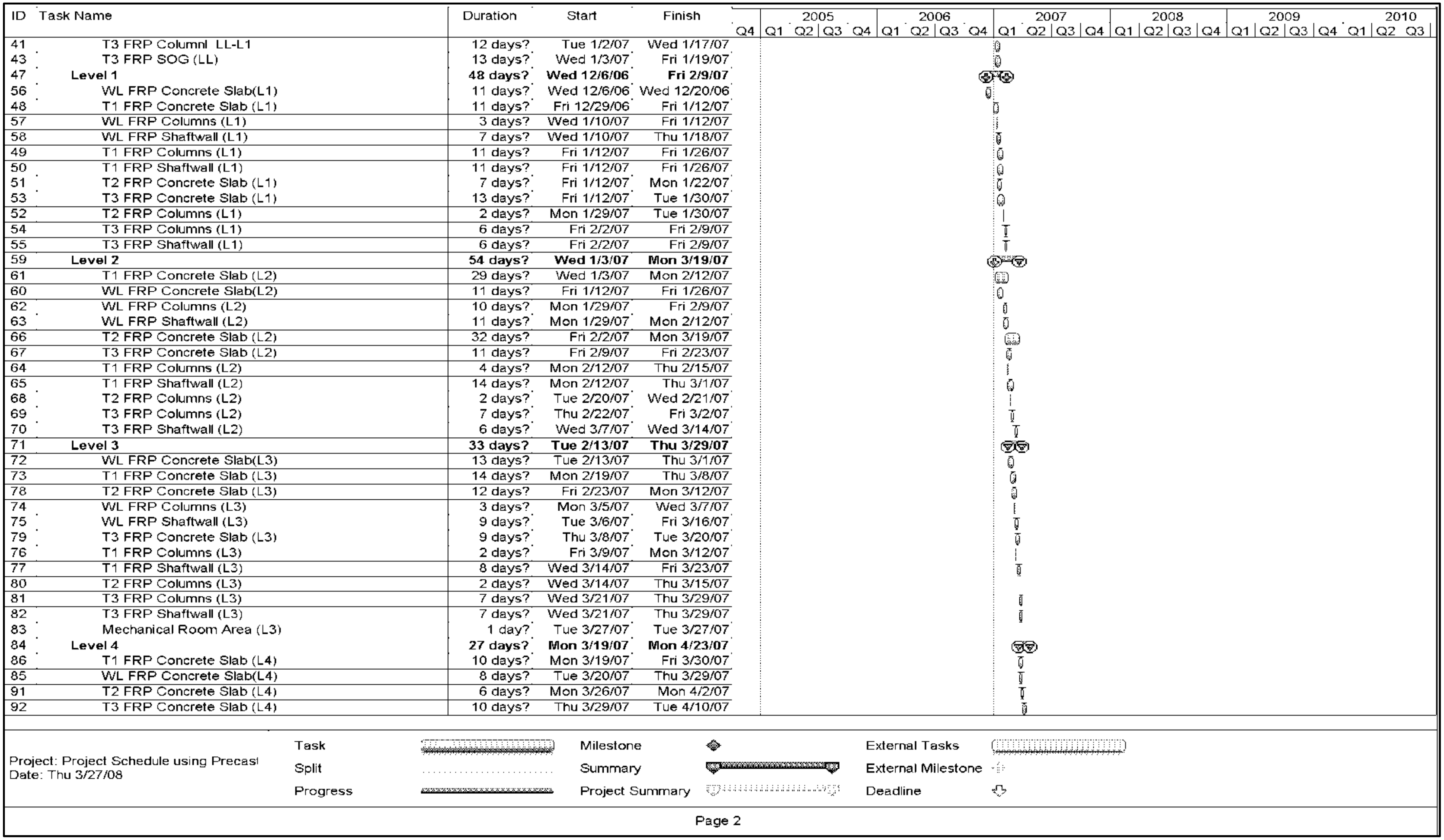
Precast Planks Structural Schedule



ID	Task Name	Duration	Start	Finish
1	**Design Phase**	**387 days?**	**Thu 3/17/05**	**Fri 9/8/06**
2	Schematic Design	44 days?	Thu 3/17/05	Tue 5/17/05
3	Design Development	132 days?	Wed 5/18/05	Thu 11/17/05
4	50% Construction Documents	1 day?	Tue 1/24/06	Tue 1/24/06
5	100% Construction Documents	1 day?	Fri 9/8/06	Fri 9/8/06
6	**Project Overview**	**810 days?**	**Tue 1/24/06**	**Mon 2/23/09**
7	Whiting-Turner Awarded Project	0 days	Tue 1/24/06	Tue 1/24/06
8	Subcontractor Bid/ Awards	69 days?	Thu 6/8/06	Tue 9/12/06
9	Building Construction Begins/ Final GMP Executed	0 days	Fri 9/22/06	Fri 9/22/06
10	Final Building Commissioning and Punch List	1 day	Mon 2/16/09	Mon 2/16/09
11	Project Substantial Completion	0 days	Mon 2/23/09	Mon 2/23/09
12	**Demolition and Sitework**	**240 days?**	**Mon 7/10/06**	**Thu 6/7/07**
13	Utilites Relocation	20 days?	Mon 7/10/06	Fri 8/4/06
14	Demolition / Excavation for New Tower	40 days?	Mon 7/31/06	Fri 9/22/06
16	Drilling Helical Piers at Existing Structure	15 days?	Mon 9/25/06	Fri 10/13/06
15	Demolition / Excavation for New Bridges	29 days?	Mon 4/30/07	Thu 6/7/07
17	Drilling Helical Piers at Proposed Bridges	5 days?	Fri 5/11/07	Thu 5/17/07
18	**Foundation**	**175 days?**	**Mon 9/25/06**	**Thu 5/24/07**
19	FRP Footings at Column M	7 days?	Mon 9/25/06	Tue 10/3/06
30	West Lobby FRP Footings	33 days?	Mon 10/2/06	Wed 11/15/06
31	FRP Truss Footings	10 days?	Mon 10/2/06	Fri 10/13/06
20	T1 FRP Footings	59 days?	Tue 10/3/06	Fri 12/22/06
27	FRP T1 Shaftwall Footings	6 days?	Wed 11/8/06	Wed 11/15/06
29	Electrical Room FRP Footings	4 days?	Fri 11/10/06	Wed 11/15/06
23	T2 FRP Foundation Wall Footings	4 days?	Thu 11/16/06	Tue 11/21/06
28	FRP T3 Shaftwall Footings	6 days	Fri 11/24/06	Fri 12/1/06
24	T3 FRP Foundation Walls	6 days?	Wed 12/20/06	Wed 12/27/06
25	T3 FRP Foundation Wall Footings	3 days?	Wed 12/20/06	Fri 12/22/06
21	T2 FRP Footings	5 days?	Fri 12/22/06	Thu 12/28/06
22	T3 FRP Footings	13 days?	Fri 12/29/06	Tue 1/16/07
26	Grade Beams and Pier Caps for Bridges	5 days?	Fri 5/18/07	Thu 5/24/07
32	**Cast-in-Place Concrete Structure**	**264 days?**	**Wed 10/4/06**	**Fri 9/28/07**
33	**Lower Level**	**78 days?**	**Wed 10/4/06**	**Fri 1/19/07**
34	T1 FRP Column LL-L1	60 days?	Wed 10/4/06	Tue 12/26/06
46	West Lobby FRP Shaftwall LL-L1	34 days?	Mon 10/16/06	Thu 11/30/06
44	West Lobby FRP SOG (LL)	29 days?	Tue 10/31/06	Fri 12/8/06
36	T1 FRP Electrical Room / Loading Dock Walls	12 days?	Mon 11/6/06	Tue 11/21/06
45	West Lobby FRP Column LL-L1	6 days?	Mon 11/13/06	Mon 11/20/06
35	T1 FRP Shaftwall LL-L1	22 days?	Thu 11/16/06	Fri 12/15/06
42	T3 FRP Shaftwall LL-L1	6 days?	Mon 12/11/06	Mon 12/18/06
37	T1 FRP SOG (LL)	4 days?	Fri 12/22/06	Wed 12/27/06
38	T1 FRP SOG (Electrical Room)	4 days?	Fri 12/22/06	Wed 12/27/06
39	T2 FRP Columns LL-L1	6 days?	Fri 12/22/06	Fri 12/29/06
40	T2 FRP SOG (LL)	2 days?	Tue 1/2/07	Wed 1/3/07

