

Executive Summary

This Campus Project located in Northeast US is a multi-building, multi-use project, built to serve as a community and cultural gathering place. It consists of five unique buildings, an underground parking garage, and a geothermal well field. The five buildings are the Turkish Bath, Convent/Monastery, Mosque, Cultural Center, and Fellowship Hall, as labeled in the image below.



Figure 1. *This Campus Project (courtesy of Balfour Beatty)*

This report will present the analyses that will be conducted through this thesis in the attempt to improve the project and its delivery. Since the focus of the project is to construct a culturally significant and expressive campus, it was deemed appropriate that this should be the theme of the four analyses conducted.

Analysis 1 is a structural redesign of the Fellowship Hall and Convent/Monastery from a steel superstructure to CIP concrete. The goal of this change is to take advantage of worker familiarity with the high amount CIP concrete used on site and to architecturally unite the site with similar façade design. This presents the opportunity to complete a structural and architectural breadth in order to conduct a proper analysis. The expected outcome is to design the new structural system, create cost and schedule estimates of the new system, and develop an architectural model to show the change in appearance.

This information will be used in Analysis 2 which is a restructuring of the concrete bid package. The goal of this change is to divide the concrete scope into multiple packages of smaller scope that can be split up between subcontractors. This also presents an opportunity to conduct a structural breadth to determine where appropriate divisions in the structure are possible without threatening the structural integrity. The expected outcome is to split the bid package and to identify challenging locations where coordination of different bid packages will be necessary.

Information from the previous two analyses will be used in the Analysis 3, which is a study of management of the workforce on the project. This will incorporate knowledge gained through Master's coursework, specifically AE 570: Production Management. The expected outcome is to develop a Workforce Management Plan that could be used on the project. Foreign artisan construction work will be analyzed to find specific management techniques.

The safety of foreign artisans on site will be studied in detail in Analysis 4. Considerations for differences in work practice, religious beliefs, and cultural beliefs will be included and planned for. The expected outcome is to develop a general Foreign Worker Safety Action Plan that can be used on any project and a Site Specific Foreign Worker Safety Action Plan that will be used on this specific project.

Appendix A includes additional information on the Breadth Opportunities and MAE Requirements included within the analyses. Additionally a Thesis Time Table is provided in Appendix B to propose a schedule that will be followed through the spring semester. If approved, this proposal will be the contract that is followed during the study of this project.

Revision Changes (1-17-2014)

- The deliverable for Analysis 3: Workforce Management is changed to be a comprehensive plan that can be applied to different projects.
- Additional information provided within Appendix A. More detail given to the Breadth Opportunities and MAE Requirements.

Revision Changes (4-9-2014)

- Updated to reflect thesis name change from "Cultural Center" to "A Campus Project".

Analysis 1: Structural Redesign

Problem

The most common structural element used on the project is CIP concrete. It is used for nearly the entire structure of the Mosque, Turkish Bath, Cultural Center, and Parking Garage, giving all of these areas a similar design and consistent architectural appearance. On the construction side, this high prevalence of CIP concrete work promotes a worker affinity to this activity. Familiarity with concrete work could potentially lead the workers to slightly higher productivity. Furthermore, these buildings have a similar design in their exterior envelope, again creating a consistent architecture and a familiar workflow. The two remaining buildings, Fellowship Hall and Convent/Monastery, have a structure composed of steel columns and beams and a façade type that differs from the other buildings. This difference in construction work could have influence on material requisition bringing steel instead of concrete on site and worker productivity because of the different style of work. Most likely, this will not result in delays, but it does not take advantage of the prevalence and familiarity of concrete work on site.

Background Research

The Fellowship Hall and the Convent/Monastery are the only two buildings on site to use a predominantly steel superstructure. The costs of these buildings are \$5.1 million and \$7.9 million respectively; that is around 20% of the total project cost. Neither of these buildings lies directly on the critical path of the project, making the majority of their work noncritical. However, some of the tasks on the Fellowship Hall are critical because they affect the beginning date of Hardscaping and Landscaping, which are critical activities.

