Technical Report 3

The Center for Sustainable Landscapes for The Phipps Conservatory and Botanical Gardens – Pittsburgh, PA

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Construction Option

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Penn State AE Senior Thesis

Executive Summary

Technical Assignment 3 critically analyzes and evaluates the Center for Sustainable Landscapes project's execution and alternative methods for construction. This report identifies problematic and non-problematic aspects of construction and investigates their potential for research, schedule compression, and value engineering. It also explores opportunities for the implementation of alternative construction practices, and evaluates their candidacy for additional analysis.

The top three unique constructability challenges are explained within this analysis. These issues include: the coordination and construction of the 3-story cast-in-place atrium stair, the sustainable submittal process, and the increasing amount of onsite congestion. The coordination and constructability issues to the atrium stair were resolved by issuing a change order to redesign and remove the stair construction from the critical path. The sustainable submittal process is significantly more time intensive than a traditional projects submittal process but can be more easily managed with additional staffing. Onsite congestion is creating additional need for coordination amongst subcontractor trades and is being resolved by planning and scheduling.

The project's critical path schedule exposed potential for compression, and the biggest risks to the project's completion. Some of the acceleration scenarios include construction of a temporary façade, use of an electronic submittal process, as well as traditional acceleration techniques, such as working overtime and increasing crew size. The largest risks to the project schedule are weather and manpower.

An analysis of the value engineering techniques implemented on this project revealed that few changes were made to the original design. This was largely due to the owner not wanting to risk increased life cycle costs for marginally lowering construction costs.

This report concludes with a summary of critical industry issues discussed at the sessions attended during the Partnership for Achieving Construction Excellence (PACE) conference, and an analysis of the specific problems and how each can be resolved and measured. The critical industry issues discussed pertain to assembling an integrated construction team and the field implementation of BIM technologies. The problem identification and analysis section will provide a basis for further research and development of a thesis proposal.

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Constructability Challenges

<u>Issue 1:</u> Atrium Stair

The construction of the Center for Sustainable Landscapes has and continues to present a multitude of challenges to the Turner construction team. The first significant challenge faced by the team was the scheduling and coordination required to construct the large atrium. The atrium space is unique in that it is designed to be passively heated and cooled. As a result, large amounts of cast-in-place concrete were specified to increase the amount of thermal mass in the space. The design requires the construction of a large three story concrete staircase reaching from the ground floor to the third floor. Although the construction of cast-in-place stairs is not unheard of, it is uncommon and generally avoided because of its increased cost and negative schedule impacts. Construction for the stairs is highly labor intensive and requires a large amount of temporary shoring. Further complicating construction, the stairs are cantilevered off a 40’ 4” cast-in-place column located in the center of the atrium. Given this design, in order to properly reinforce the stairs their construction requires the simultaneous construction of the column, which also supported a portion of the atrium roof. Scheduling complications arose after the column construction was located on the critical path. It was determined that the completion of the steel superstructure and consequently the watertight milestone would be delayed if affirmative action was not taken. Figure 1 shows the location of the atrium stair in section, while Figure 2 shows the same stair in plan.

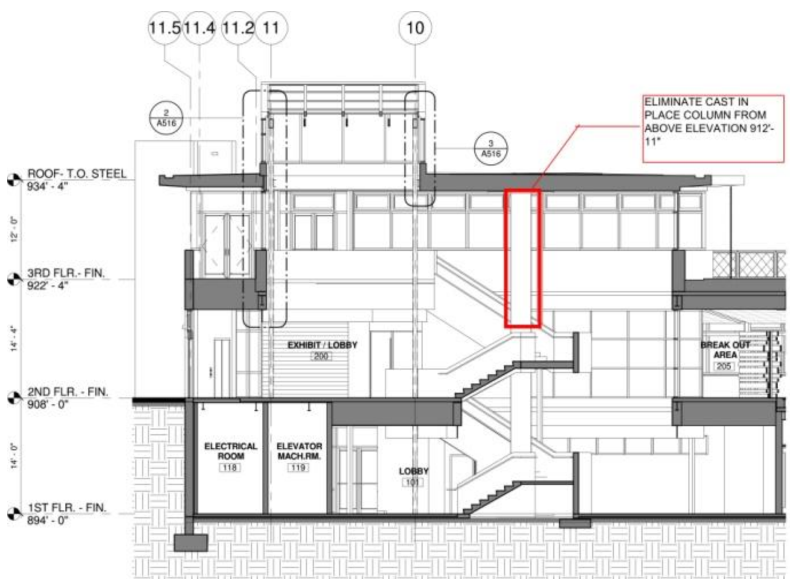

Figure 1 -The area outlined in red depicts the column

In order for the Turner team to remove the atrium stair construction from the project's critical path, the top portion of the column supporting the roof members was removed and the roof members were resized to span the entire atrium. Roof member sizes were increased from a W12x19 to a W12x40, and a W12x14 and W10x22 into one W12x45. The changes to the roof structure are shown in Figure 3.