Project: Project Schedule using Precas
Date: Thu 3/27/08

Page 1

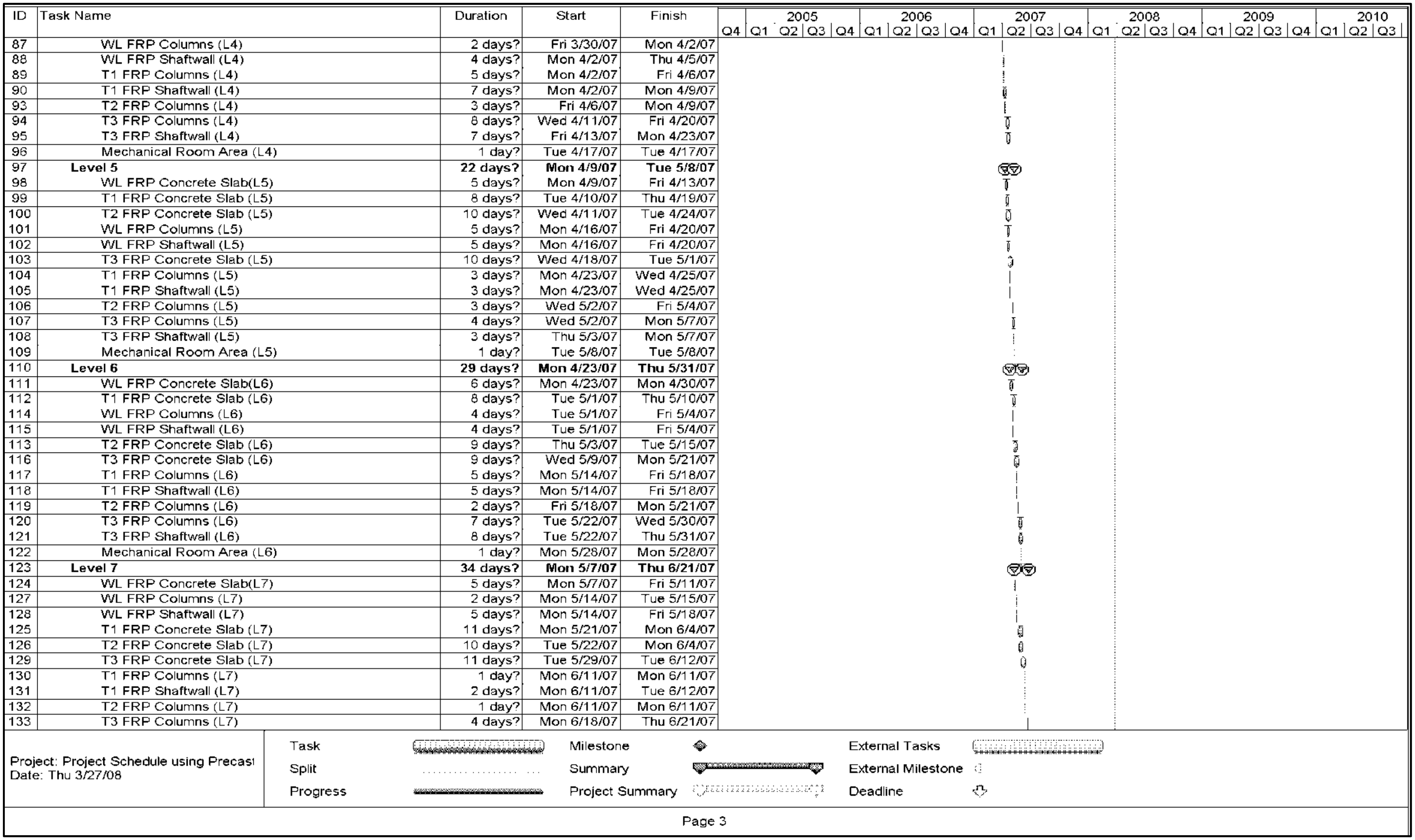


ID	Task Name	Duration	Start	Finish
41	T3 FRP Columnl LL-L1	12 days?	Tue 1/2/07	Wed 1/17/07
43	T3 FRP SOG (LL)	13 days?	Wed 1/3/07	Fri 1/19/07
47	**Level 1**	**48 days?**	**Wed 12/6/06**	**Fri 2/9/07**
56	WL FRP Concrete Slab(L1)	11 days?	Wed 12/6/06	Wed 12/20/06
48	T1 FRP Concrete Slab (L1)	11 days?	Fri 12/29/06	Fri 1/12/07
57	WL FRP Columns (L1)	3 days?	Wed 1/10/07	Fri 1/12/07
58	WL FRP Shaftwall (L1)	7 days?	Wed 1/10/07	Thu 1/18/07
49	T1 FRP Columns (L1)	11 days?	Fri 1/12/07	Fri 1/26/07
50	T1 FRP Shaftwall (L1)	11 days?	Fri 1/12/07	Fri 1/26/07
51	T2 FRP Concrete Slab (L1)	7 days?	Fri 1/12/07	Mon 1/22/07
53	T3 FRP Concrete Slab (L1)	13 days?	Fri 1/12/07	Tue 1/30/07
52	T2 FRP Columns (L1)	2 days?	Mon 1/29/07	Tue 1/30/07
54	T3 FRP Columns (L1)	6 days?	Fri 2/2/07	Fri 2/9/07
55	T3 FRP Shaftwall (L1)	6 days?	Fri 2/2/07	Fri 2/9/07
59	**Level 2**	**54 days?**	**Wed 1/3/07**	**Mon 3/19/07**
61	T1 FRP Concrete Slab (L2)	29 days?	Wed 1/3/07	Mon 2/12/07
60	WL FRP Concrete Slab(L2)	11 days?	Fri 1/12/07	Fri 1/26/07
62	WL FRP Columns (L2)	10 days?	Mon 1/29/07	Fri 2/9/07
63	WL FRP Shaftwall (L2)	11 days?	Mon 1/29/07	Mon 2/12/07
66	T2 FRP Concrete Slab (L2)	32 days?	Fri 2/2/07	Mon 3/19/07
67	T3 FRP Concrete Slab (L2)	11 days?	Fri 2/9/07	Fri 2/23/07
64	T1 FRP Columns (L2)	4 days?	Mon 2/12/07	Thu 2/15/07
65	T1 FRP Shaftwall (L2)	14 days?	Mon 2/12/07	Thu 3/1/07
68	T2 FRP Columns (L2)	2 days?	Tue 2/20/07	Wed 2/21/07
69	T3 FRP Columns (L2)	7 days?	Thu 2/22/07	Fri 3/2/07
70	T3 FRP Shaftwall (L2)	6 days?	Wed 3/7/07	Wed 3/14/07
71	**Level 3**	**33 days?**	**Tue 2/13/07**	**Thu 3/29/07**
72	WL FRP Concrete Slab(L3)	13 days?	Tue 2/13/07	Thu 3/1/07
73	T1 FRP Concrete Slab (L3)	14 days?	Mon 2/19/07	Thu 3/8/07
78	T2 FRP Concrete Slab (L3)	12 days?	Fri 2/23/07	Mon 3/12/07
74	WL FRP Columns (L3)	3 days?	Mon 3/5/07	Wed 3/7/07
75	WL FRP Shaftwall (L3)	9 days?	Tue 3/6/07	Fri 3/16/07
79	T3 FRP Concrete Slab (L3)	9 days?	Thu 3/8/07	Tue 3/20/07
76	T1 FRP Columns (L3)	2 days?	Fri 3/9/07	Mon 3/12/07
77	T1 FRP Shaftwall (L3)	8 days?	Wed 3/14/07	Fri 3/23/07
80	T2 FRP Columns (L3)	2 days?	Wed 3/14/07	Thu 3/15/07
81	T3 FRP Columns (L3)	7 days?	Wed 3/21/07	Thu 3/29/07
82	T3 FRP Shaftwall (L3)	7 days?	Wed 3/21/07	Thu 3/29/07
83	Mechanical Room Area (L3)	1 day?	Tue 3/27/07	Tue 3/27/07
84	**Level 4**	**27 days?**	**Mon 3/19/07**	**Mon 4/23/07**
86	T1 FRP Concrete Slab (L4)	10 days?	Mon 3/19/07	Fri 3/30/07
85	WL FRP Concrete Slab(L4)	8 days?	Tue 3/20/07	Thu 3/29/07
91	T2 FRP Concrete Slab (L4)	6 days?	Mon 3/26/07	Mon 4/2/07
92	T3 FRP Concrete Slab (L4)	10 days?	Thu 3/29/07	Tue 4/10/07

Project: Project Schedule using Precast
Date: Thu 3/27/08

Task	▨	Milestone	◆	External Tasks	▭
Split	………	Summary	▬	External Milestone	◇
Progress	▬	Project Summary	▭	Deadline	⇩