The façade of the Fellowship Hall is comprised of Portland cement plaster on metal lath supported by cold formed metal steel. Ornamental wood trim is attached to the surface of the Portland cement across the entire façade. Convent/Monastery has a façade of anchored stone veneer on the first floor and Portland cement plaster on metal lath on the remaining floors, both supported by cold formed metal studs. In comparison, the façades of the other buildings are typically stone panels supported by channel and rail systems and CMU wall. Below, *Figures 1* and *2* shows an example of the architectural differences between the Fellowship Hall and the Cultural Center.



Figure 1: Fellowship Hall



Figure 2: Cultural Center

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Potential Solutions

In order to take advantage of worker familiarity with construction method, the steel structures of the Fellowship Hall and Convent/Monastery will be redesigned as CIP concrete. This will keep a consistent structural design throughout the site and will unify the site with a similar architectural and cultural appearance. This structural adjustment will increase the size of the concrete bid package and the workload of the foreign artisans, as they will have additional exterior finishes to complete. Consideration for these two items will be taken into account when completing the depths related to those issues. The architectural design of these two buildings may be altered as necessary in order to match the appearance of the other buildings.

Analysis Methodology

- Structural Analysis of the Fellowship Hall and Convent/Monastery As Is with Steel Structure
- Redesign of Structure to CIP Concrete
- Cost and Schedule Analysis of the CIP Concrete
 - Compared to Cost and Schedule of Steel Structure
 - Used with Analysis 2: Redesign of Concrete Bid Package and Analysis 3: Workforce Management
- Architectural Design Analysis
 - Modify Façade to Reach a Similar Appearance to Other Buildings

Expected Outcome

The structure of the Fellowship Hall and Convent/Monastery will be sized as CIP concrete instead of steel. This information will be utilized to complete a cost and schedule analysis to determine the implications of making this structural change. It is important this data is accurate because it will be utilized in later depths. The architectural façade of these buildings will also be modified to more closely match the façades of the other buildings on the project. A Revit model will be created to visualize the change in appearance.

The change in structure will most likely result in an increase in cost with a decrease in schedule. This will be taken into account when performing Analysis 2 and Analysis 3. The increase in concrete work due to this structural change will be accommodated during the changes made in those analyses.

see Appenaix A: Breadth Opportunities and MAE Requirements to review the potential for structural and architectural breadths.

Analysis 2: Restructure of Concrete Bid Package

Problem

With three of the five buildings on site almost entirely structured using CIP concrete and the entire Underground Parking Garage formed of CIP concrete, the concrete scope on the project is very large. This places a significant amount of pressure on the shoulders of Facchina, the subcontractor in charge of the concrete package. If they fall behind in their work due to error or unforeseen circumstances, it will almost certainly affect the entire project. A majority of their structural work lies upon the critical path, whether directly or indirectly. It is absolutely essential that Facchina remain on task so that their work remains on schedule and does not negatively impact other subcontractor work.

Background Research

The total cost of concrete work on the project is \$15.5 million. With the cost of all construction work totaling about \$65 million that means the concrete scope is almost 25% of the entire project cost. In addition, the entire concrete scope totals nearly 25,000 cubic yards of concrete. The three areas that have the majority of the cost within the concrete scope are the Parking Garage, the Mosque, and the Turkish Bath. The table below provides a brief breakdown of concrete, steel, and MEP costs on the project.

	Volume of Concrete (CY)	Cost of Concrete	Cost of Steel	Cost of MEP
Parking Garage	13200	\$6,320,000	--	\$2,889,000
Mosque	2900	\$3,800,000	--	\$3,774,000
Turkish Bath	5400	\$3,463,000	\$151,000	\$5,870,000
Cultural Center	1400	\$974,000	\$181,000	\$2,155,000
Convent/Monastery	1300	\$728,000	\$769,000	\$2,163,000
Fellowship Hall	400	\$215,000	\$483,000	\$1,516,000
Total	24,600	\$15,500,000	\$1,584,000	\$18,367,000

