November 29, 2010

TECHNICAL ASSIGNMENT THREEE

PENN STATE AE SENIOR THESIS

SUPPORT SERVICES BUILDING

PENN STATE MILTON S. HERSHEY MEDICAL CENTER – HERSHEY PA

WILL LAZRATION

CONSTRUCTION MANAGEMENT

DR. RILEY

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EXECUTIVE SUMMARY

Technical Assignment Three is intended to identify areas of the project that are good candidates for research, alternative methods, value engineering and schedule compression for the Support Services Building at the Penn State Milton S. Hershey Medical Center. Included in the scope of work is the construction of a new 42,796 SF medical warehouse/office/support services building as well as the re-alignment of Lion Life Drive with Campus Drive. Unique challenges associated with this project are the small odd-shaped proposed site and construction above the existing utility tunnel that houses the main steam and chilled water lines for the main hospital.

To gather the required information for Technical Assignment III, an interview with Jeff Smith, Project Manager for the Support Services Building took place on Monday, November 8, 2010 at Alexander's field office trailer located onsite. Contents of the interview are summarized within this report and include constructability issues that the project team identified/encountered, as well as possible schedule acceleration techniques and value engineering ideas.

From the interview the top three constructability issues that were identified are; construction above and around the existing utility tunnel, the micropile foundation system, and the offset roof in conjunction with the specified cold-applied asphalt roofing system. Each issue provided a unique challenge to the project team and must be addressed accordingly. A more detailed explanation of each issue can be found in the ***Constructability Issues*** section.

Due to issues with micropile installation, the schedule was delayed 5 weeks. To make up for the lost time, the project team decided to break the steel erection into two sequences. This re-sequence caused the exterior enclosure and first floor interior finishes to become the new critical path activities for the remainder of the project. Although the construction team is still searching for ways to accelerate the schedule, it was pointed out within the interview that if several design changes/material substitutions were implemented, it would have shortened the project's schedule. These ideas included, elimination of the micropile foundation system, elimination of the offset roof, and substitution of the cold-applied asphalt roof with either an EPDM or TPO roofing system. A more detailed explanation of how these changes would have shortened the schedule can be found in the ***Schedule Acceleration Scenarios*** section.

Value engineering was not performed on the Support Services Building. However, the construction team identified several areas/items though could have been possible value engineering topics. Potential topics include a re-design of the foundation system, eliminating of the offset roof, and substitution of the roofing material. A more detailed explanation of why no value engineering was performed and how these topics could have provided a more cost-effective solution can be found in the ***Value Engineering*** section.

Through the in-depth analysis of the constructability challenges, schedule acceleration scenarios and value engineering topics several features were identified as potential problematic areas on the Support Services Building project. Several of the identified problems include re-design of the foundation system, elimination of offset roof & roofing material substitution, schedule acceleration for exterior enclosure and sustainable techniques. A more detail explanation of each problem can be found in the ***Problem Identification*** section. In the ***Technical Analysis Methods*** section each of the methods are discussed into further detail to provide further insight into possible research topics for the spring thesis proposal.

CONSTRUCTABILITY ISSUES

CONSTRUCTION ABOVE EXISTING UTILITY TUNNEL

Although the Support Services Building has a relatively small footprint (21,000 SF), the northwestern tip of the building is constructed atop an existing utility tunnel as shown at right in figure 1. Due to the function of the building, simply rotating the building to avoid the tunnel was not an option. Access to the tunnel from inside the building was required in order to move medical supplies from shipping/receiving docks to the main hospital. On the northern side of the tunnel, the lower level of Support Services Building matches the elevation of the existing tunnel floor. This is the only location in the building where this occurs and is also the only location where the building is 3-stories. On the southern side of the tunnel, the building is two stories, with the lowest level being 29' above the existing tunnel floor.

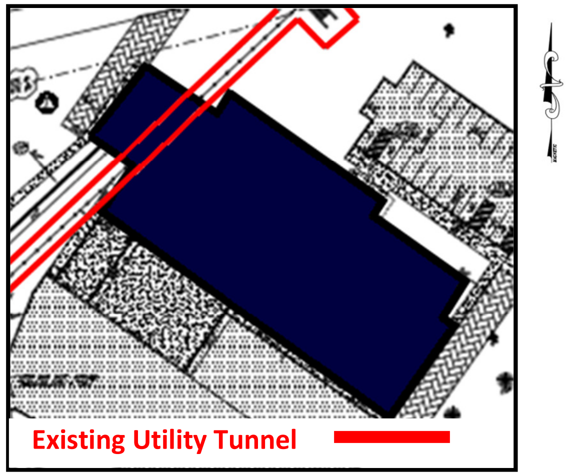

Figure 1: Location of Existing Utility Tunnel

In order to construct the building around the utility tunnel, the tunnel had to be "bridged". This bridging effect placed pile caps and columns on either side of tunnel. To complete the pile caps on the northern side of the tunnel, a 30' deep excavation was required. However, there was minimal room for this excavation to occur. In order to reduce costs, the construction team chose to let the site subcontractor engineer a sloped excavator rather than install an earth retention system. Figure 2 at right shows what the excavation looked like. Although this was a good idea, the site subcontractor didn't place enough emphasis at the beginning of the project on getting the engineered excavation drawings approved. Thus, it delayed the construction of the pile caps and gradebeams in this area. It was also discovered that to achieve the proper slope of excavation, work inside the excavation had to be sequenced in order to maintain the slope.