Page 2



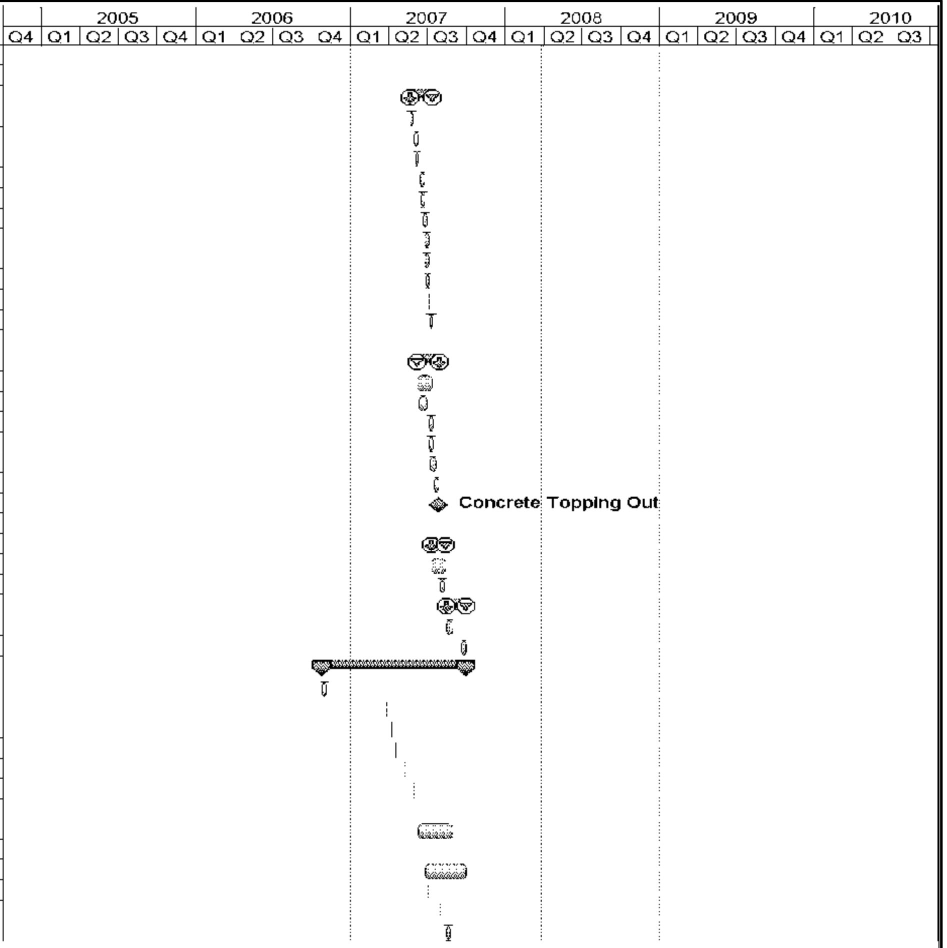
ID	Task Name	Duration	Start	Finish
87	WL FRP Columns (L4)	2 days?	Fri 3/30/07	Mon 4/2/07
88	WL FRP Shaftwall (L4)	4 days?	Mon 4/2/07	Thu 4/5/07
89	T1 FRP Columns (L4)	5 days?	Mon 4/2/07	Fri 4/6/07
90	T1 FRP Shaftwall (L4)	7 days?	Mon 4/2/07	Mon 4/9/07
93	T2 FRP Columns (L4)	3 days?	Fri 4/6/07	Mon 4/9/07
94	T3 FRP Columns (L4)	8 days?	Wed 4/11/07	Fri 4/20/07
95	T3 FRP Shaftwall (L4)	7 days?	Fri 4/13/07	Mon 4/23/07
96	Mechanical Room Area (L4)	1 day?	Tue 4/17/07	Tue 4/17/07
97	**Level 5**	**22 days?**	**Mon 4/9/07**	**Tue 5/8/07**
98	WL FRP Concrete Slab(L5)	5 days?	Mon 4/9/07	Fri 4/13/07
99	T1 FRP Concrete Slab (L5)	8 days?	Tue 4/10/07	Thu 4/19/07
100	T2 FRP Concrete Slab (L5)	10 days?	Wed 4/11/07	Tue 4/24/07
101	WL FRP Columns (L5)	5 days?	Mon 4/16/07	Fri 4/20/07
102	WL FRP Shaftwall (L5)	5 days?	Mon 4/16/07	Fri 4/20/07
103	T3 FRP Concrete Slab (L5)	10 days?	Wed 4/18/07	Tue 5/1/07
104	T1 FRP Columns (L5)	3 days?	Mon 4/23/07	Wed 4/25/07
105	T1 FRP Shaftwall (L5)	3 days?	Mon 4/23/07	Wed 4/25/07
106	T2 FRP Columns (L5)	3 days?	Wed 5/2/07	Fri 5/4/07
107	T3 FRP Columns (L5)	4 days?	Wed 5/2/07	Mon 5/7/07
108	T3 FRP Shaftwall (L5)	3 days?	Thu 5/3/07	Mon 5/7/07
109	Mechanical Room Area (L5)	1 day?	Tue 5/8/07	Tue 5/8/07
110	**Level 6**	**29 days?**	**Mon 4/23/07**	**Thu 5/31/07**
111	WL FRP Concrete Slab(L6)	6 days?	Mon 4/23/07	Mon 4/30/07
112	T1 FRP Concrete Slab (L6)	8 days?	Tue 5/1/07	Thu 5/10/07
114	WL FRP Columns (L6)	4 days?	Tue 5/1/07	Fri 5/4/07
115	WL FRP Shaftwall (L6)	4 days?	Tue 5/1/07	Fri 5/4/07
113	T2 FRP Concrete Slab (L6)	9 days?	Thu 5/3/07	Tue 5/15/07
116	T3 FRP Concrete Slab (L6)	9 days?	Wed 5/9/07	Mon 5/21/07
117	T1 FRP Columns (L6)	5 days?	Mon 5/14/07	Fri 5/18/07
118	T1 FRP Shaftwall (L6)	5 days?	Mon 5/14/07	Fri 5/18/07
119	T2 FRP Columns (L6)	2 days?	Fri 5/18/07	Mon 5/21/07
120	T3 FRP Columns (L6)	7 days?	Tue 5/22/07	Wed 5/30/07
121	T3 FRP Shaftwall (L6)	8 days?	Tue 5/22/07	Thu 5/31/07
122	Mechanical Room Area (L6)	1 day?	Mon 5/28/07	Mon 5/28/07
123	**Level 7**	**34 days?**	**Mon 5/7/07**	**Thu 6/21/07**
124	WL FRP Concrete Slab(L7)	5 days?	Mon 5/7/07	Fri 5/11/07
127	WL FRP Columns (L7)	2 days?	Mon 5/14/07	Tue 5/15/07
128	WL FRP Shaftwall (L7)	5 days?	Mon 5/14/07	Fri 5/18/07
125	T1 FRP Concrete Slab (L7)	11 days?	Mon 5/21/07	Mon 6/4/07
126	T2 FRP Concrete Slab (L7)	10 days?	Tue 5/22/07	Mon 6/4/07
129	T3 FRP Concrete Slab (L7)	11 days?	Tue 5/29/07	Tue 6/12/07
130	T1 FRP Columns (L7)	1 day?	Mon 6/11/07	Mon 6/11/07
131	T1 FRP Shaftwall (L7)	2 days?	Mon 6/11/07	Tue 6/12/07
132	T2 FRP Columns (L7)	1 day?	Mon 6/11/07	Mon 6/11/07
133	T3 FRP Columns (L7)	4 days?	Mon 6/18/07	Thu 6/21/07

Project: Project Schedule using Precas
Date: Thu 3/27/08

Task	▨	Milestone	◆	External Tasks	▨
Split	………………	Summary	▬	External Milestone	◆
Progress	▬	Project Summary	▬	Deadline	⇩