Table 1: Project Breakdown

On the project schedule, much of the concrete work lies on the critical path of the project or can have influence on items that are on the critical path. In particular, nearly all of the foundation and superstructure concrete work of the Bath is critical. Due to a difference in elevation of almost 20 feet, this is a complicated work area that features underground recreational facilities, large retaining walls, and post-tensioned beams. Challenging work areas are also present on the Mosque, which is composed of a multitude of differently shaped columns, arches, domes, and two minarets. The Parking Garage does not have critical activities, but its completion affects nearly every other building on the project, especially the Mosque. Delays here do not have a direct effect on the schedule, but it will cause issues for Facchina since they have such a large amount of work to complete

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During the project, Facchina has fallen behind at some points, typically due to unforeseen challenges with construction, such as issues with the Styrofoam dome formwork and the challenging columns and arches. It is possible that some of these difficulties could have been avoided or appropriately prepared for if the scope of work was smaller and a subcontractor was able to focus on one building rather than all of them.

Potential Solutions

The bid package will be split into smaller, separate packages so that it can be split between multiple subcontractors. There are a number of opportunities to divide the project into separate areas that will each be part of a bid, and these will be explored through the completion of this analysis. The Parking Garage and Mosque may be considered to include within one package, as their building components are integrated together. The Turkish Bath, due to its complexity, may be considered within one package as well. The remaining buildings will be assessed and included in the bid packages as seems applicable.

Analysis Methodology

- Analyze the Current Scope of Concrete on the Project
 - Facchina's Ability to Handle the Current Work Load
 - Actual Issues that Have Arisen Due to the Size of the Scope
- Additional Research Information
 - Typical Size of Concrete Scope on a Project
 - Case Studies of Projects where Bid Package was Divided
 - Competitiveness in Area and for Project Size
- Incorporation of Data from Analysis 1 into the Current Bid Package
- Divide Concrete Package into More Manageable Pieces
 - Develop Schedules and Costs for Each Package
 - Identify Locations of Interest where Different Packages Meet and High Coordination is Needed

Expected Outcome

The current concrete bid package will be divided into smaller, more easily managed sections. These can then be divided up amongst multiple subcontractors, giving them the chance to focus on their specific tasks and decrease the risk of delays due to overabundance of work. The sizes of the packages will be reflective of the work going into place and how it can be structurally divided, the number of concrete subcontractors in the immediate area, and information gained from case studies. Cost and schedule estimate will be prepared for each package and specific challenge areas will be identified. It is anticipated that these will be areas where separate packages meet and order of construction will need to be identified in order to have good coordination and work flow.

See Appendix A: Breadth Opportunities and MAE Requirements to review the potential for a structural breadth.

Analysis 3: Workforce Management

Problem

This Campus Project, having multiple buildings, has a strong opportunity to have a larger workforce and high productivity. Operations for different subcontractors can occur in many different spaces throughout the site. This gives them the opportunity to find and complete work as they are capable and bring on a larger manpower if they are able. Also, it creates the opportunity for subcontractors to adjust their working location if for some reason they are unable to work in a scheduled area. For example, if Trade A is scheduled to begin work in the Cultural Center, but cannot because Trade B is still working in that area, Trade A can move to and work in another building. This helps avoid the presence of idle workers and keeps Trade A working. However, this situation does present an issue returning to the schedule when Trade B finishes and Trade A needs to resume work according to the schedule. There are also challenges with monitoring this larger workforce and ensuring that their operations are proceeding according to schedule.

Background Research

Through discussions with Balfour Beatty, the project team vocalized that managing the workforce is an integral part of the project. Construction operations in multiple buildings grant a great opportunity to have a larger workforce and construct in different areas simultaneously. However, with that practice it is much more difficult to track all of the different activities going on across the site, and keep an accurate record of work as it is completed. It becomes a challenge to track all of these operations while ensuring that they are proceeding in a safe and proper manner.