Figure 2: Tunnel Excavation

Two additional issues that arose with the excavation above the tunnel was due to the fact that the drawings called for the entire area above the tunnel through column line 12 to be excavated down to the top of the existing tunnel roof. Figure 3 on the next page shows the area that had to be excavated. However to completed the bridge over the tunnel the design called for a series of regular gradebeams and cantilevered grade beams in this same area. One of the issues was that backfill needed to be placed prior to pier and gradebeam completion. To solve this problem the concrete subcontractor suggested pouring retaining walls around the piers in order for backfill to be placed before the piers were poured. Figure 4 on the next page shows the installed retaining walls prior to pier and gradebeam placement.

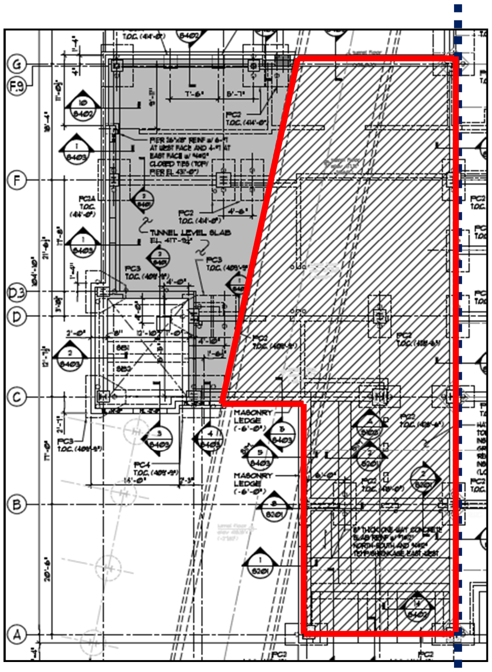

Figure 3: Area of Excavation Above Tunnel

Figure 4: Added Retaining Walls to Allow for Backfill Prior to Pier Placement

The second issue involved the construction of the cantilevered gradebeams. It was discovered by the concrete subcontractor that they needed a better way to form these and support their formwork. Due to the tunnel, there was no place where intermediate supports for the formwork could be located. They needed to develop a way to support the weight of the formwork and concrete without any intermediate supports. To solve the problem their engineer designed a system using C15x33.9 channels at the bottom of the forms in order support the weight of the concrete and formwork. Two of his sketches are shown below in figures 5 & 6.

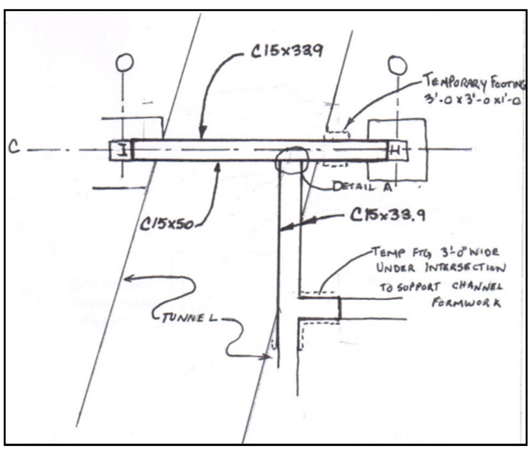

Figure 5: Concrete Subcontractor's Engineer's Sketch of Cantilevered Gradebeams

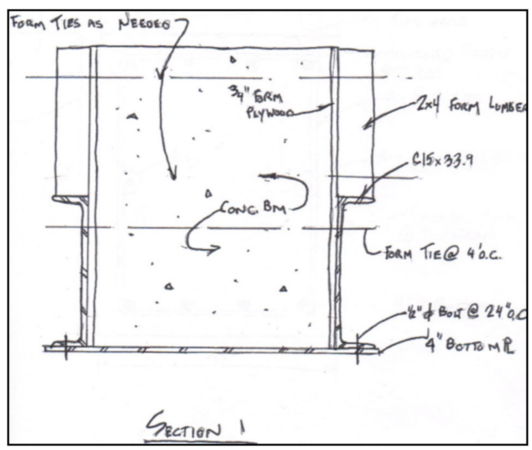

Figure 6: Section of C15x33.9 Channels at Bottom of Cantilevered Gradebeam

Located inside the tunnel are the main chilled water and steam lines for the hospital. Any damage to these would shut down the entire hospital. This only added to the complexity of construction above and around the tunnel. Knowing this, the construction team installed vibration monitors inside the tunnel and monitored them closely to insure that nothing happened during construction.

MICROPILES

Micropiles themselves are typically not an issue with installation, therefore often are hardly considered a constructability issue. However in the case of the Support Services Building, several issues arose with the installation of the micropiles that eventually took them an extra five weeks to complete. Upon installation of all 152 piles, the Micropile Contractor began testing several piles as required by the project's specifications. Of the first several piles tested, it was discovered that nearly 1/3 of them were failing before meeting the design load, yet alone the load they were supposed to be testing at. Even worse it was also discovered that the piles were be tested at 1.5 x the design load and not 2.5 x the design load as called out in the specifications. To solve their problem, all 152 piles were tested and any pile that failed was pulled out and a new pile was installed.

Two major questions for the construction team were what was the reason all of these piles failed and why did the 2-story Support Services Building need to be placed on micropiles? It was discovered that the issue with piles failing resulted in poor quality control from the pile contractor. The exact issue that caused these to fail was due to the underlying bedrock. Because it was a karst formation, there were many voids within the bedrock. These voids filled with grout before the grout could get to the bottom of the pile, therefore the shortening the length of the pile, resulting in a weaker pile.