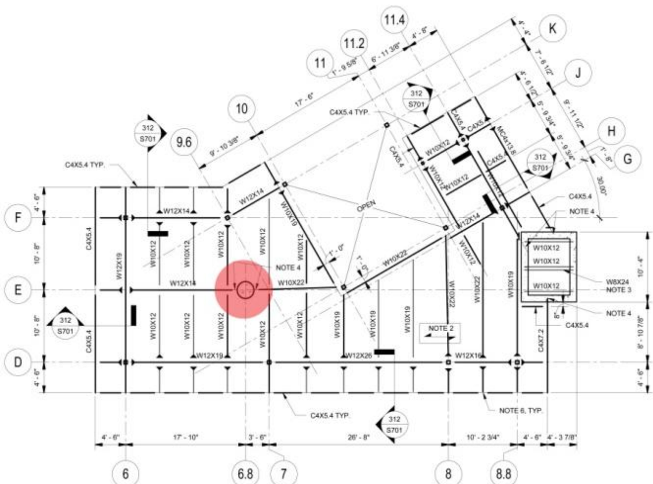

Figure 2 - Original roof framing plan. Area highlighted in red depicts removed column.

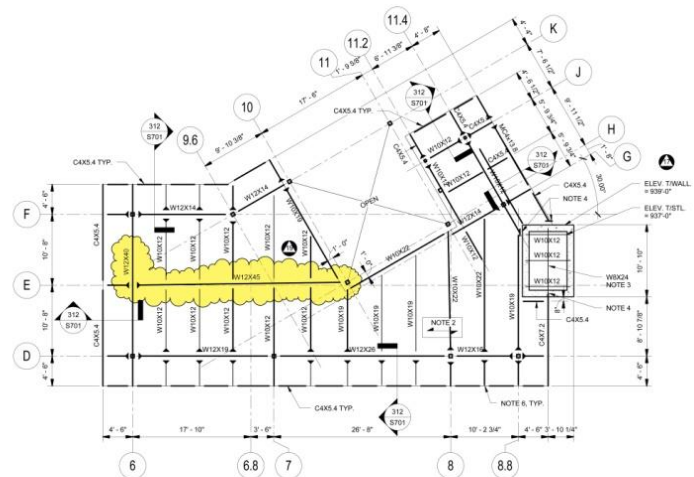

Figure 3 - Redesigned roof framing plan. Area highlighted in yellow depicts changes.

<u>Issue 2</u>: Submittal Process

The second significant challenge facing the Turner construction team is the issue of receiving, processing, and getting approval for the necessary product submittals and sustainable certifications prior to product installation. On all construction projects, prior to installation, all products and materials must go through the submittal process. For the Center for Sustainable Landscapes, this process has been significantly complicated by both the LEED and Living Building certifications. Getting the submittals approved prior to construction has proven to be challenging, particularly for the Living Building certification pilot project. New sustainability ratings are requiring an increasing about of product data that until recently has not been needed. As a result, additional time and resources must be invested by all members of the material supply chain in gathering the correct information to verify whether or not a product or material has been sustainably produced.

Throughout preconstruction and construction, the Turner team has maintained an aggressive approach to the submittal process. The most critical resource required to manage this process is time. Turner has mitigated this risk by having an adequately sized staff for the project. Currently, the job is staff consists of three full-time Turner employees of ranging experience levels. Up until this point, the team has been successful in avoiding any schedule delays with regards to material acquisition.

Issue 3: Site Congestion

The third significant but minor challenge being faced by the Turner team is the increasing amount of site congestion. As the project progresses, the amount of available space has been rapidly decreasing and has required an increasing amount of coordination. Although site congestion has only recently become a more significant problem, coordination of site work and site utilities has been an ongoing struggle. Depicted in Figure 4 is the phase 3 site plan for the nearly completed project. As indicated, the flow of site work will start in the northeast corner of the site and progress toward the southwest. Once the lagoon construction is complete, the building will only be accessible from the south side of the building. In addition to access, problems that also result from increased site congestion include losses in productivity and increases in safety hazards. Creating and sustaining a clean and safe working environment requires constant effort on this project.