The schedule of the project also requires the incorporation of work conducted by foreign artisans. It is an essential part of keeping the schedule accurate, but can be challenging to do because they have a limited workforce and have operations in nearly every building. The foreign artisans typically conduct work such as installation of lead sheet metal roofing, installation of exterior and interior stone panels, detailed finishing work on the interior, and installation of ornamental trim. Much of this work ties into the operations of other subcontractors, so incorporation of their work is important to keep to the schedule. An accurate way of tracking the workforce would be a powerful tool to use when updating and monitoring the schedule and when incorporating the work done by foreign artisans.

Potential Solutions

There are many different techniques that can be used to accurately manage and track the work force on the project. These options will be researched and analyzed for the effectiveness and applicability to this project. This data will then be used to develop a Workforce Management Plan that be used on projects with diverse and extensive workforces. Ideally this plan will be used to alleviate the challenges with managing the workforce in these scenarios. Activities can be better planned for and better sequenced

Analysis Methodology

- Research Potential Opportunities of Workforce Management
- Incorporate Data from Analysis 1 and Analysis 2 into Workforce Management
- Utilize Knowledge Gained through MAE Studies
 - Specifically AE 570: Production Management
- Gather Data on Activities
- Create a Workforce Management Plan
 - Include an Example of Results that Could be received with Use of this System

Expected Outcome

A management program will be developed to accurately track and monitor the workforce throughout the project.

Analysis 4: Foreign Artisan Safety

Problem

According to contract, much of the interior and exterior finishing work must be completed by foreign artisans. This is done to preserve the architectural and cultural integrity of the design and integrate the culture into the construction process. The purpose of this is very understandable as the entire complex is dedicated to cultural and communal growth and organization. However, it does present some challenges and potential difficulties with the typical work practices of the foreign artisans. These artisans do not follow the same codes, laws, or general procedures in their country as are followed in the United States. It is a safety concern to protect the artisans by ensuring they understand safe working practices used here and typical warning and hazard scenarios and signs that are used here. It is also a code concern because OSHA can fine the project if the foreign artisans are not following construction laws.

Background Research

On the project, Balfour Beatty brought foreign artisans through safety training before they were allowed on site. This involved briefings with safety personnel, facilitated with a translator because of a language barrier. This was necessary because the worker's host country does not have the same rules and regulations on construction that are placed here in the United States, specifically OSHA, which is an American organization, one that is not found throughout the world. When the workers are here in the US, they must follow all of OSHA's regulations, potentially requiring some changes in their work behaviors, or else the project could be fined.

Furthermore, they do not have the same work practices that we have here. In the US, the schedule is the driving force of the project, but in the host country that is not so. In addition, shop drawings are used extensively in the US for coordination and planning purposes. It is essential to communicate these to the entire team so that other subcontractors can utilize them in their own design and planning. However, in the foreign country, shop drawings are not used frequently or do not have the level of detail that is typical here in the US. This is an actual issue on the project because information on the foreign artisan work is not readily available. Other subcontractors need this information in order to plan their work accordingly. For example, the foreign artisans are to install lead sheet metal roofing on several of the buildings. There is a lack of shop drawings and detailed information on how the sheets are attached, the spacing between them, and other data that would be useful to the other subcontractors working in that area.

There is also a cultural difference between the foreign country and the US that results in differences in holidays, particularly due to the religion of the foreign country, Islam. The Islamic religion includes various holidays that are not federally recognized within the US. However, some of these holidays are very strictly practiced due to the devotion and belief of the Muslim community. These holidays need to be considered within the schedule of the project and also with a concern of safety for the foreign

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artisans. For example, Ramadan, is a holiday that requires Muslims to fast for an entire month, eating and drinking only before sunrise and after sunset. This is a very physically, emotionally, intellectually, and spiritually demanding holiday. It is a very important holiday within the Islamic religion and so considerations should be made for it within the project schedule. During this holiday, foreign artisans will be more prone to injury and illness, particularly because it typically falls during the summer. Safety considerations need to be made so that the artisans are not placed in dangerous situations because they are physically weaker due to the challenge they are placing on their mind, spirit, and body.