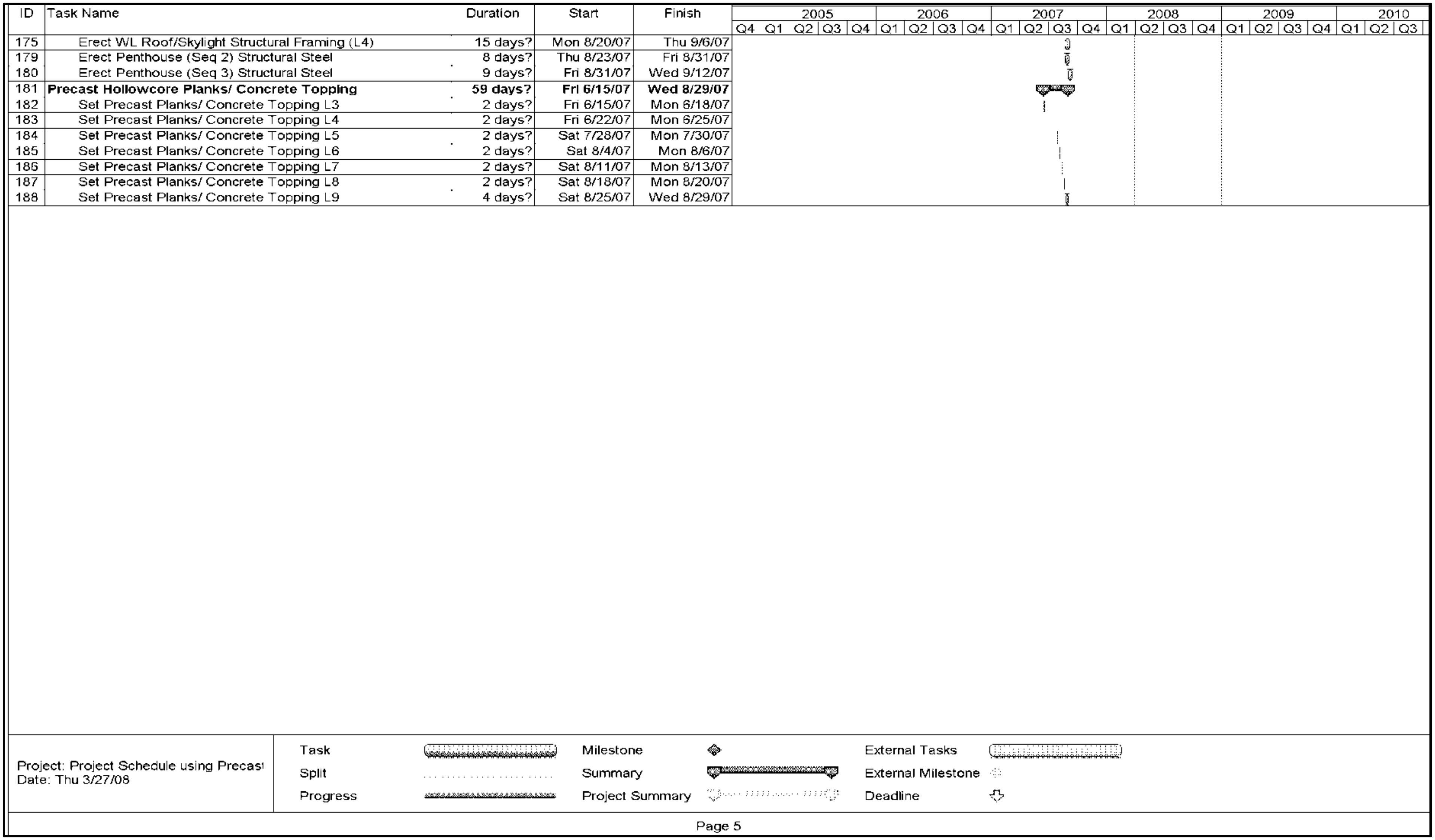
Page 3

ID	Task Name	Duration	Start	Finish
134	T3 FRP Shaftwall (L7)	3 days?	Mon 6/18/07	Wed 6/20/07
135	Mechanical Room Area (L7)	1 day?	Tue 6/19/07	Tue 6/19/07
136	**Level 8**	**37 days?**	**Mon 5/21/07**	**Tue 7/10/07**
137	WL FRP Concrete Slab(L8)	5 days?	Mon 5/21/07	Fri 5/25/07
140	WL FRP Columns (L8)	9 days?	Tue 5/29/07	Fri 6/8/07
141	WL FRP Shaftwall (L8)	6 days?	Fri 6/1/07	Fri 6/8/07
138	T1 FRP Concrete Slab (L8)	8 days?	Wed 6/13/07	Fri 6/22/07
139	T2 FRP Concrete Slab (L8)	6 days?	Fri 6/15/07	Fri 6/22/07
142	T3 FRP Concrete Slab (L8)	9 days?	Tue 6/19/07	Fri 6/29/07
143	T1 FRP Columns (L8)	7 days?	Fri 6/22/07	Mon 7/2/07
144	T1 FRP Shaftwall (L8)	7 days?	Fri 6/22/07	Mon 7/2/07
145	T2 FRP Columns (L8)	4 days?	Wed 6/27/07	Mon 7/2/07
146	T3 FRP Columns (L8)	3 days?	Tue 7/3/07	Thu 7/5/07
147	T3 FRP Shaftwall (L8)	4 days?	Thu 7/5/07	Tue 7/10/07
148	Mechanical Room Area (L8)	1 day?	Fri 7/6/07	Fri 7/6/07
149	**Level 9**	**38 days?**	**Wed 6/6/07**	**Fri 7/27/07**
155	T3 FRP Shaftwall EL. 160 to 172	25 days?	Wed 6/6/07	Tue 7/10/07
156	WLFRP Concrete Slab (L9)	15 days?	Mon 6/11/07	Fri 6/29/07
150	T1 FRP Concrete Slab (L9)	9 days?	Tue 7/3/07	Fri 7/13/07
153	T2 FRP Concrete Slab (L9)	9 days?	Tue 7/3/07	Fri 7/13/07
154	T3 FRP Concrete Slab (L9)	11 days?	Fri 7/6/07	Fri 7/20/07
151	T1 FRP Shaftwall EL. 160 to 181	9 days?	Mon 7/16/07	Thu 7/26/07
152	Concrete Topping Out	0 days	Thu 7/26/07	Thu 7/26/07
157	Mechanical Room Area (L9)	1 day?	Fri 7/27/07	Fri 7/27/07