The Turner team is managing this problem, largely on a weekly basis, with major construction events such as the lagoon construction, PV array installation, and other sizable site work tasks scheduled well in advance. Maintaining a safe and clean construction site is one of the team's priorities. Thus far, no significant accidents or congestion problems have resulted in a loss of time for any of the trades working onsite.

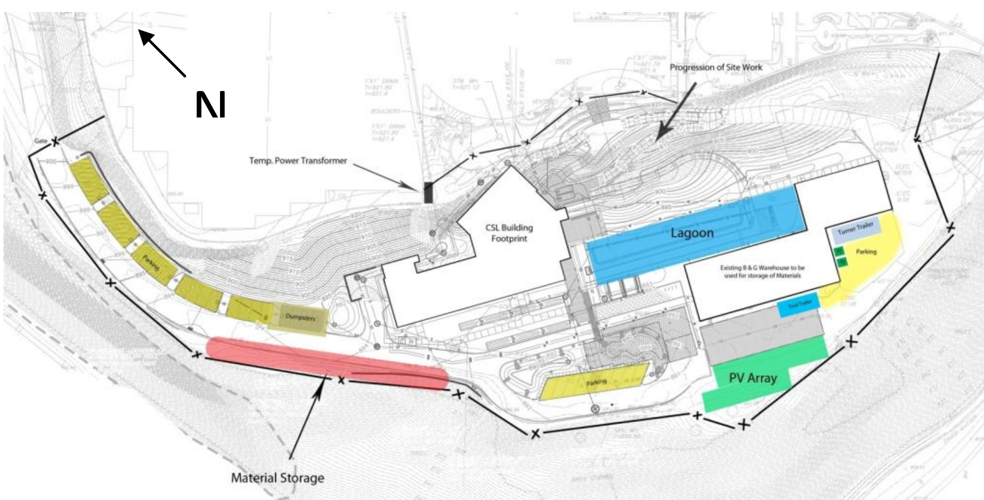

Figure 4 –Phase 3 site layout plan of temporary construction facilities, significant site features, and direction of site development.

Schedule Acceleration Scenarios

The critical path for the construction schedule of Center for Sustainable Landscapes begins with foundation excavation and continues through to the completion of the façade. Figure 5 illustrates the significant activities that reside on the critical path. Additional supplemental activities located along the critical path are not listed. Not expressed in the figure are the critical path are preconstruction subcontractor and supplier buy-outs.