As for the construction teams question about why micropiles were chosen as the foundation system for the Support Services Building. The Geotechnical Report recommended the micropile foundation system based on the design load and differential settlement requirements given to them by the structural engineer. Loads given to the Geotechnical Engineer were a 350-kip column load near the tunnel and 250-kip column load elsewhere. Shown in figure 7 below and based in comparison with actual column loading, the 350-kip column load near the tunnel is acceptable, but the 250-kip column load elsewhere is well above the 98-kip column load average for the remaining portion of the building. In fact there are several columns whose load is less than 50-kips. However as mentioned above, micropiles themselves are not inadvertently a constructability issue, but in the case of the Support Services Building became one. The question still remains; did micropiles need to be utilized on this entire project?

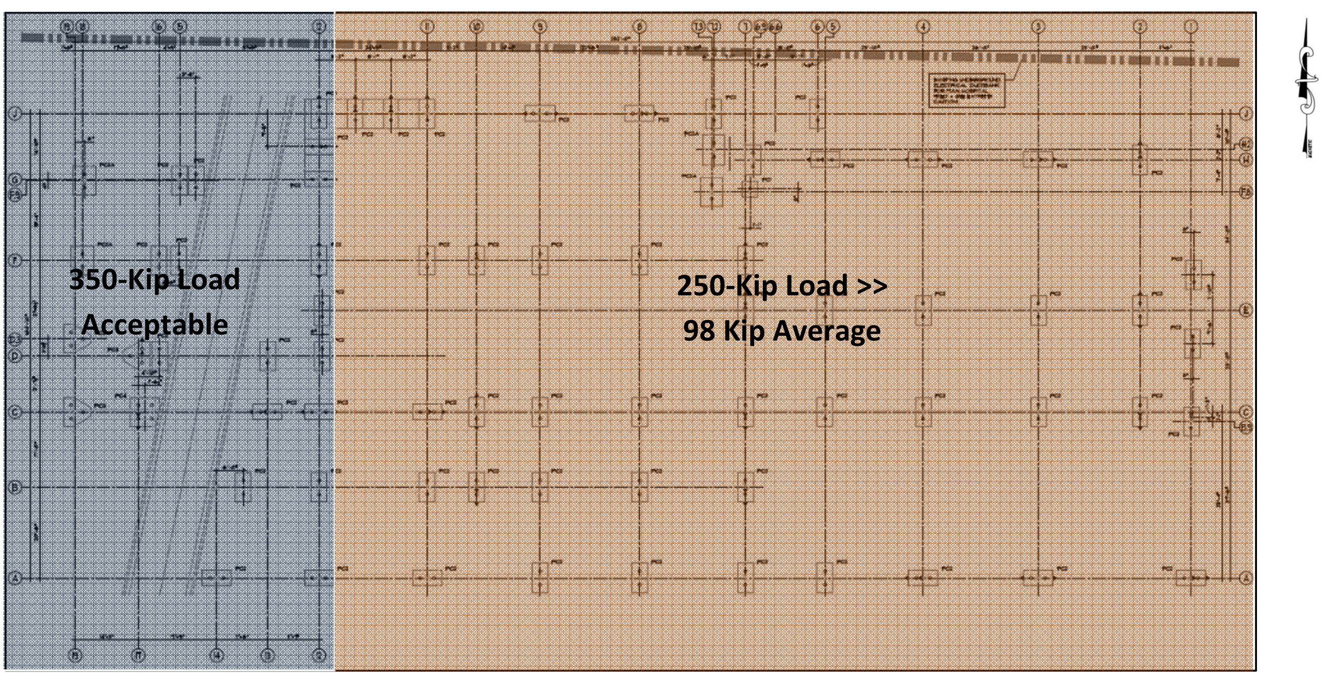

Figure 7: Geotechnical Report Column Loads

SUNKEN ROOF/ROOF TYPE

Mostly all of the mechanical equipment for the Support Services Building is located on the rooftop. To hide this equipment, the roof above the Central Campus Storage is offset 5’-0” below the main roof. Figure 8 below highlights this area as well as the surrounding roof heights.

