# TECHNICAL REPORT III

A Campus Project
Northeastern US

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# Table of Contents

## Executive Summary

This Campus Project, located in the northeastern 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.

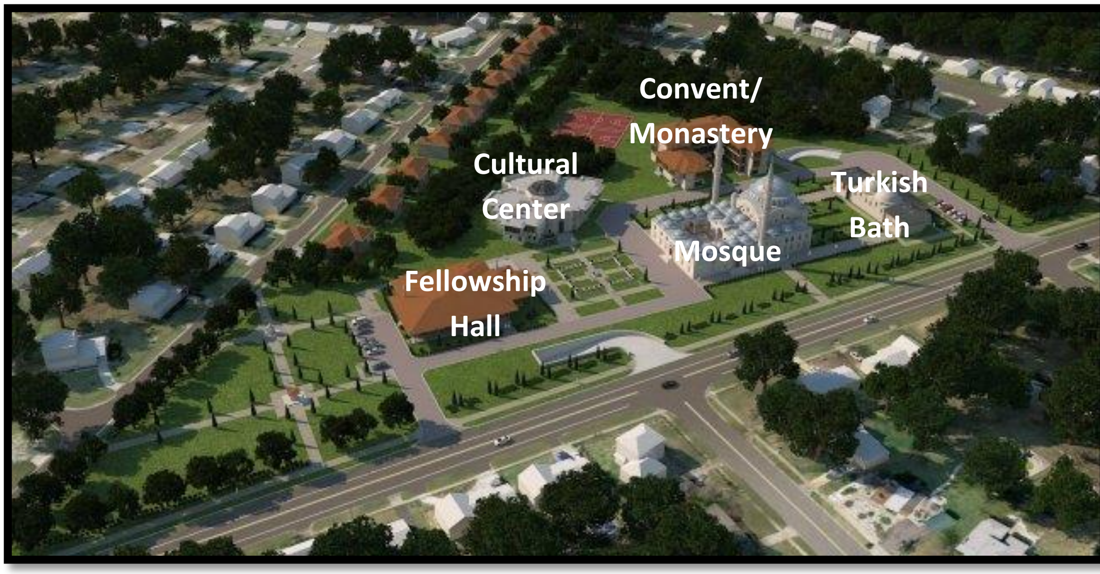


**Figure 1**. *Overall Site (courtesy of Balfour Beatty)*

This report will present information garnered through conversations and interviews with project staff on the project and industry personnel at the PACE Roundtable. Through interviews with the project staff, it was determined that the critical path of the schedule follows the Turkish Bath, Mosque, Fellowship Hall, and Hardscape/Landscape. Opportunities to accelerate the schedule are not pre-included within the schedule, but are considered as needed. These primarily take the form of overtime pay. Major issues facing the schedule include constructability issues and inclusion of foreign artisan work within the schedule.

In addition, several value engineering approaches were conducted on the project. These primarily focused upon mechanical and electrical issues, where major cost savings could be employed. The sessions observed at the PACE Roundtable were Prevention through Design and Multi-Trade Prefabrication. These discussed how safety analysis can be employed in the design phase and how prefabrication gives advantages and disadvantages to the construction process.

Lastly, time was spent with Ed Gannon, Manager of Design Services at Penn State's Office of the Physical Plant, to discuss research opportunities formulated from the attended sessions. This resulted in recommendations on safety topics, precast concrete panels, and industry contacts to assist with further research and information.

## Schedule Acceleration Scenarios

This Campus Project is unique in relation to the critical path because there is not one building for the path to follow. Since there are five different buildings, plus an underground Parking Garage, it is natural for the critical path to move from building to building. Although it is focused in a few of the buildings and tasks, that is typically the case. This presents both positive and negative aspects to schedule monitoring. Having multiple buildings grants the opportunity to work in different areas and utilize subcontractors almost constantly. There will typically be some work in at least one of the buildings available to subcontractors. It also creates more space for larger crews and more men to be on site. Subcontractors can employ more workers in order to operate in more locations throughout the site.