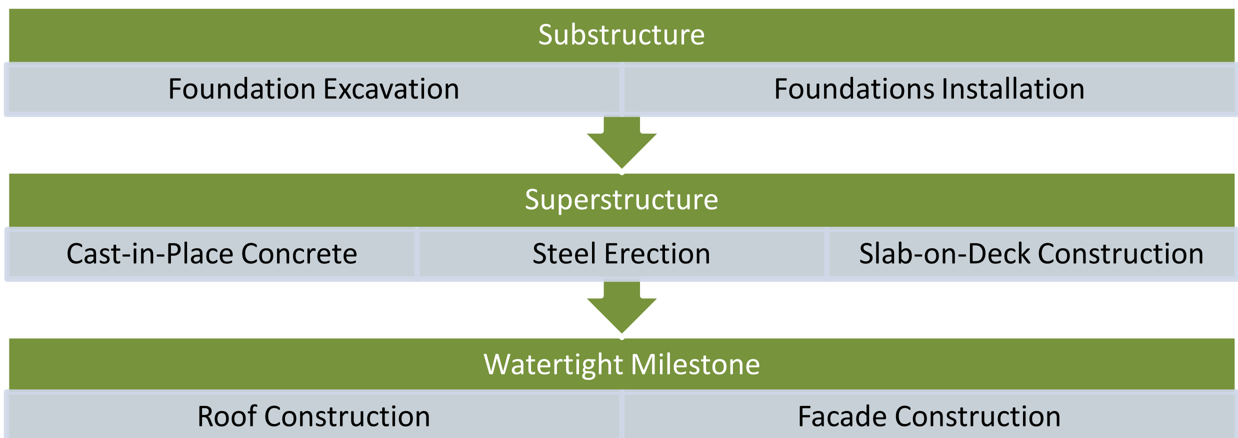

Figure 5 - Center for Sustainable Landscape's Critical Path Summary

An almost infinite amount of delays could occur that would alter the completion date for a given project. For the Center for Sustainable Landscapes, the biggest project specific risk that could potentially impact the critical path is weather. Although weather is not a particularly unique threat to construction schedules, it only has the potential to cause unforeseen delays. For this project, the only delays that have occurred are a result of consistently rainy weather occurring during substructure construction. These delays were only further amplified by the poor draining characteristics of the clayey soils located onsite. As a result, the project is still attempting to recover the time lost during construction in the spring of 2011. With the onset of winter of conditions, a large push to accelerate the schedule is necessary in order to get the building enclosed before added winter condition costs are incurred. Another significant risk faced by the Turner team is the variability of manpower. The quality and quantity of labor is changing constantly and primarily depends on the amount of work a subcontractor or supplier has. Thus, manpower is constantly questionable, varies on a daily basis and is constantly creating the potential for delays. Furthermore, on this project, a blend of union and non-union trades are employed, creating a potential for strikes, which could also significantly delay the project.

One of the major opportunities to accelerate this project’s schedule is the construction of a temporary façade to enable MEP and interior finish trades to complete their critical path activities at an earlier date. Construction of the temporary façade would be phased into the construction of the superstructure, allowing the watertight milestone to be achieved with the completion of the roof. In order to reduce the interruption to construction of the permanent façade, the temporary façade would be recessed from the exterior of the building far enough to allow the permanent façade to be constructed overtop of the temporary façade. An additional strategy for accelerating this project’s schedule during the preconstruction portion of the project is utilizing electronic media, specifically an electronic submittal system, to streamline the flow of information between all vested parties. When done correctly, this technique can eliminate the time and money wasted sending documents through the postal service.

Perhaps the most frequently used generic methods for accelerating the construction schedule is working overtime or increasing the crew size. These techniques, although used frequently, are generally avoided because of the added costs, but can be performed on nearly every activity on a schedule. No cost information for schedule acceleration has been made available by the construction team.

Value Engineering Topics

The Center for Sustainable Landscapes did not consider a large amount of value engineering alternatives as a result of the unique needs of both the building and the owner. Due to the highly sustainable and complex nature of the building's design, vestigial design elements that could normally be reconsidered for value engineering were not. Most importantly, the owner did not want to risk an increase in life cycle building cost, by only marginally reducing the cost of construction. As a result, few value engineering ideas were entertained and implemented.

The one key area that value engineering was implemented on this project was to increase the constructability of the passively designed atrium space. On the west perimeter of the atrium space is a large concrete encased spandrel beam designed to support a portion of the roof structure in addition to increasing the space's thermal mass. Located 28' off of the slab on grade, the construction of this spandrel beam would have increased the atrium's construction duration, and a required a large amount of temporary shoring to support the elevated formwork. As a more affordable alternative, the spandrel beam was redesigned to be a bulk head with a limestone plaster coat. Additional changes to the atrium space during construction included the removal of thermo radiant ceiling tiles, and the removal of an operable thermal blanket that covered the lantern portion of the atrium space (space located at the top of the atrium, highlighted in Figure 6). Both features where designed to reduce the heat loss from the space during the winter months but were not implemented due to the added cost (cost data not available).

The Phipps Conservatory, the project owner, did not want to detract from the Center for Sustainable Landscapes by making a large amount of changes to the original design during construction. The changes made to the atrium space largely only detracted from the project by reducing its performance but were accepted because of the constrained budget. The other changes to design that were considered involved material substitutions to reduce cost. It was ultimately discovered that material substitutions was particularly difficult to perform while still attempting to meet the sustainable goals for the project. Alternatively, when the construction team was forced to make material changes as a result of the specified material not meeting the sustainable criteria, material prices tended to increase.

Figure 6 - View of exterior from northeast site. Lantern outlined in red.

Critical Industry Issues

The Penn State Architectural Engineering's (AE) fall Partnership for Achieving Construction Excellence (PACE) roundtable was held November 9, 2011. This conference was attended by industry members, AE faculty members, and AE students. The conference discussed several practices being implemented in the current construction industry and was intended to stimulate research ideas for AE students working on their senior capstone project.