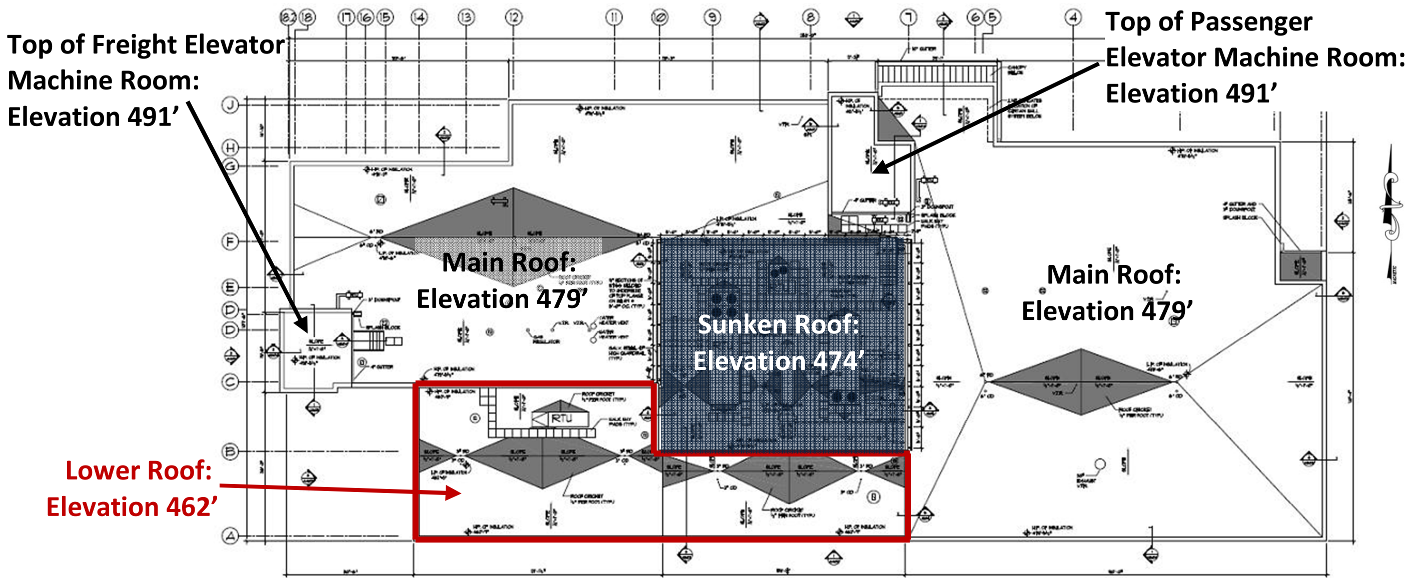

Figure 8: Support Services Building Roof Elevations

What makes the sunken/offset roof a challenge to construct is the type of roofing used on the project. Hershey Medical Center utilizes a standard cold applied asphalt on all of their projects. With this type of roof, all of the parapet walls need to be installed prior to the installation of the roofing material, due to the interface detail between the two materials. Offsetting the roof also requires extra materials and added time to construct vs. if the roof was not offset. An added issue with the cold-applied asphalt roof is that it cannot be applied under certain temperatures. Giving the project schedule, the roofing has to wait until spring 2011 to be installed. Knowing this, the construction team has set money aside for the installation of a temporary roof if they cannot get the parapet walls finished in time, or if the temperatures drop below the minimum installation temperature for the asphalt roof.

PILE CAP ELEVATIONS

One item that the construction team found that provided them a challenge they didn’t foresee was all of the different pile cap elevations. In the design there were only four different types of pile caps used on the project, but these pile caps were all located at 13 different elevations. Most of the elevations changes from pile cap to pile cap were minimal (1-2’), except for around the tunnel. Even though these changes were minimal, careful attention had to be placed on the installation of the pile caps. Since steel fabrication was nearly complete as the pile caps were being installed, installing a pile cap at the wrong elevation could have been a costly mistake. It was also discovered that because of the differing elevations, work associated with the pile caps took longer to complete than usual.

Although it provided them with an added challenge, the construction team utilized a stringent quality control program, which insisted of constantly checking elevations and was able to install all of the pile caps without any major issues.

SCHEDULE ACCELERATION SCENARIOS

PROJECT CRITICAL PATH

Early in the project the critical path of activities for the Support Services Buildings is like most typical construction projects. Starting with micropiles, the critical proceeded as depicted in figure 9 up until steel erection.

Figure 9: Early Critical Path Activities for the Support Services Building

A major setback in the project schedule occurred during the installation of the micropiles. For a more detailed explanation of what caused the setback, see the Micropile section on page 6 of this report. To make-up for the extra five weeks of micropile installation, the construction team decided to break the concrete foundation elements and steel erection into two sequences. As shown below in figure 10 Sequence one is from column lines 1-12, where sequence 2 is from column lines 12-19. Column line 12 is the column line located adjacent to the southern side of the existing underground utility tunnel.

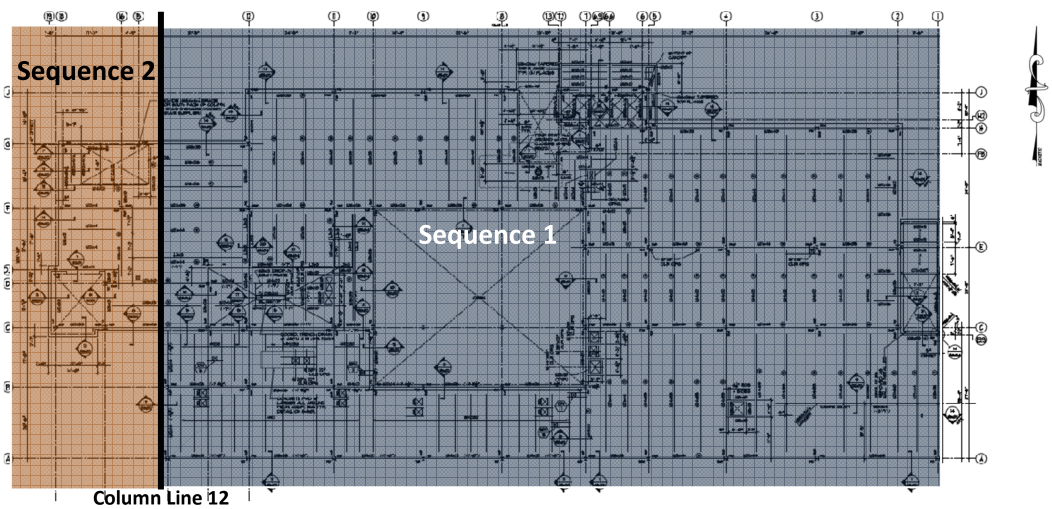

Figure 10: Steel Erection Sequences

Upon completion of steel erection in sequence 1, the critical path shifts to follow a path more unique to the Support Services Building. Unlike most buildings where the critical path will follow major MEP installations and finishes, the critical path for the Support Services Building will follow the exterior envelope and the first floor interior finishes. It is critical to get the exterior envelope finished in order to get the building 100% watertight so interior finishes can take place. First floor interior finishes are also part of the critical path because they lag the second floor by three weeks.

Setbacks have plagued the Support Services Building from day one. Starting with a missed fiber optic line in the center of the site that delayed site utilities, and then the micropile issue, minimizing any new setback is vital to the success of the project. A potential setback/risk still to come is issue with weather. Winter is just around the corner, and the schedule shows steel erection and exterior walls both being installed during this time. Many elements are affected by temperature and weather with the exterior envelope. Not getting the project 100% watertight on time could severely hurt the projects finish date. Also, severe weather could delay interior MEP rough-in, metal stud and CMU walls, which would add further delays to the interior finishes.