158	**Elevator Machine Rooms**	**26 days?**	**Tue 7/10/07**	**Fri 8/10/07**
160	FRP Elev. 13/14 Mach. Rm.	26 days?	Tue 7/10/07	Fri 8/10/07
159	FRP Elev. 17/18 Mach. Rm.	8 days?	Mon 7/30/07	Tue 8/7/07
161	**North and South Bridge**	**36 days?**	**Tue 8/14/07**	**Fri 9/28/07**
162	Place South Bridge Concrete Slabs L2-L6	12 days?	Tue 8/14/07	Mon 8/27/07
163	Place North Bridge Concrete Slabs L4-L6	8 days?	Wed 9/19/07	Fri 9/28/07
164	**Structural Steel**	**251 days?**	**Mon 10/23/06**	**Fri 9/28/07**
165	Erect Structural Steel Truss L1-L4	9 days?	Mon 10/23/06	Thu 11/2/06
166	Erect Steel Beams and Metal Decking- Level 3	1 day?	Mon 3/26/07	Mon 3/26/07
167	Erect Structural Steel Truss L5-L6	1 day?	Sat 4/7/07	Sat 4/7/07
168	Erect Steel Beams and Metal Decking- Level 4	1 day?	Mon 4/16/07	Mon 4/16/07
169	Erect Steel Beams and Metal Decking- Level 5	1 day?	Mon 5/7/07	Mon 5/7/07
170	Erect Steel Beams and Metal Decking- Level 6	1 day?	Mon 5/28/07	Mon 5/28/07
172	Erect Structural Steel Truss L7-Penthouse	1 day?	Fri 6/1/07	Fri 6/1/07
173	Erect South Bridge Steel Structure/ Decking L2-L6	62 days?	Fri 6/8/07	Mon 8/27/07
171	Erect Steel Beams and Metal Decking- Level 7	1 day?	Mon 6/18/07	Mon 6/18/07
174	Erect North Bridge Steel Structure/ Decking L4-L6	75 days?	Mon 6/25/07	Fri 9/28/07
176	Erect Steel Beams and Metal Decking- Level 8	1 day?	Mon 7/2/07	Mon 7/2/07
177	Erect Steel Beams and Metal Decking- Level 9	1 day?	Mon 7/30/07	Mon 7/30/07
178	Erect Penthouse (Seq 1) Structural Steel	8 days?	Tue 8/14/07	Wed 8/22/07