On the other hand, multiple buildings can be a negative situation because it requires close supervision by the management staff. Coordination of trades is essential in order to have a good crew flow throughout the site. It is imperative to plan and track work in order to ensure that each subcontractor will have enough work available for the crew they have. For example, if subcontractor A falls behind in their work, and is unable to complete it on time before subcontractor B is supposed to move into their area, then subcontractor B will be idle or will have to find a different area to work until subcontractor A finishes. This can create issues with congestion of subcontractors on top of each other or even further disruption to the schedule and other subcontractors. Therefore, it is very important for the project team to monitor subcontractor progress and stay on top of the schedule.

In addition, having multiple buildings can be unhelpful for subcontractors that have a small workforce. Where large subcontractors with a large manpower will thrive because of the opportunity to work in many areas and buildings, small subcontractors will be hard pressed to complete their work because they do not have the sufficient number of men. A small subcontractor may be able to work in only one or two buildings, where as a large subcontractor may be able to work in all of them. In order to match these different work speeds, it may be necessary to hire multiple subcontractors within the same discipline so together they can handle the work load, or carefully sequence work so the larger, faster subcontractors are not slowed down by the smaller subcontractors. Fortunately, all of the subcontractors hired to the job have been able to adequately handle the workload that is presented to them. However, these considerations need to be made when faced with projects where there are multiple buildings, such as this Campus Project.

As stated previously the critical path of the project is mainly focused in a few buildings and areas. It follows initial site establishment, the Turkish Bath, the Mosque, the Fellowship Hall, and Hardscaping/Landscaping. A flow chart of the path with examples of construction items can be seen on the following page in **Figure 2**. Site establishment, such as, construction fencing and roads, signage, and temporary facilities, are essential to complete before further construction can begin. From there the critical path moves to the Turkish Bath. Excavation, foundations, substructure and superstructure, and roof assembly control the sequence and speed of construction. Excavation and foundations are of particular importance because they are lower in elevation than is typical for the rest of the site. Delays in these tasks will influence the entire project because it will also delay construction of the Parking Garage.

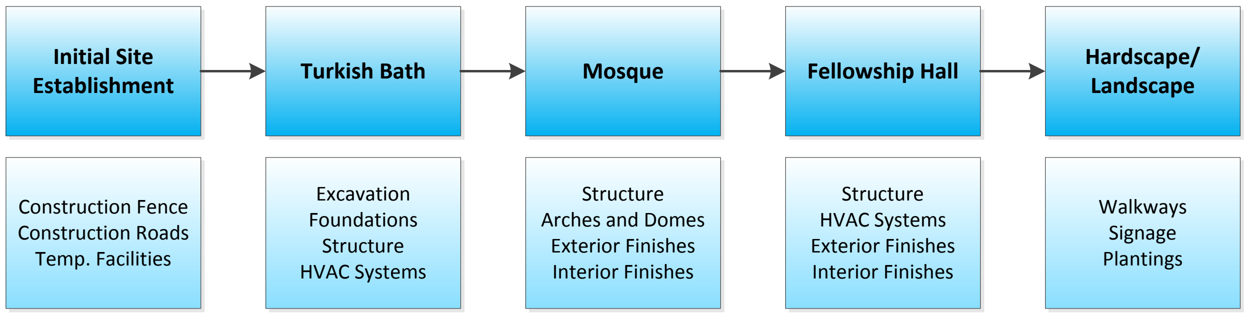


**Figure 2.** *Critical Path of Project*

A major item of risk in this situation is the retaining wall between the underground pool and the end of the garage. This issue was addressed in the Constructability Concerns of Tech Report II. Basically, the timeline of when the wall could be poured was of concern due to the pressures that would be created by construction of the pool and the end of the garage. There was concern that the wall could rotate if construction was not sequenced properly. Ultimately, backfill was temporarily used in the pool area in order to provide the necessary load required to counteract loads created by construction of the garage. This resulted in an actual schedule delay to the project that was ultimately made up later. However, it brings to light that excavation at this depth can be very influential because of the consideration for the difference in soil pressures.

Continuing from the structure, the critical path mainly follows the installation of HVAC piping and equipment. This is probably due to the fact that domestic water for the site is connected to the Turkish Bath first. Other items that are along the critical path are interior and exterior finishes, such as, painting of walls, installation of flooring and ceiling grids, placement of athletic equipment and door frames, and assembly of roof domes and skylights.