ACCELERATION TECHNIQUES

As shown on the previous page, after the delay due to issues with micropile installation, and delay in getting the engineered excavation drawings for the tunnel excavation approved, the construction team chose to break the concrete foundation system elements and steel erection into two sequences. Besides the micropile issue, the concrete foundation elements located in sequence 2 are more complex and will take longer to complete. Steel erection in sequence 1 will commence prior to completion of the concrete foundation elements in sequence 2 to allow the project to make up lost time. Beyond gaining time with steel erection, the sequencing will also allow the exterior enclosure and interior rough-in to begin sooner. An extra feature to sequencing the work is that there are no added costs associated with it.

Beyond sequencing, the construction team is still looking for other acceleration scenarios. With the exterior enclosure and first floor interior finishes being the two components remaining in the critical path after steel erection, finding a way to accelerate the schedule is difficult. A possible way to accelerate the project would be to add an extra crew with the exterior enclosure. Currently the plan is to only work on elevation at a time. Adding an extra crew would allow work to take place in two locations simultaneously. Finishing the exterior sooner would allow interior finishes to start earlier. Besides adding extra crews, another option the construction team could consider would be increasing work hours. Rather than working 40hrs/week, key subcontractors could work 48, or even 50 hrs/week. This would increase production without adding extra manpower. However, increasing the number of work hours would come at the added cost of overtime. There is no definite answer on who would cover the added costs associated with working overtime.

After my discussion with the construction team, they believe there are ways the schedule could have been accelerated based on some material substitutions and design changes if they would have been implemented. They believe that if the cold applied asphalt roof had been substituted for a regular EPDM or TPO roof, significant time could have been saved with the schedule. Unlike the cold applied asphalt roof, the EDPM or TPO roof, the roof can be installed before the exterior walls and parapet walls are completed. This means that right after the metal roof deck is installed, the roof can be installed. Greatly reducing the time required to complete the exterior enclosure.

If the cold applied asphalt roof if not substituted, the construction team believes eliminating the offset roof above the Central Campus Storage would have saved time on the schedule. Matching the height of the main roof would eliminate the 5' high wall around the perimeter of the offset roof. This wall (shown in figure 11 at right) has to be constructed prior to installation of roof. If the roof was the same height as the surrounding roof, then only the exterior walls of the building would have to be constructed prior to installation of the roofing. Time is also saved with steel erection and detailing, as there would be fewer members and connections to install.

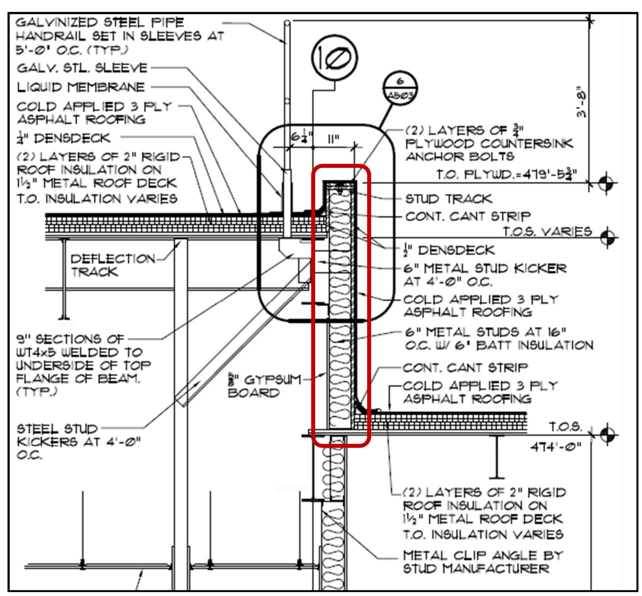

Figure 11: 5' High Wall at Offset Roof

VALUE ENGINEERING TOPICS

Unlike most construction projects, Value Engineering was not implemented on the Support Services Building. Upon closer examination, there are several reasons why value engineering was not preformed on the Support Services Building. One reason why value engineering was never performed was due to the fact that by the time the CM (Alexander) was selected, the final design was nearly complete. Another reason was simply that Penn State/Hershey Medical Center did not wish to pursue any value engineering. They were satisfied with the design and felt that any value engineering would detract from the final look of the building. Also, the estimated costs of the project were under budget, therefore the need to reduce the cost of the project was not an issue. Although no value engineering was implemented, the construction teams has several ideas that could have reduced costs/added value to the project. These ideas are summarized below.

FOUNDATION RE-DESIGN

Following the recommendations of the Geotechnical Report, the entire Support Services Building is set on micropiles. As mentioned on page 6 of this report, the Geotechnical Report was based on a 350-kip column load near the tunnel and 250-kip column load elsewhere. Shown in figure 7 on page 6, the 350-kip column load near the tunnel is acceptable, but the 250-kip column load elsewhere is well above the 98-kip column load average for the remaining portion of the building. In fact there are several columns whose load is less than 50-kips. Total costs of the micropile contract were $791,301.00. Looking at this figure and seeing the column loads, the construction team fills that eliminating some of the micropiles and substituting the associated pile caps with spread footings could have saved the project in upwards of $250,000.00. This number is purely a rough estimate, but yet is something that should be considered. A re-design of the foundation system could be similar to that shown in figure 12 below.

