AE 481W

SENIOR THESIS FINAL PROPOSAL

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[The following report presents a detailed overview of the research topics to be done on the Office Renovation Building. A series of four technical analyses will be investigated to help the project delivery a final product with more efficiency and quality assurance. These topics will be researched and developed throughout the course of the Spring 2011 Semester.]

Executive Summary

The following proposal outlines four analyses that will be performed on the Office Renovation Building project. These research topics are intended to improve the quality of the project while increasing the efficiency of the construction team's efforts. The analyses will cover a variety of industry issues including: Building Information Modeling and technologies, prefabricated design, renewable energy, and new field technologies. Throughout the course of the Spring 2011 semester, the contents of this proposal will be researched, critiqued and edited. The results of these analyses will be presented to the Penn State Architectural Engineering Faculty.

Analysis 1: BIM Execution and Utilization/Phase Planning

The Gilbane Grunley Joint Venture team currently has a 3D Revit Model of the renovation project. However, the model is used only for visual presentation to the owner. Aside from 3D coordination, there are no substantial BIM efforts for the project. The goal of this analysis is to develop a project specific BIM execution guide to further utilize the existing 3D Model. Also, particular BIM applications will be research to better coordinate the transition and phase planning of building's renovation stages.

Analysis 2: Schedule Acceleration through Prefabrication

The current phase of the Office Renovation Building involves the construction of an electrical equipment enclosure to be erected within one of the building's interior courtyards. The activities associated with the 20,000 SF facility contribute to site congestion and schedule delays. The goal of this analysis is to utilize prefabricated concrete floor slabs to redesign the structure. It is expected that the implementation of a prefabricated system will minimize congestion while accelerating the project schedule.

Analysis 3: Feasibility and Design Study for Photovoltaic Energy System

The General Services Administration is making major commitments to transition into sustainable building. The Office Renovation Building is currently listed to receive LEED® Gold Status but does not present any goals to create on-site renewable energy. This analysis incorporates a photovoltaic energy system than will help power the facility's electrical equipment enclosure. Results show that the invest will present a payback of approximately 8 years.

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Project Background

Figure 1: Aerial Image of the Office Renovation Building

The Office Renovation Building is one of the largest civil buildings owned by the General Services Administration. Completed in 1932, the structure houses 1.8 million square feet of office space for a variety of government agencies. Located in a downtown metropolitan area in the northeastern part of the United States, the $500 million project is scheduled for completion in multiple phases during the next 13 years. While over 3,500 workers continue to occupy the historic building, the project will use a swing space completed in phase 1 of its construction to move employees out of the construction zones. Gilbane Building Company and Grunley Construction have formed a joint venture to act as the project's general contractor for phases 1, 2, and 3.

Figure 2: GGA rendering of exterior restoration

The seven story Indiana limestone façade and granite base structure will be undergo a major modernization to upgrade all major building systems. Once complete, the building will sport new fire and life-safety systems, enhanced perimeter security, and high-efficiency electrical and HVAC systems. A major focus of the project is to achieve LEED silver certification for the Office Renovation Building. This accreditation will be attained primarily through energy efficient systems and the re-use and recycling of existing

materials. During phase 2, Gilbane-Grunley Joint Venture (GGJV) is to replace the existing steam utilization system with a new hot water heating system that will feed several thousand fan coil units. GGJV is to also upgrade the structure's mechanical system with new shell-and-tube heat exchangers in addition to the utilization of gasketed plate heat exchangers. For the building's cooling, three (3) new electrical centrifugal water chillers will be installed in the chiller plant located in the courtyard 1 basement, they will also feed into the structure's numerous fan coil units as direct outside air handlers will provide ventilation air for the mechanical system.

Figure 3: Section through Courtyard 1 of the Office Renovation Building showing the structure's new EEE

A major task within the project involves the construction of a new electrical equipment enclosure. This 20,000 SF two story facility is to be erected within one of the building's interior courtyards and will be constructed above an existing level of the office building. The electrical equipment enclosure (EEE) will house a variety of transformers, switchgear, and emergency generators to ensure the building remains operable at all times. Figure 2 shows the location of the EEE in the center of courtyard 1 of the structure.