Because construction takes place concurrently, the critical path moves back and forth between the Mosque and the Turkish Bath. In the Mosque, the items that are most important are structural columns and deck for the ground and mezzanine levels, various domes and arches throughout the building, and interior and exterior stone finishes. Interior finishes cannot begin until the exterior finishes are completed. This is because exterior finishes are essential to keeping the building waterproof. Typically this may be accomplished by enclosure work of some sort and then additional finishes would be done on the exterior as needed. However, the stone finishes of the Mosque are part of this enclosure and are required to be completed before interior finishes can begin. In addition, all of these finishes must be completed by foreign artisans, requiring additional time and consideration for their work time. Incorporation of the schedule of work by foreign artisans will be addressed later.

A challenging issue within the Mosque is construction of the structural elements. As described in Tech Report I, the Mosque is almost entirely formed of cast-in-place concrete, and the structure is typically columns, arches, and domes intersecting in unusual or atypical shapes. Because of these unique intersections, it can create tight and challenging spaces that are difficult to complete work in a productive manner. It also creates situations where formwork and rebar can be difficult to erect. Fortunately, Facchina, the concrete subcontractor, is very experienced at producing unusual and difficult concrete shapes. They have a huge availability of supplies for the project. For example, they have over 50,000 SF of flying formwork in order to handle the massive amount of cast-in-place concrete, as seen in **Figure 3** to the right.

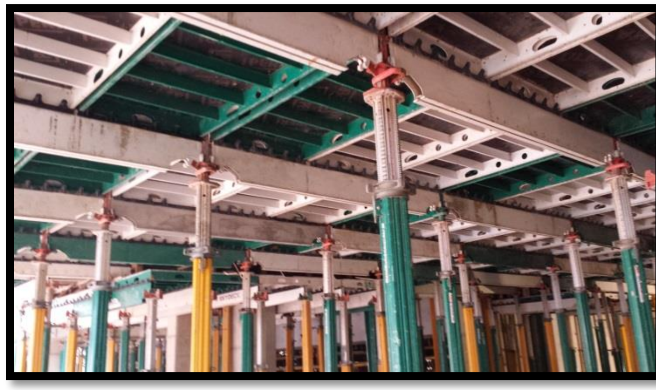

**Figure 3.** *Table or Flying Formwork on the Project*

Also, they are very adept at creating unusual formwork and finding solutions to concrete issues. They built their own screed to smooth the outer surface of the domes of the Mosque, as explained in the Constructability Concerns of Tech Report II. They also hand made the forms required to erect the two minarets, which change shape and taper as they increase in height. Furthermore, it is essential for Facchina to remain on schedule. Cast-in-place concrete has a part in at least every building, and some buildings are entirely structured in this manner. Therefore, if Facchina is pushed behind schedule, it will in turn delay almost every other facet of the job.

After the Turkish Bath and the Mosque, the critical path transfers to the Fellowship Hall. The structure, both steel and CMU, HVAC and plumbing piping and equipment, and interior finishes are all critical tasks. Interior finishes such as installation of marble floors and ceiling grids take the most time and will be important to keep on schedule. Primarily of concern, is that Hardscaping and Landscaping of the project cannot begin until the Fellowship Hall is completed. That work is planned to begin from that area and then travel across the site. Walkway pavers, sidewalks, fountains, signage, and planting of trees and shrubs are all critical and finishing tasks to the project. Hardscaping and Landscaping tasks are the final activities within the critical path, leading to completion of the project.

An additional overall scheduling risk to the entire project is incorporation of foreign artisans into the schedule. A majority of the interior and exterior finishes throughout the buildings must be completed by these artisans, giving them a fairly consistent work load. Some of their work is on the critical path while some of it is not. However, all of it is fairly related to the work conducted by other subcontractors, and any delays in the artisan's process can have negative impacts on others. Near the beginning of the project, the artisans provided durations for their activities and scope of work. Since then they have given periodic updates and details as requested. This information is used to incorporate the artisan work into the project schedule. In this way, the project team can better coordinate and plan for this work to occur. As was explained in the case of smaller subcontractors, the artisans may not have a large enough workforce to work in all of the buildings simultaneously, since they are traveling to the US from a foreign country. Instead they will have to move from building to building, according to the schedule they have laid out. If there are issues or complications with their schedule, this can impact the schedule of the project.