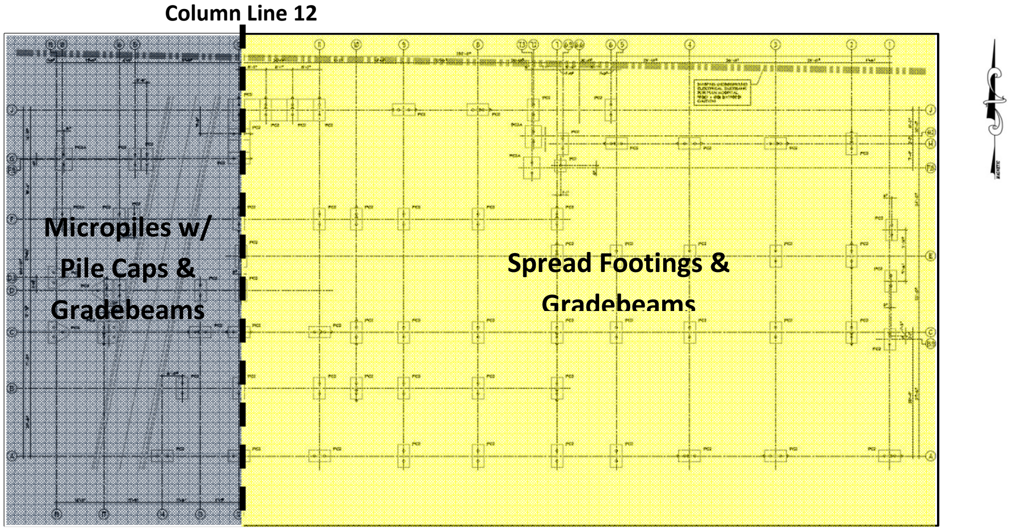

Figure 12: Potential Foundation System Re-Design

Essentially, the foundation system in the tunnel area (column lines 12-19) would remain as designed and from columns lines 1-12 would be redesigned. These same "zones" are utilized during steel construction. Breaking the foundation systems into these two zones could also improve the projects schedule. It should be noted that even if spread footings were substituted for micropiles, some method of soil improvement may still be required per the Geotechnical Report. However the construction team still feels even if soil improvement is required, there is still a potential for cost savings.

ELIMINATION OF OFFSET ROOF

As shown in figure 8 on page 7, the roof above the Central Campus Storage room (approx. 3,600 SF) is offset below the main roof by five feet. To achieve this offset there is a substantial amount of added materials and extra work required. If this roof were to match the surrounding main roof elevation, the following items depicted in figure 13 could be eliminated.

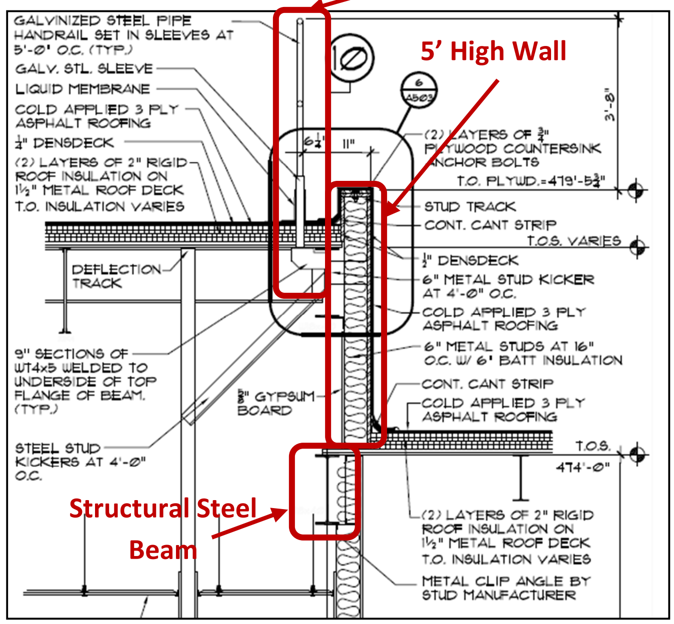

Figure 13: North, West & East Wall Detail at Offset Roof

In total, material savings alone would be; 135 LF of the 5' wall, 2.4 tons of structural steel, and 240 LF of galvanized handrail. Besides material savings, there would also be a labor savings. Eliminating the offset would also allow the roofing material to be installed sooner, because they won't have to wait for the walls to be constructed. This would allow the roof to be finished sooner, which would allow interior finish work to start earlier.

Although eliminating the offset roof would alter the look of the Support Services Building by longer hiding the mechanical equipment, the construction team feels this is a viable cost savings solution. As far as hiding the mechanical equipments, if that is a necessity, it could be achieved by different, more cost effective means.

SUBSTITUE COLD-APPLIED ASPHALT ROOF WITH EDPM or TPO ROOF

Penn State Milton S. Hershey Medical Center's standard roof is a cold-applied asphalt roofing system. Although this roof has proven to be reliable, it is rather expensive. It also provides several installation issues that could affect the construction schedule. Such issues include the air temperature. Cold applied asphalt roofing cannot be installed below a certain temperature. Knowing this, this roofing installation is schedule for spring 2011 whereas an EPDM or TPO roof could be installed upon completion of steel erection in January 2011. Another issue with the cold-applied asphalt roof is that all of the exterior walls and any parapet walls need to be completed prior to installation of the roof due to the complex interface detail between the two systems.

It is the believe of the construction team that if Penn State Milton S. Hershey Medical Center had substituted the cold applied asphalt roof with either a EPDM or TPO roofing system they would have seen a significant cost savings. Both EPDM and TPO roofing systems cost less to purchase and install. Newer technology within these roofing systems allows them to meet the same LEED requirements and provide the same (or even better) warranty periods as compared to the cold applied asphalt roof. Also roofing installation is not dependent on completion of the exterior walls and parapet walls. EPDM and TPO roofs can be installed immediately after the metal roof deck is completed. The roofing material is then draped over the edge of the building and once the exterior walls are completed, the interface detail is completed. This would have significant schedule implications given that interior finishes could begin earlier. However, exact cost savings of this substitution are unknown, but worth considering.