In addition to the erection of the EEE, the entire restoration of the building's exterior façade and windows are contracted under the phase 2 scope of work. The restoration of the structure's limestone façade is scheduled to take place throughout the entire duration of the project. The work will conclude over the course of 22 months, scheduled to be complete in November of 2011.

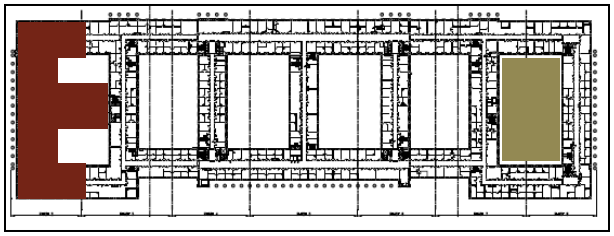

Figure 4: Overall floor plan of the Office Renovation Building, the area shaded in maroon represents the current phase of construction. The other shaded region illustrates the location of the swing space for relocating tenants.

The efforts of thesis research assignment will be strictly focused on the current phase of construction. Work began in November of 2009 and will cover the duration of approximately 24 months. The original GMP for the second phase of the building's renovation was approximately $115 million.

Analysis 1: BIM Execution and Utilization/Phase Planning

Problem

The Gilbane-Grunley team proclaims to be utilizing building information modeling to help construct a more efficient project. Unfortunately, GGJV has only been using Autodesk Navisworks® to coordinate MEP drawings for the new system. Also, the project team has created a 3D Revit model of the building, but uses it only to provide the owner with a visualization of the construction process. After learning about the opportunities that exist within the utilization of BIM applications, it seems that the project team is not effectively using their resources.

Research Goal

The goal of this technical analysis is to implement *Penn State's BIM Project Execution Planning Guide V2.0* on the Office Renovation Building project. The execution plan is intended to help the project team identify which BIM Uses can directly benefit the project. Implementing these uses will help better utilize the 3D Revit® model already constructed.

Also, BIM applications can also help improve the phase planning of the project. Over the course of the building's 8 renovation phases, all of the building's employees will be impacted by relocation. The transition into phase 2 proved difficult for the project team. BIM Research will be focused on utilizing BIM to implement a transition planning and management system to help with future phase planning.

Methodologies

- Research GGJV's current goals and expectations for their 'BIM' application
- Apply the project's constraints to the *BIM Project Execution Planning Guide V2.0*
- Develop which BIM *Uses* are most beneficial to the renovation project
- Research Facilities Management software to integrate with 3D Model
- Utilize FM application to improve phase planning
- Develop improved phase planning approach for renovation project

Resources and Tools

- Industry Professionals (Grunley BIM Coordinator)
- AE 597G: BIM Execution and Planning, course content
- PSU *BIM Project Execution Planning Guide V2.0*
- Dr. Messner, Dr. Leicht, Craig Dubler and other AE faculty members

Expected Outcomes

Following the research on BIM execution and planning, it is believed that the GGJV team will be able to directly benefit from the project's 3D Model. The Execution Guide specific to the renovation project will present several BIM *Uses* that will benefit both the construction and operations stages of the building. Particularly, the development of an Asset Management and Tracking application will contribute towards the improvement of the phase planning of the project.

Analysis 2: Schedule Acceleration through Prefabrication

Problem

The 20,000 SF Electrical Equipment Enclosure designed to be erected in courtyard 1 of the Office Renovation Building is the only new construction to take place on the project. The structural steel facility's floor slabs are currently designed to be cast in place composite concrete slab on one way metal decking. The area of each level is relatively small totaling approximately 6,600 SF. The roof of the structure is also designed to be cast in place concrete to support the loads relative to the currently proposed green roof. Following the completion of the 2nd floor, large electrical equipment is scheduled to be put in place before the pouring of the 4th floor; the same is scheduled for the 4th floor prior to the placement of the roof. Each floor must achieve its appropriate curing strength prior to the placement of floor's electrical equipment.

The duration and cost of mobilization, formwork, concrete pouring, and curing time associated with placing concrete are significant to the project schedule and total cost for the Electrical Equipment Enclosure. Due to the size of the EEE and because of site congestion, incorporating a precast concrete floor structure may be cost incentive while decreasing the schedule duration for the project.