In the event that an issue arises and there are delays, the schedule needs to be accelerated to get back on track. Nothing is officially planned or included within the schedule, but weekly meetings are held to determine if there is a need to speed up the schedule. These meetings will compare actual work progress to the schedule in order to search for problem areas. Typically, accelerating the schedule would involve paying a subcontractor overtime to complete the work faster. In some situations, it can be difficult to determine which subcontractor should be paid the overtime. Paying one subcontractor may speed them up drastically, but have a very small impact on the overall schedule. Paying another subcontractor may speed them up just slightly, but have a stronger impact on the schedule overall. Choosing which subcontractor to pay overtime requires detailed research into the situation and careful measurement of the work completed and the work remaining.

## Value Engineering Topics

Balfour Beatty incorporated value engineering (VE) on the project during design and construction. Because they are operating on a GMP, they need to remain on budget. At times value engineering was utilized in order to keep materials and activities within their budget. To do this, less expensive but equal value options were chosen in place of more expensive options. This keeps the quality of work up to par with the specifications and keeps Balfour Beatty under budget so they can complete the project successfully.

During the design phase, value engineering is likely to have been done in conjunction with the designer, Fentress Architects. This is the best time in the process to explore opportunities for savings without sacrificing quality. Input from both the construction and design teams aids creative and unique thinking to develop potential solutions. Further in the process, during construction, subcontractors will have the majority of the input on value engineering. They have the experience and the knowledge to understand the different options available and to establish which would be better suited for the project and budget. On this Campus Project, the mechanical and electrical subcontractors were brought on very early in order to assist with value engineering options. The equipment and supplies for these divisions usually come with a long-lead time, making it important to get their input early on in the design process.

In order to ensure that any potential changes will meet the owner's desires and expectations, the owner always has the final say on each value engineering option. After thoroughly analyzing and researching each VE option, it is formally prepared and presented to the owner. Comparing the available options, the owner can decide which item they would like to pursue. At times, they will choose the cheaper option because it does not sacrifice their vision for the final product. Other times they will choose the original, more expensive option because it sticks with the owner's original vision for the project. If the owner chooses the more expensive option, then they typically pay Balfour Beatty the difference in cost with the project allowance.

The overall value engineering process is a very collaborative example of good teamwork. The construction manager, Balfour Beatty, the designer, Fentress Architects, the subcontractors, and the owner all work together to find VE possibilities and to ensure they follow the standard of quality expected. Bringing the owner into the discussion ensures that they understand what they are purchasing, and gives them a chance to clarify the quality and specifications required on the job. Typically, the owner is very on board with VE options because they are aware of the budget constraints caused by the GMP contract.

There are several items that were value engineered into the project. One of the largest savings was garnered by replacing expensive spider glass curtain wall system with a simple butt glazed system. Images of these systems can be seen in **Figure 4** below. This decision ultimately saved several hundred thousand dollars. Although the owner still wanted the spider glass system, it was well outside the budget and they accepted the use of a butt glazed system to save money.

*Spider Glass Curtain Wall* *Butt Glazed Curtain Wall*

**Figure 4.** *VE of Curtain Wall Systems*

Other implementations of VE can be broken down into two categories: mechanical and electrical. Since these subcontractors were brought on early, they were able to provide many major opportunities that were implemented. On the mechanical side, PVC pipe was used instead of Cast-Iron pipe. This resulted in a savings of several hundred thousand dollars in both material and labor costs. On the electrical side, aluminum feeders were used instead of copper feeders because of the decrease in cost. Also, for in-slab conduit, PVC coated conduit was used instead of regular coated conduit. These options resulted in cost savings without compromising the quality of the project.

On the other hand, there were many cases where VE options were proposed, but not chosen. Again, on the mechanical side, upsizing air handling units and removing the radiant floor heating in the Turkish Bath and the Mosque would have saved a considerable amount of money. However, the owner chose to keep the radiant floor heating because it was there to create a spiritually and culturally cleansing atmosphere. Deletion of the glycol cooling system used throughout the project would have saved money, but it was kept because of the advantages and longevity it brought to the mechanical systems. In the generator room, free standing fuel tanks would have been cheaper than the underground storage system planned, but the original system was kept.

On the electrical side, the lighting in the Parking Garage was the main debate. By design, LED lights were used to illuminate the interior of the garage. LED lights have a rather high up front cost, but this comes with a low maintenance cost, low operating cost, and a very long lifetime. It was proposed to replace them with halogen lamps, which are inexpensive but have a shorter lifetime, requiring more maintenance. In the long term, the cost of either system would probably have been approximately equal. However, the owner decided to stick with the LED lighting system in order to show an example of their embrace of new and advancing technologies.