PROBLEM IDENTIFICATION

After interviewing Alexander's Project Manager and through an in-depth analysis of the constructability issues, schedule acceleration scenarios and value engineering topics of the Support Services Building, several features were identified as potential or were problematic areas. The following issues may possibly be pursued in upcoming research topics.

TUNNEL EXCAVATION

A 30' deep excavation was required in order to complete the foundation work for the Support Services Building on the south side of the tunnel. There was little room to complete the excavation and in order to reduce costs the project team decided to slope the excavation rather than install an earth retention system. Getting approved engineered excavation drawings took longer than expected, and because of the amount of room the sloping required, work in this area had to be phased in order to maintain a safe excavation.

Excavation around the tunnel also created several problems with pier and gradebeam placement. In order to pour these elements the concrete subcontractor had to develop a system of retaining walls around the piers in order for backfill to be placed prior to pier installation. Placement of the cantilevered gradebeams above the tunnel was also affected. Intermediate supports for formwork could not be placed atop the tunnel; therefore the concrete subcontractor had to design a form system using C15x33.9 channels to span the distance without intermediate supports.

FOUNDATION DESIGN/MICROPILES

Design of the foundation system, in particular the micropiles was based on the recommendations of the Geotechnical Report. However the loads given to the geotechnical firm at the time of the geotechnical were only accurate in the tunnel portion of the building. The remaining two-thirds of the building is completely over designed. In several instances the actual load on the column is less than 1/5 of the load that the Geotechnical Report was based on. Based on past experience it is the belief of the construction team that the foundation system for the Support Services building is entirely over designed significant cost savings could have been achieved with a re-design of the foundation system.

Installation of the micropiles became a major issue on the project. Upon initial testing, several piles failed before the specified design load. It was then discovered that testing was being perform at only 1.5x the design load and not 2 x the design load as specified in the Geotechnical Report. In the end, all 152 piles were tested and any pile that failed was pulled, and a new pile was installed. This caused major schedule delays (5 weeks) on the project. Upon closer examination, and after a third-party testing agency was brought in, it was determined that the piles failed due the grout had seeped into voids within the bedrock before settling in the bottom of the pile, therefore reducing the developed length of the pile.

MULTIPLE PILE CAP ELEVATIONS

Due to different number of pile cap elevations, the installation of these components needs a higher level of attention from the construction team. These pile cap elevations differ from bay to bay. The sub-grade is cut to the same elevation, and the first floor is slab-on-grade. Layout and placing these pile caps takes more attention to detail, and constant monitoring. It also adds time to the schedule because although each pile is the same size, more excavation is required for piles at a lower elevation. Concrete foundation elements are on the critical path of the schedule and installation of a pile cap at the wrong elevation would cause delays in the already tight schedule.

EXTERIOR ENCLOSURE/FIRST FLOOR INTERIOR FINISHES DELAYS

Due to the issues encountered with the installation of the micropiles and the five week schedule delay, upon steel erection the critical path of the schedule follows the exterior enclosure and first floor interior finishes. Exterior enclosure work will commence in late December 2010. Severe weather could have a major impact on the current schedule. Any delay with the exterior enclosure would affect the start time of the interior finishes which would have a direct effect on the final completion date.

Issues with some of the selected materials also arise with the exterior enclosure. The cold applied asphalt roof can only be installed during certain temperatures and must wait until exterior walls and parapet walls are completed. Because of this the roof is not scheduled for installation until late April, early May 2011.

OFFSET ROOF

Although not a major issue, construction of the offset roof is an added complexity in the already right schedule. Its location, not on exterior perimeter of the building, provides logistical issues with getting the necessary tools/equipment and material in place to construct it. It also is just adds to the amount of work that needs to occur before the roofing material can be installed.

LEED CERTIFICATION

Currently the Support Services Buildings is on track to achieve a LEED Certification rating under LEED version 2.2. Most of the projects LEED points come from an effective use of material and resources and a high indoor air quality. Although these features are a good start, this process is identified as a problem because the sustainable features of the project are not being pursued to the fullest potential.

Penn State Milton S. Hershey Medical Center, a subsidiary of the Pennsylvania State University, follows the university's LEED guidelines. However many of these guidelines are geared more towards the University Park campus, and they don't allow individual project teams to investigate/propose alternate techniques that could help make the Support Services Building project more sustainably beneficial to Hershey Medical Center and the environment. This project is ideal to pursue higher levels of sustainable features since it will not generate any revenue for the medical center and will only cost PSUHMC more money to operate in the future.

TECHNICAL ANALYSIS METHODS

TECHNICAL ANALYSIS METHOD 1: RE-DESIGN OF FOUNDATION SYSTEM

As mentioned in all of the previous sections, the micropile foundation system had installation issues resulting in a five week schedule delay. It also was mentioned that the foundations were designed as typically done, based on the Geotechnical Report. However it was also pointed out that the loads given to the geotechnical firm who created the report were up to five times greater than actual loading conditions for portions of the building footprint. Based on prior experience the construction team felt the foundation system was completely overdesigned and that the building could easily have been supported by spread footings and gradebeams with a significant cost savings when compared to the micropile foundation system.