Project: Project Schedule using Precast
Date: Thu 3/27/08

Task	▨	Milestone	◆	External Tasks	▨
Split	……	Summary	▬	External Milestone	◇
Progress	▬	Project Summary	▭	Deadline	⇩



ID	Task Name	Duration	Start	Finish
175	Erect WL Roof/Skylight Structural Framing (L4)	15 days?	Mon 8/20/07	Thu 9/6/07
179	Erect Penthouse (Seq 2) Structural Steel	8 days?	Thu 8/23/07	Fri 8/31/07
180	Erect Penthouse (Seq 3) Structural Steel	9 days?	Fri 8/31/07	Wed 9/12/07
181	**Precast Hollowcore Planks/ Concrete Topping**	**59 days?**	**Fri 6/15/07**	**Wed 8/29/07**
182	Set Precast Planks/ Concrete Topping L3	2 days?	Fri 6/15/07	Mon 6/18/07
183	Set Precast Planks/ Concrete Topping L4	2 days?	Fri 6/22/07	Mon 6/25/07
184	Set Precast Planks/ Concrete Topping L5	2 days?	Sat 7/28/07	Mon 7/30/07
185	Set Precast Planks/ Concrete Topping L6	2 days?	Sat 8/4/07	Mon 8/6/07
186	Set Precast Planks/ Concrete Topping L7	2 days?	Sat 8/11/07	Mon 8/13/07
187	Set Precast Planks/ Concrete Topping L8	2 days?	Sat 8/18/07	Mon 8/20/07
188	Set Precast Planks/ Concrete Topping L9	4 days?	Sat 8/25/07	Wed 8/29/07

Project: Project Schedule using Precast
Date: Thu 3/27/08

Page 5

APPENDIX F: LIFE CYCLE COST CALCULATIONS FOR EIFS AND GFRC

Table 24: Life Cycle Cost of EIFS

Life Cycle Cost of EIFS				
	Quantity	Unit	Unit Cost	Total Cost
Initial Cost of System	45690	sf	14.67	$670,272
Description of Maintenance				
Cleaning	45690	sf	$0.30	$13,707
Re-coat Panels	45690	sf	$2.00	$91,380
Replace Joint Sealant	12000	lf	$2.50	$30,000

Table 25: Life Cycle Cost of GFRC

Life Cycle Cost of GFRC				
	Quantity	Unit	Unit Cost	Total Cost
Initial Cost of System	45690	sf	48.78	$2,228,758
Description of Maintenance				
Cleaning	45690	sf	$0.72	$32,897
Replace Joint Sealant	12000	lf	$2.50	$30,000

APPENDIX G: FAÇADE SCHEDULE DURATIONS

Table 26: GFRC Schedule Durations Estimate

GFRC Schedule Durations Estimate					
Area	Façade sq. ft.	Avg. sf. / piece	# GFRC Panels	Avg. # Panels /Day	Duration (Days)
Tower North Face	9427	150	63	15	4
West Lobby North Face	3328	150	22	15	1
Tower East Face	7450	150	50	15	3
Tower West Face	10860	150	72	15	5
Tower South Face /South Bridge	4725	150	32	15	2
West Lobby South Face	6490	150	43	15	3
North Bridge	3410	150	23	15	2
				Total Duration (Days) :	20

Table 27: Façade Window Schedule Durations

Window Schedule Durations	
Area	Duration (Days)
Tower North Face	11
West Lobby North Face	1
Tower East Face	14
Tower West Face	13
Tower South Face /South Bridge	4
West Lobby South Face	2
North Bridge	6

Table 28: EIFS Total Schedule Durations

EIFS Total Schedule Durations	
Area	Duration (Days)
Metal Studs (All Faces)	50
EIFS	65
Total EIFS plus Windows	72
Extra Time for Windows L1-L8 After EIFS Finished	7
Total Duration (Days) :	**122**

Table 29: GFRC Total Schedule Durations

GFRC Total Schedule Durations	
Area	Duration (Days)
GFRC	20
Total GFRC plus Windows	29
Extra Time for Windows After GFRC Finished	9
Total Duration (Days) :	**29**