## Critical Industry Issues

The PACE Roundtable is a daylong event meant to give students the opportunity to meet with and learn from professionals throughout the industry. Several sessions are offered, giving variance for the student to choose based upon his or her project demands. The two sessions attended were Prevention through Design and Multi-Trade Prefabrication.

### Session 1: Prevention through Design

The first attended session was Prevention through Design. It explored the possibility of incorporating safe practices, designs, and methodologies into the actual design process. Typically, safety really only becomes a major concern during construction, whenever unsafe conditions and practices are readily seen. It can be very difficult to visualize a concept or design mentally and analyze it for safety conditions. Nevertheless, incorporating safety early on can benefit the team later during construction by elimination of unsafe design conditions or by incorporation of safety features into the design. These could include the addition of tie off points connected to the structure or the removal of pinch points.

An integrated project team is necessary in order to create the culture of safety necessary to promote safe design. Usually, the designer is not going to consider safety as a main part of their responsibilities. Also, they may not have an adequate knowledge of safety concerns in order to properly analyze the design for unsafe conditions. This is where the entire team aspect comes into play. All players (owner, contractors, construction manager, designers) should collaborate actively in order to promote and establish safety in all aspects of the project. The owner can both contractually require the designer to engage in design safety checks and encourage the designer to actively participate in design reviews. The contractors and construction managers can bring their experience and knowledge on safety from the construction site into the design room.

Not only should safety during construction be considered during this process, but safety during occupancy and use should also be considered. In particular, safety for maintenance personal is key. For example, it is much easier and safer for maintenance personnel to repair a valve at chest height than at 10 feet above the ground on a ladder. In order to ensure this requirement is being met, maintenance personnel can be brought into the discussion at an early stage as well. They can give insight into the design that may not be apparent by the rest of the project team.

Overall, this meeting was quite interesting in its analysis of a design team's typical perception of safety. Since it is difficult to recognize how the design can impact safety in the field, the designer may not understand their role in promoting and establishing safety on the project. Therefore, it is the responsibility of the other team members to assist them and show them that it is possible to incorporate safety elements into the design. This process is not a simple or common one, however, it is growing in popularity, much like how BIM slowly grew in use. In order to keep this culture of safety growing, it is up to new generations and workers to keep pushing for new practices that constantly incorporate and promote safety.

For this Campus Project, this topic presents the possibility of analyzing the difference in design methods between Turkey and the US. Since the design was initially created in Turkey and then brought to the US to reach code level, there will naturally be some differences that may be deemed unsafe. Incorporating safety analysis into design could catch many of these issues before they reach the construction phase. In addition, it is worth analyzing different working practices between Turkish and American workers. It is not uncommon for construction practices in different countries to be vastly different from one another. This is a matter of culture, not because one country has better practices than the other. However, on US soil, Turkish workers will be responsible for following all laws pertaining to construction here. Since they may not know or follow many of these laws, it could be challenging for Balfour Beatty to teach these workers the US working procedures and practices. Any breach in these laws could result in a violation and a fine to Balfour Beatty.

### Session 2: Multi-Trade Prefabrication

The second attended session was Multi-Trade Prefabrication. This session explored the advantages and disadvantages of using prefabrication on a project. In particular, it delved into the requirements and challenges associated with fabricating, transporting, and installing modules.

Prefabrication of elements can be done either on-site or off-site. On-site fabrication allows construction of larger modules without consideration of transportation requirements. It also makes for easier logistical and installation planning. On a negative side, on-site fabrication is not typically as precise or controlled as off-site fabrication. Also, useful space on site is taken up by the fabrication area. Construction sites with limited space, such as in a city, are not recommended for on-site fabrication. Off-site fabrication grants a very controlled and accessible environment to produce the elements, typically at a higher quality. This higher quality of product naturally comes from the more controlled environment it is built in. More space is also available off-site so more elements can be prepared before being brought to the site and put into place. On the other hand, transportation costs and restrictions must be considered when fabricating off-site. All of these factors should be considered when choosing where to fabricate the elements.