Assembling and procuring an integrated team

Break-out session one discussed the assembling and procuring of an integrated project team, and industry's perception of the barriers that are holding back its implementation. In the event an integrated project delivery (IPD) project is executed, team member selection is performed similarly to other projects where firms are chosen based on their ability to perform and compatibility with other team members. Firms entering into IPD contractual agreements should be aware of the open book nature and culture shift associated with this method of project delivery. Several obstacles exist in the industry that inhibit the development and execution of projects delivered via IPD. Obstacles confronted by the delivery method range from a host of minor and major issues concerning: financial, political, contractual, and legal aspects. The two most significant obstacles confronted by IPD are inexperience, and on publicly funded projects in Pennsylvania, the legality of having a firm contribute to a project's design and construction. Although contractual arrangements are available from the American Institute of Architects, implementation is rarely done due to the more favorable guaranteed maximum price (GMP) alternative where the owner does not assume risk. Largely, the major deterrent of IPD for the owner is generally a combination of their own inexperience in conjunction with the additional risk that they must assume.

It was found to be surprising that the industry had yet to find a formalized method for the implementation of IPD. Throughout the meeting, it was evident that a large amount of the knowledge on IPD was based on experience, but only revealed what is inhibiting this progressive delivery method rather than how its teams are created. Industry members ultimately agreed that a formal means of IPD implementation has not yet been widely accepted by the industry.

The Center for Sustainable Landscapes utilizes a traditional design-bid-build delivery method, implementing a more progressive delivery method may result in schedule and cost savings. An evaluation of the current delivery method will be performed and a selection of an alternative delivery system will be chosen. Alternative methods considered include: IPD, GMP, and CM at Risk. Additional investigation will be performed to determine what additional services would need to be provided by a CM Agency to offer an IPD service contract as a third party facilitator for the Center for Sustainable Landscapes project.

Strategies and Opportunities for taking BIM into the field

Break-out session two discussed current capabilities of the industry and assessed the strategies and opportunities for taking BIM into the construction field. Industry members discussed how their firms perceived BIM and how they each uniquely implemented it. It was recognized that as the capacity for BIM in the industry increased additional capabilities are being explored. One capability discussed was the ability to have a virtual model constructed to match the progress of the project and making its delivery more transparent, providing the owner the ability to access real time project specific information. In addition to the owner, real time information is valuable to all members of the project team. Streamlining the flow of information is problematic for the industry for two significant reasons: limitations to the technologies that deliver the information, and the accuracy and liability associated with inaccuracy of the information imbedded into the model. Industry practices suggested for onsite model use include: smart-boxes (job boxes that contain a computer and large monitor for viewing and extracting information in the model), and tablet PCs that allow the user to access the model at all times. It was ultimately concluded that both implementation practices had substantial drawbacks and should be evaluated on a per-use basis. Regardless, when using BIM its success is hinges on the project's needs and the metrics used to assess its success. Prior to using BIM, the questions that must always be asked are: Why is it needed? How can it be used? And what are the metrics that are going to be used to measure its success?

What was found to be the most surprising was the level of ignorance that the industry members that operate as owner's representatives possessed. Owner's inexperience with new technologies and recent construction technologies was suggested to be one of the largest obstacles that has yet to be overcome, raising the question, as to whether the owner has had the opportunity to be educated? What was not discussed but would have been interesting to consider was the ways that owners could be educated to help facilitate BIMs use.

The delivery of the Center for Sustainable Landscapes does not take advantage of any BIM technologies during construction. VERIFY Portions of design were performed in BIM related technologies but they were not shared due to contractual liability. The Center for Sustainable Landscapes is rich with technology and innovative design and possess a large amount of potential for the use of BIM. Investigation will be performed to expose the reasons why BIM was not utilized on this project, specifically during the construction portion of the project. Research will be performed considering the practical implementation of BIM into the installation of work exposing how it is done, and what is currently being developed.

A large amount of resources for information have been made available at the PACE roundtable including industry members, faculty, and graduate students. Initially, research will be invested in the development of a financial model, similar to what a developer would use to evaluate to financial feasibility of a project. Industry member Spencer Brott of Trammel Crow Company is a developer and expresses interest in helping in its creation. Additional resources will also be considered when quantifying the alternative progressive methods of project delivery as well as the larger scale application of BIM technology. For more general contemporary construction practice alterations, Bob Grottenthaler from Barton Malow will prove to be a valuable resource.