APPENDIX H: FAÇADE SYSTEMS SCHEDULES
GFRC Facade Schedule

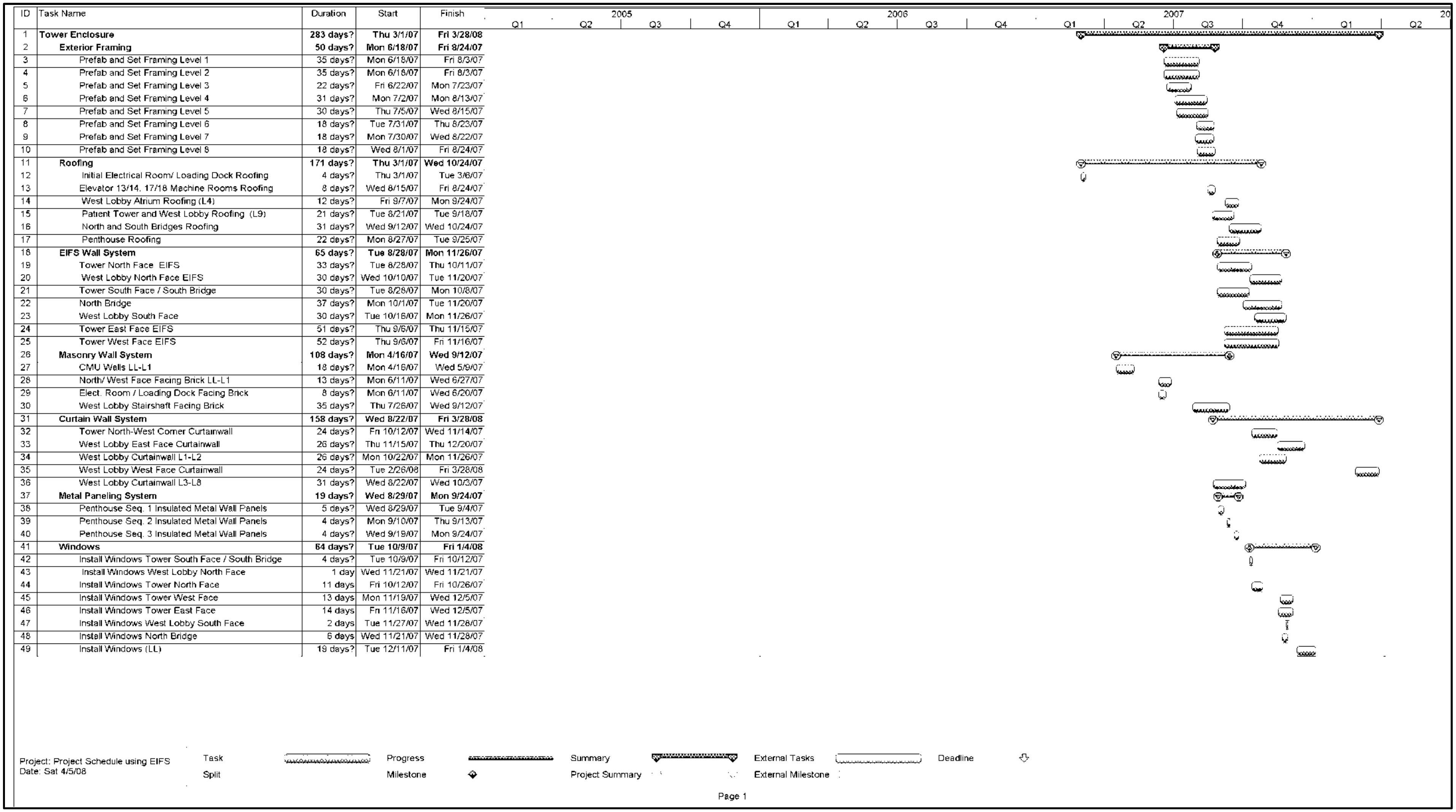
ID	Task Name	Duration	Start	Finish
1	**Tower Enclosure**	**283 days?**	**Thu 3/1/07**	**Fri 3/28/08**
2	**Roofing**	**171 days?**	**Thu 3/1/07**	**Wed 10/24/07**
3	Initial Electrical Room/ Loading Dock Roofing	4 days?	Thu 3/1/07	Tue 3/6/07
4	Elevator 13/14, 17/18 Machine Rooms Roofing	8 days?	Wed 8/15/07	Fri 8/24/07
6	Patient Tower and West Lobby Roofing (L9)	21 days?	Tue 8/21/07	Tue 9/18/07
8	Penthouse Roofing	22 days?	Mon 8/27/07	Tue 9/25/07
5	West Lobby Atrium Roofing (L4)	12 days?	Fri 9/7/07	Mon 9/24/07
7	North and South Bridges Roofing	31 days?	Wed 9/12/07	Wed 10/24/07
17	**Masonry Wall System**	**108 days?**	**Mon 4/16/07**	**Wed 9/12/07**
18	CMU Walls LL-L1	18 days?	Mon 4/16/07	Wed 5/9/07
19	North/ West Face Facing Brick LL-L1	13 days?	Mon 6/11/07	Wed 6/27/07
20	Elect. Room / Loading Dock Facing Brick	8 days?	Mon 6/11/07	Wed 6/20/07
21	West Lobby Stairshaft Facing Brick	35 days?	Thu 7/26/07	Wed 9/12/07
22	**Curtain Wall System**	**158 days?**	**Wed 8/22/07**	**Fri 3/28/08**
27	West Lobby Curtainwall L3-L8	31 days?	Wed 8/22/07	Wed 10/3/07
23	Tower North-West Corner Curtainwall	24 days?	Fri 10/12/07	Wed 11/14/07
25	West Lobby Curtainwall L1-L2	26 days?	Mon 10/22/07	Mon 11/26/07
24	West Lobby East Face Curtainwall	26 days?	Thu 11/15/07	Thu 12/20/07
26	West Lobby West Face Curtainwall	24 days?	Tue 2/26/08	Fri 3/28/08
9	**GFRC Wall System**	**20 days?**	**Tue 8/28/07**	**Mon 9/24/07**
11	West Lobby North Face GFRC	1 day?	Mon 9/3/07	Mon 9/3/07
10	Tower North Face GFRC	4 days	Tue 8/28/07	Fri 8/31/07
16	Tower West Face GFRC	5 days?	Tue 9/4/07	Mon 9/10/07
12	Tower South Face / South Bridge	2 days?	Tue 9/11/07	Wed 9/12/07
15	Tower East Face GFRC	3 days	Thu 9/13/07	Mon 9/17/07
14	West Lobby South Face	3 days?	Tue 9/18/07	Thu 9/20/07
13	North Bridge	2 days?	Fri 9/21/07	Mon 9/24/07
28	**Metal Paneling System**	**19 days?**	**Wed 8/29/07**	**Mon 9/24/07**
29	Penthouse Seq. 1 Insulated Metal Wall Panels	5 days?	Wed 8/29/07	Tue 9/4/07
30	Penthouse Seq. 2 Insulated Metal Wall Panels	4 days?	Mon 9/10/07	Thu 9/13/07
31	Penthouse Seq 3 Insulated Metal Wall Panels	4 days?	Wed 9/19/07	Mon 9/24/07
32	**Windows**	**93 days?**	**Wed 8/29/07**	**Fri 1/4/08**
39	Install Windows West Lobby North Face	1 day?	Wed 8/29/07	Wed 8/29/07
36	Install Windows Tower North Face	11 days	Tue 9/4/07	Tue 9/18/07
38	Install Windows Tower West Face	13 days?	Tue 9/11/07	Thu 9/27/07
35	Install Windows Tower South Face / South Bridge	4 days	Thu 9/13/07	Tue 9/18/07
37	Install Windows Tower East Face	14 days	Tue 9/18/07	Fri 10/5/07
40	Install Windows West Lobby South Face	2 days?	Fri 9/21/07	Mon 9/24/07
34	Install Windows North Bridge	6 days?	Tue 9/25/07	Tue 10/2/07
33	Install Windows (LL)	19 days?	Tue 12/11/07	Fri 1/4/08