There are a limited number of transportation methods available for large prefabricated pieces. They can be shipped by truck, rail, boat, or air lifted. The most common and typical method will be by truck. The cost of transporting modules is not very expensive. Of greater concern are the restrictions placed upon the size and weight of the module based upon the transportation method. For trucking, bridge heights and capacities, roadway slopes and turn radiuses, and state size limitations all need to be considered when planning the transportation route and the size of the module. Another potential issue arises if a truck transporting a completed module gets into an accident and the module becomes damaged or destroyed. In this situation, it is difficult to determine who is liable for the damages. Typically the transportation agency would be responsible for ensuring safe delivery of each module. However, it is possible that one or more subcontractors could hold some responsibility for the module before it is delivered.

Additional requirements for prefabrication involve multiple inspections by governing agencies. Usually these inspections will take place both in the prefabrication factory and on-site. Sometimes a third party can be authorized to perform the inspections, but often times the governing agency prefers to conduct them themselves. These inspections take time and are required.

Coordination of each subcontractor is also very important. This is useful to keep the schedule on track and to make sure that work is being conducted efficiently. It is imperative to use when managing the different design and construction tolerances used by each trade. As modules are installed in place, these tolerances will add up and gradually shift the modules out of position. It can be a good practice for subcontractors to leave some leeway when fabricating the modules so that they can be adjusted later into their final positions.

This meeting was interesting in its analysis of subcontractor interaction required to perform prefabrication. Coordinating the different subcontractors is necessary to ensure good collaboration and a sequenced schedule. At times this can require working with unions in order to negotiate working contracts. Unions can sometimes be watchful of prefabrication factories because, understandably, they want to ensure that their specific scope is protected during construction.

For this Campus Project, this presents the idea of using precast concrete panels throughout the site. Across the entire site, cast-in-place concrete is used almost exclusively as a structural element. It would be interesting to examine how replacing CIP concrete with precast panels would affect the schedule and the cost of the project. The most obvious benefit to using precast panels would be improvement to the schedule. Cost benefits could also be possible but may not yield drastic results. An example of precast panels can be seen in **Figure 5** below.

**Figure 5.** *Precast Concrete Panels*
*Courtesy of Nexus*

## Feedback from Industry Roundtable

During the PACE roundtable, time was available to speak with an industry professional about the details of this project and request advice. It is difficult to present an entire project and its details within 10 minutes but some useful information was garnered during this session. Ed Gannon, Manager of Design Services at Penn State's Office of the Physical Plant, offered his time and insight into the project.

On the topic of safety, building a culture of safety is essential to bringing safety into every aspect of the project. It is the responsibility of the project team to bring safety concerns into the design and construction efforts. So long as it is actively promoted, safety will become an integral part of daily activity and will be a part of every worker's routine. Sometimes it can be difficult to weigh the cost of safe practice against the benefit of having a safe job site. Specifically it can be difficult to know how dangerous an activity is or how much effort needs to go into making a practice safe. This can make it difficult to justify to the owner any expenditures that are specifically going towards safety. However, human lives are invaluable and regardless of the cost, having a safe job site is always a priority. This idea needs to be stressed to the owner so that they can further press it on the other team members.

Specifically related to this Campus Project, the working practices of foreign workers can be vastly different from working practices in the US. These are built out of a cultural element, and are simply the way these workers are used to completing their work. However, when in the US, they are required to follow all work safety laws and regulations that US workers must follow. Therefore, it is important to provide training to foreign workers so that they understand their roles and responsibilities. Additional monitoring may be required in order to ensure that they follow through with safe practice.

On the topic of precast concrete panels, one of the biggest gains to utilizing precast panels is an increase in available site space. Cast-in-place concrete requires space for staging areas, laydown areas, mixing plants, and other areas dedicated to holding the materials and equipment needed for CIP concrete. Precast panels simply require space for delivery, potential layout, and crane utilization. These panels are clearly a huge benefit to the site in the essence of creating open space for other use. Since site restrictions are not a large concern on this project, this topic will have to be explored for other benefits such as schedule or cost decrease.

Many different contacts will serve as great resources in the future. These are listed below:

- Balfour Beatty Safety Coordinator: Don Head
- Concrete Subcontractor: Facchina
- Balfour Beatty Project Team
- Southland, Safety in Design: Andy Rhoades
- Prefabrication: John Messner & Ray Sowers

# Appendix A: Notes from PACE Roundtable