Potential Solutions

A general Foreign Worker Safety Action Plan will be created that can be applied to different projects, without regard to the nationality of the workers. This will be used as a guideline to develop a Site Specific Foreign Worker Safety Action Plan that will plan and prepare for the foreign artisans on this project. This detailed plan will address concerns of schedule tracking and incorporation, daily work planning, safe practice monitoring and teaching, and pre-construction preparation. Cultural and religious considerations will be included that they can be made a part of the schedule.

Analysis Methodology

- Further Interviews with Balfour Beatty Project Team
 - Considerations and Preparations Made for Foreign Artisans
- Interview with PSU Graduate Student Pelin Gultekin
 - Discuss Differences Between US and Foreign Country
 - Customs, Beliefs, Ideas, Work Practices
- Research Case Studies of Construction Projects that Included Foreign Workers
- Continue Background Research on the Foreign Country
- Research Work Practices of Other Countries and How They Differ from the US
- Develop a General Foreign Worker Safety Action Plan
- Develop a Site Specific Foreign Worker Safety Action Plan for this project

Expected Outcome

Two Foreign Worker Safety Action Plans will be created in the process of this depth analysis: a general one and a site specific one. The general plan will include information and consideration that can be used on any site with any nationality of foreign worker. The site specific plan will include the details and requirements necessary for this project specifically. It will address the foreign artisans, their work, and specific building hazard conditions. In addition, this analysis will provide a further knowledge and understanding of the foreign culture and religion and how it should be considered within the schedule and completion of the project.

Breadth Opportunities and MAE Requirements

Breadth Opportunities

Structural Breadths

The requirement to conduct a structural breadth is present in Analysis 1: Structural Redesign and Analysis 2: Restructure of Concrete Bid Package. In Analysis 1, a structural analysis is necessary to size the CIP concrete structure that will be replacing the steel structure. This information will be needed to conduct a proper cost and savings analysis to determine the implications of this redesign. It will also be needed to properly include this addition of concrete work into Analysis 2 and Analysis 3: Workforce Management. Due to the size of the buildings, a bay representative of the building will be designed and then extrapolated to represent the entire building. This will keep the scope of the design to a manageable level. Computer and hand calculations will be conducted. Deliverables will include a description of the new system, a comprehensive list of calculations and sizings, and a scaled image to visually represent the new system. A structural examination may be needed in Analysis 2 to determine how the work on site can be divided into separate bid packages. Of particular concern is the meeting point of the Turkish Bath and the Parking Garage due to the difference in elevation and the effects of construction surcharge loads. It is necessary to see where a division in work can occur while keeping the structural integrity intact, thus requiring a structural breadth. Knowledge gained from the redesign in Breadth 1 will be used to help analyze the structures of these buildings. Computer and hand calculations will be conducted as necessary. Deliverables will include calculations, proposed divisions, and assumptions made for the structures.

Architectural Breadth

The opportunity to complete an architectural breadth is present in Analysis 1: Structural Redesign. Not only will the structure of the Fellowship Hall and Convent/Monastery be changed, but also the façade. There is potential to alter the exterior construction of these buildings to more closely match that of the other buildings on the campus. An architectural breadth is needed to visually observe the change in appearance. This may require research into cultural design of the foreign country as well as the development of a Revit model. The model will be used to compare the designed facade to the original facade, visually showing changes in architectural features, elevations, and any other modifications. Floor plans may also be affected by the new design and these will be compared to review changes in area. Deliverables will include descriptions of the changes and various images comparing the original and new facades by using the Revit model.

MAE Requirements

Knowledge gained through the Integrated Master's Program will be incorporated into these analyses whenever possible. In particular, AE 570: Production Management will be of use. In the depth in Analysis 3: Workforce Management, various tools from AE 570 will be utilized to manage and track the work force. Additional tools will also be used to monitor productivity and crew level functionality, and will be given as examples within the plan developed in this analysis. Potential recommendations for managing productivity include space planning, last planner, capacity planning, and short interval production scheduling. The efficiency, effectiveness, productivity, and production of the workforce can be monitored and measured using interviews, questionnaires, time studies, and other means. It is expected that this information will be integral in creating a well-constructed plan to managing the diverse workforce on the project.