To re-design the foundation system, an in-depth look into the actual column loads, soil conditions and potential settlements will be necessary. If re-designed the system would be similar to figure 12 on page 10. Due to the tunnel and column loadings, the foundation system from column lines 12-19 would remain as designed and only the foundation system from column lines 1-12 would change. This would also allow work to occur in both places simultaneously. If it is discovered that some means of soil improvement is necessary in order to the change from micropile foundation to a spread footing foundation, then geo-piers will be analyzed as a soil improvement method. This analysis will provide the opportunity to fulfill the requirements of the structural breath because it will significantly alter the substructure of the building.

To perform the analysis, research into soil characteristics, bearing capacities as well as how loads are transferred from foundation system to surrounding earth will be needed. Total estimated costs will be calculated for the new foundation system and then compared with the original system. The project schedule will be altered to reflect both areas of the foundation system occurring simultaneously. Any resulting change in the projects schedule will cause the general conditions of the project to change. The general conditions estimate and will be corrected to reflect any alterations to the project schedule. In the end the total project costs will be calculated and compared with the actual project's costs.

TECHNICAL ANALYSIS METHOD 2: ELIMINATION OF OFFSET ROOF & ROOFING MATERIAL SUBSTITION

As mentioned in the previous sections, the offset roof and cold-applied asphalt roof provide constructability issues and both are rather expensive. Both are items on the critical path of the schedule and any delay could severely hurt the project schedule. With the cold-applied asphalt roof, it cannot be applied in cold temperatures; therefore the construction team must wait until April and May 2011 to install it. Using a different roofing material would allow the roof to be installed at an earlier time. Penn State Milton S. Hershey Medical Center uses the cold-applied asphalt roof on all of their projects. They have found it to be a very reliable roofing system. However roofing systems such as EPDM or TPO roofing systems both offer similar warranties, and take less time to install. Eliminating the offset roof would save both time and materials, but would sacrifice the "hidden" aspect of the mechanical equipment on the rooftop.

To perform this analysis, careful considerations of lines of site will be necessary in order to determine how much of the mechanical equipment will be seen once the offset roof is eliminated. Detailed material and labor savings will be calculated due to the elimination of the 5' high walls surrounding the offset roof. A detailed analysis including total costs, advantages, disadvantages, and installation time will be performed on all three roofing systems (cold-applied asphalt roof, EPDM, and TPO) to see which roofing material is the most cost effective solution for the project.

Based on what roofing material is selected, the project schedule will be altered to reflect the installation time. If it is discovered that and EPDM or TPO roof is a more effective solution for the Support Services Building, the schedule will be re-sequenced to reflect installation at an earlier time in the project. Also, the project schedule will be altered to reflect the time savings in eliminating the offset roof. If a reduction in the projects schedule is found, the savings in general conditions will be calculated. Lastly, total project costs will be re-calculated to reflect the savings when compared to the actual project costs.

TECHNICAL ANALYSIS METHOD 3: SCHEDULE ACCELERATION OF EXTERIOR ENCLOUSE

Due to the five week schedule delay with the installation of micropiles, the exterior enclosure (particularly wall framing and sheathing) became a more critical to meeting the projects schedule. Exterior walls are comprised of both CMU's and metal studs with DensGlass sheathing. Finishes on the exterior walls include both Centria insulated metal panels and Arriscraft masonry veneer. Completion of the exterior walls (at least sheathing) must be completed prior to installation of the roof. Interior finishes cannot start until the roof is completed. Currently the schedule shows one wall being completed at a time.

This analysis will take a closer look at activity durations and ways to shorten their duration. Possible ways to shorten durations include re-sequencing activities to determine the most efficient progression of work and the addition of additional manpower/man-hours. It will also include an in-depth analysis of the site in order to determine if there is ample room for two crews work simultaneously on different elevations of the building without over congesting the site. If it is found that the site will allow two crews to work simultaneously, a closer look into manpower availability in the area will be performed.

New durations for activities will be calculated based on if the amount of manpower/man-hours is increased. Using the newer durations, the project schedule will be updated. Estimated costs of increasing man-hours and added equipment necessary to complete the work will also be calculated. If a reduction in the overall project schedule is the savings in general conditions will be calculated. In the end, all costs will be compared to determine if reducing the projects schedule is either a cost savings, or worth the added costs.

TECHNICAL ANALYSIS METHOD 4: SUSTAINABLE TECHNIQUES

Currently the Support Services Building project is slated to achieve Penn State's LEED requirement of a LEED Certification rating upon completion. However, the project has utilized very few sustainable techniques that could provide financial benefits to Hershey Medical Center, because the Penn State's LEED standards don't push project teams to pursue higher ratings. Features such as photovoltaic roof panels, or a solar hot water heater could be very beneficial to HMC to offset the operating costs of the building. Unlike most buildings on the medical centers campus, the Support Services Building will generate no income to offset operating costs.

This analysis will include an in-depth investigation into the financial feasibility of installing a photovoltaic array and/or a solar hot water heater system on the roof of the Support Services Building. In order to determine the required size of the photovoltaic array, an in-depth analysis of the buildings electrical load will be calculated and could serve as a potential electrical breath study. A solar study of the area will be conducted. Research will be performed to determine the optimal array layout on the roof and to size the inverter required to convert the DC power into AC power. For the solar hot water heater, size will be based on the capacity of the two gas-fired hot water heaters currently in the project scope. In order to add PV panels to the roof, an analysis of the roof structures will be required in order to determine if the additional weight can be supported. This analysis may require several structural steel to be re-sized in order to support the additional weight.

Estimated total costs of the system will be calculated and a life-cycle cost feasibility study will be performed to determine if incorporating solar technology into the Support Services Building would be a financially attractive option for the Hershey Medical Center. Part of the life-cycle cost feasibility study could include several options on sizes of the PV system to compare up-front costs vs. long term costs.