Research Goal

The goal of this analysis is to perform the design of a precast concrete floor system and assess the impacts on schedule and overall cost of the Electrical Equipment Enclosure. Results of such analysis will present how much the schedule can be reduced while displaying any cost reductions associated with the change in design. Site utilization will also be researched in regards to the utilization of the project's crane already scheduled to be on site. Utilizing the precast system will also accelerate the schedule in regards to placing the large electrical equipment on each floor so that further work may commence.

Methodology

- Research precast alternative systems applicable to the EEE
- Contact manufacturers and the project's structural engineers to determine appropriate design
- Analyze how the precast structure will impact the structural design
- Design preliminary precast floor slab system for Electrical Equipment Enclosure
- Discuss design impacts with electrical subcontractor for feasibility of EEE equipment tie in
- Research manufacturer costs for precast system
- Develop alternative schedule analyzing delivery of components and associated lead times
- Present cost and schedule comparison with initial design and delivery

Resources and Tools

- Industry Professionals and relative contacts from past internship experience
- Precast Panel Manufacturers
- AE Faculty- Structural
- AE 570: Production Management- course content and concepts
- Thornton Tomasetti and Superior Ironworks- Structural engineer and steel fabricator/erector
- Southland Concrete- Current concrete subcontractor
- Singleton Electric Company- Current electrical subcontractor
- Applicable literature
- RAM Structural System Software

Expected Outcome

After extensive research and completing an in-depth design, it is expected that a precast structural floor system will be feasible and will significantly reduce the duration of erecting the Electrical Equipment Enclosure for the Office Renovation Building. Though it will be difficult to compare the prices of the precast system in contrast to the originally designed cast in place, it is expected that the accelerated schedule will compensate for any additional costs associated with the new system. Also, great efforts will be taken to successfully implement a precast floor system for the EEE, if other changes must be made (i.e. the structural steel design of the structure), they will be adjusted accordingly

Analysis 3: Feasibility and Design Study for Photovoltaic Energy System

Problem

The Office Renovation Building is currently scheduled to achieve LEED® Silver certification for New Construction and Major Renovations under LEED V2.2; recent interests of the owner and architect have refocused the project to earn LEED® Platinum status. Based off the project's current LEED scorecard, the most opportunities for the Office Renovation Building to earn this certification lay under the Sustainable Sites and Energy & Atmosphere categories. It is very important for the owner to earn LEED Platinum status and it is worthwhile for the design team to research additional sustainable applications for the project.

Research Goal

The goal of this analysis is to investigate what technologies and green practices can be implemented on the Office Renovation Building.

Research on this analysis will be strictly focused on the preliminary design of a photovoltaic energy system and to determine the financial practicability to incorporate the system to reduce energy costs for the owner. A model will be created to determine the most ideal location for the PV system. Following the location of the system, research will be done as to how the array will tie into the building. A financial life-cycle cost analysis will also be done to further solidify the decision of whether or not to implement the system.

Methodology

- Research of Photovoltaic panel technologies
- Contact PV manufacturers for implementation and design support
- Determine quantities necessary to be placed on the structure
- Determine how the PV system will be tied into the rest of the facility
- Analyze how the structure will be impacted with PV installation
- Perform feasibility analysis on life-cycle costs and payback period

Resources and Tools

- Industry Professionals
- PV Manufacturers and Designers
- AE Faculty- Structural, Electrical
- URS Corporation MEP Engineers/Designers
- AE 598C (Sustainable Design Techniques) Course content
- Dr. David Riley- AE 598C Professor
- Applicable Literature

Expected Outcome

Following the research and preliminary design of an acceptable PV system, it is expected that the panels will provide considerable energy for the facility. It will be difficult to apply enough On-Site Renewable energy to earn all three credits for LEED® certification but it will provide long term savings for the owner. Furthermore, it does not seem practical to have a system that will support the entire building; research will be done as to what loads are required to help power Phase 2 of the project. It is expected that the final array design will be used to help power some aspect of the structure's Electrical Equipment Enclosure (EEE).

Analysis Weight Matrix

The weight matrix illustrated in Table 1, demonstrates the amount of time that will be spent on each analysis throughout the course of the Spring 2011 semester. The figure also exemplifies how each topic pertains to the core areas of investigation required for this course.