Problem Identification and Technical Analysis Options:

Problem Analysis 1: Project Delivery Method

In comparison to more progressive delivery methods, the current design-bid-build (DBB) project delivery method does not provide the Phipps Conservatory (owner) with the highest valued project. Under this traditional system, the project is contractually limited by: not facilitating the use of a shared BIM model between design and construction phases, owner bearing a high risk for schedule and cost growth, and providing no incentive for cost savings or collaboration. Several reasons external to the project can influence an owners decision or obligation to use this project delivery method some of which include owner inexperience, legislation, and project type. Due to the Center for Sustainable Landscapes being a partially publicly funded project, the decision to use DBB was largely governed by state legislation controlled by Pennsylvania's Department of General Services. Benefits to using a more progressive project delivery method are numerous but can be summarized in that they all offer services that increase project value.

To most appropriately analyze the use of DBB, research will be performed to determine all of the contributing factors for its selection in addition to why alternative delivery methods could not be used. A large part of this research will be focused on uncovering the loop-holes used to avoid this project delivery method on other publicly funded projects. Based on the results of this research, an alternative delivery method will be recommended. The metrics used to determine the successfulness of this analysis will be: feasibility, and potential schedule and cost benefits to using a different delivery method.

Problem Analysis 2: Constructability of Atrium Stair

As previously discussed in the *Constructability Challenges* section of this technical report, the cast-in-place stair located in the atrium space has complicated coordination and construction of the atrium. The atrium space is unique in that it is designed to be passively heated and cooled. As a result, large amounts of cast-in-place concrete were specified to increase the amount of thermal mass in the space. The design requires the construction of a large 3 story concrete staircase reaching from the ground floor to third floor. Construction for the stairs is highly labor intensive and requires a large amounts of temporary shoring. Further complicating construction, the stairs are cantilevered off a 40' 4" cast-in-place column located in the center of the atrium. Due to design, in order to properly reinforce the stairs their construction requires the simultaneous construction of the column. Scheduling complications arose after it was determined that the column was structural member that supports a portion of the roof in addition to the stairs. More in depth analyses will be performed on the externalities that the existing stair creates.

Design and construction analyses will be performed to develop value-adding alternatives that better utilize onsite resources. Research will be performed in developing a stair design that is aesthetically pleasing, improves constructability, and does not compromise the passive design of the space. This design will attempt to utilize the vacant 8,700 square foot warehouse located onsite by investigating opportunity for onsite concrete prefabrication. This analysis attempts to reduce site and building congestion, and improve the flow of the project schedule. The metrics used to assess this analysis will be: cost, aesthetics, constructability, meeting prescribed thermal mass design criteria, and sustainability.

Problem Analysis 3: Façade Assembly Construction

Due to the high sustainability of this project, material selection is often times determined purely to satisfy the conditions of the LEED or Living Building Challenge point systems. A prime example of this is the use of reclaimed barn wood for the façade. Although sustainable, this material choice may not be the most ideal or valued. Furthermore, façade type selected does not offer the thermal resistivity and mass benefits that other alternative reclaimed materials may possess.

The analysis would include evaluating façade alternatives that would provide higher value to the owner. The value improving metrics considered for this evaluation would include: wall system R-value, cost, and sustainability. Material alternatives that would be explored include reclaimed stone, and reclaimed brick. Additional research will be performed on the reclaimed and salvaged material industry to evaluate additional façade alternatives. Wall assemblies will be designed and compared based on the metrics described above. Depending on the façade type constructed, additional analysis may need to be performed on the capacity of the structural steel frame and foundations. This analysis will determine the capacity of the frame and dictate how the alternative façade systems will be designed.

Problem Analysis 4: Raised Floor System

Similarly to façade, the high sustainability of the project also influences the mechanical system selection. For this project a raised floor system was specified for a large portion of the building. Although sustainable, significant costs are added to incorporate this feature and may only contribute marginally to the overall sustainability of the building. In addition, this system is a redundancy in that it does not remove the above ceiling plenum space, nor does make MEP and interior finish trade coordination more easily done.

This analysis would involve the elimination of the raised floor system, and subsequently the replacement with necessary above ceiling duct work. The metrics that would be used to determine the effectiveness of this analysis would be: sustainability, and system cost. This analysis will also consider how the building's structure and design will be changed. The removal of two raised floor systems could reduce the overall height of the building in addition to its cost.