Project: Project Schedule using GFRC
Date: Sat 4/5/08

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

Page 1

EIFS Facade Schedule



ID	Task Name	Duration	Start	Finish
1	**Tower Enclosure**	**283 days?**	**Thu 3/1/07**	**Fri 3/28/08**
2	**Exterior Framing**	**50 days?**	**Mon 6/18/07**	**Fri 8/24/07**
3	Prefab and Set Framing Level 1	35 days?	Mon 6/18/07	Fri 8/3/07
4	Prefab and Set Framing Level 2	35 days?	Mon 6/18/07	Fri 8/3/07
5	Prefab and Set Framing Level 3	22 days?	Fri 6/22/07	Mon 7/23/07
6	Prefab and Set Framing Level 4	31 days?	Mon 7/2/07	Mon 8/13/07
7	Prefab and Set Framing Level 5	30 days?	Thu 7/5/07	Wed 8/15/07
8	Prefab and Set Framing Level 6	18 days?	Tue 7/31/07	Thu 8/23/07
9	Prefab and Set Framing Level 7	18 days?	Mon 7/30/07	Wed 8/22/07
10	Prefab and Set Framing Level 8	18 days?	Wed 8/1/07	Fri 8/24/07
11	**Roofing**	**171 days?**	**Thu 3/1/07**	**Wed 10/24/07**
12	Initial Electrical Room/ Loading Dock Roofing	4 days?	Thu 3/1/07	Tue 3/6/07
13	Elevator 13/14, 17/18 Machine Rooms Roofing	8 days?	Wed 8/15/07	Fri 8/24/07
14	West Lobby Atrium Roofing (L4)	12 days?	Fri 9/7/07	Mon 9/24/07
15	Patient Tower and West Lobby Roofing (L9)	21 days?	Tue 8/21/07	Tue 9/18/07
16	North and South Bridges Roofing	31 days?	Wed 9/12/07	Wed 10/24/07
17	Penthouse Roofing	22 days?	Mon 8/27/07	Tue 9/25/07
18	**EIFS Wall System**	**65 days?**	**Tue 8/28/07**	**Mon 11/26/07**
19	Tower North Face EIFS	33 days?	Tue 8/28/07	Thu 10/11/07
20	West Lobby North Face EIFS	30 days?	Wed 10/10/07	Tue 11/20/07
21	Tower South Face / South Bridge	30 days?	Tue 8/28/07	Mon 10/8/07
22	North Bridge	37 days?	Mon 10/1/07	Tue 11/20/07
23	West Lobby South Face	30 days?	Tue 10/16/07	Mon 11/26/07
24	Tower East Face EIFS	51 days?	Thu 9/6/07	Thu 11/15/07
25	Tower West Face EIFS	52 days?	Thu 9/6/07	Fri 11/16/07
26	**Masonry Wall System**	**108 days?**	**Mon 4/16/07**	**Wed 9/12/07**
27	CMU Walls LL-L1	18 days?	Mon 4/16/07	Wed 5/9/07
28	North/ West Face Facing Brick LL-L1	13 days?	Mon 6/11/07	Wed 6/27/07
29	Elect. Room / Loading Dock Facing Brick	8 days?	Mon 6/11/07	Wed 6/20/07
30	West Lobby Stairshaft Facing Brick	35 days?	Thu 7/26/07	Wed 9/12/07
31	**Curtain Wall System**	**158 days?**	**Wed 8/22/07**	**Fri 3/28/08**
32	Tower North-West Corner Curtainwall	24 days?	Fri 10/12/07	Wed 11/14/07
33	West Lobby East Face Curtainwall	26 days?	Thu 11/15/07	Thu 12/20/07
34	West Lobby Curtainwall L1-L2	26 days?	Mon 10/22/07	Mon 11/26/07
35	West Lobby West Face Curtainwall	24 days?	Tue 2/26/08	Fri 3/28/08
36	West Lobby Curtainwall L3-L8	31 days?	Wed 8/22/07	Wed 10/3/07
37	**Metal Paneling System**	**19 days?**	**Wed 8/29/07**	**Mon 9/24/07**
38	Penthouse Seq. 1 Insulated Metal Wall Panels	5 days?	Wed 8/29/07	Tue 9/4/07
39	Penthouse Seq. 2 Insulated Metal Wall Panels	4 days?	Mon 9/10/07	Thu 9/13/07
40	Penthouse Seq. 3 Insulated Metal Wall Panels	4 days?	Wed 9/19/07	Mon 9/24/07
41	**Windows**	**64 days?**	**Tue 10/9/07**	**Fri 1/4/08**
42	Install Windows Tower South Face / South Bridge	4 days?	Tue 10/9/07	Fri 10/12/07
43	Install Windows West Lobby North Face	1 day	Wed 11/21/07	Wed 11/21/07
44	Install Windows Tower North Face	11 days	Fri 10/12/07	Fri 10/26/07
45	Install Windows Tower West Face	13 days	Mon 11/19/07	Wed 12/5/07
46	Install Windows Tower East Face	14 days	Fri 11/16/07	Wed 12/5/07
47	Install Windows West Lobby South Face	2 days	Tue 11/27/07	Wed 11/28/07
48	Install Windows North Bridge	6 days	Wed 11/21/07	Wed 11/28/07
49	Install Windows (LL)	19 days?	Tue 12/11/07	Fri 1/4/08

Project: Project Schedule using EIFS
Date: Sat 4/5/08

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

Page 1