Analysis Description	Research	Value Engineering	Constructability Review	Schedule Reduction	Total
BIM Execution & Planning	10%		10%	10%	30%
Prefabricated System	5%	10%	10%	15%	40%
Photovoltaic System	15%		15%		30%
Total	30%	10%	35%	25%	100%

Table 1: Weight Analysis Matrix

The results of this table demonstrate that a majority of time will be spent researching each applicable topic with a heavy focus in constructability (feasibility) and schedule reduction specific to the Office Building Renovation project. Cumulatively, the most time will be spent investigating a prefabricated system to make the construction of the facility's electrical equipment enclosure more time efficient and cost effective.

Timetable

In an effort to remain organized and on track throughout the Spring 2011 semester, a preliminary semester timetable has been created. The schedule can be seen in ***Appendix B: Spring Semester Preliminary Schedule***.

Conclusions

The efforts of the previously described analyses are an effort to provide a comprehensive review of today's industry practices. Outcomes are expected to help improve the means and methods of the Office Renovation Building project. BIM utilization is where the future of the construction industry is going. Helping the project team develop an execution plan specific to the Office Renovation Building project will help them better utilize the resources at hand to deliver a higher quality project. The prefabricated structural floor system for the Electrical Equipment Enclosure will help accelerate the project schedule while reducing site congestion. Incorporating a photovoltaic system to the EEE will contribute to the concept of sustainability in design and construction.

Revisions to this proposal are expected to occur throughout the duration of the Spring 2011 semester. This assignment is designed to be a continued work in progress based on feedback and research findings.

[Appendix A]

BREADTH TOPICS AND MAE REQUIREMENTS

BREADTH Topics:

The following breadths involve research and investigation within other technical disciplines within the Architectural Engineering major. Each topic pertains to the analyses previously mentioned within this proposal.

Structural Breadth: Contributes to Technical Analysis #2 and Technical Analysis #3

The erection of the Office Renovation Building's Electrical Equipment Enclosure is the only new construction to take place during phase 2. The structure is currently designated to be composed of steel columns and beams and will include three levels of elevated concrete slabs on metal decking

Substituting cast in place floor slabs as described in *Technical Analysis #2* will have some structural impacts on the facility's current design. The structural steel design and connection details originally applied to the structure's design will be impacted with the proposed alternate system. Furthermore, the application of a Photovoltaic System on the roof of the Office Renovation Building will require design checks for applicable loads. If the roof structure requires redesign work, it will be performed accordingly.

Renewable Energy/Electrical Breadth: Contributes to Technical Analysis #3

The building electric service is primarily 208V and is supplied through various transformers and switchgear that have been modified over the years. Most of the electrical work is comprised within the construction of the structure's new Electrical Equipment Enclosure. Four (4) 13.8 KV feeders from PEPco Power, an electric and natural gas utility subsidiary of The Exelon Corporation, will be provided will to (4) Medium Voltage (MV) switchgear. Also, MV power will be distributed to (4) transformer vaults. The entire electrical system will be backed up by three (3) emergency generators each rated at 2000Kw.

Incorporating renewable energy from a PV energy system into the existing design of the Electrical Equipment Enclosure will be analyzed to determine the electrical equipment and connection requirements. Research will be done in regards to how the new renewable energy system will alter the existing design and how it will be connected to provide power to the facility. The Photovoltaic system will be designed to tie into the Electrical Equipment Enclosure's lighting system. Feasibility studies and constructability reviews will be executed to analyze what energy contributions the new system will make to the facility.

MAE Requirements

The knowledge gained from an array of 500 level MAE courses will be applied to each of the technical analyses proposed. Research and references from *AE 597G: BIM Execution and Planning* will be applied to the implementation of *BIM Project Planning and Execution*. Furthermore, the conceptual foundation and methodologies of *AE 570: Production Management* will be applied to effectively accelerate construction of the Electrical Equipment Enclosure and its *Prefabricated* components. Also, the topics discussed in *AE 598C: Sustainable Building Methods* will be used to optimize the design and implementation of a *Photovoltaic Energy System.*

- AE 597G: BIM Execution and Planning
- AE 570: Production Management
- AE 598C: Sustainable Building Methods

[Appendix B]

SPRING SEMESTER PRELIMINARY SCHEDULE