2010

WESTINGHOUSE BUILDING 4

TECHNICAL ASSIGNMENT 3

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11/29/2010

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Executive Summary

Technical Assignment Three is intended to expose some of the complications of the Westinghouse Building 4 project and describe how these issues could be researched and overcome. This project involved constructing a 3 story, 121,000 square foot office building in the Cranberry Woods Complex in Cranberry, PA. The original schedule was a demanding 14 months were very little allowance for delays. The largest constructability issue on the project was changing the building façade, which was determined to be too plain after the construction contracts were already signed. A two week delay in the very beginning of the project forced the project team to develop innovative schedule recovery methods to get the project back on schedule early. Extra costs were incurred unexpectedly by Turner, which persuaded them to utilize value engineering to regain some of their losses.

The top three constructability issues on the project involved the changing, hanging, and sealing of the building façade and the addition of a second set of utility lines into the building. Changing the building façade was a primary issue in the early stages of the project. Changing the façade made the building look better, but called for puncturing holes in the building's vapor barrier. The new façade also had to be spray foamed so that it more closely mimicked the original façade's thermal insulation values. Several schedule acceleration techniques were used to recover the lost time on the very beginning of the project. Overtime and project phasing were used to make up the two weeks that were lost and inevitably led to the project finishing 3 months ahead of schedule. Unexpected changes to the design led to Turner incurring extra expenses on the project. Value engineering was used to resize the air handlers and change the type of insulation used in the HVAC ductwork, which ended up saving hundreds of thousands of dollars on the project.

Finally, specific problems on the project were identified and technical analysis methods were discussed. In these sections every issue on the project was scrutinized and methods of investigating possible improvements were discussed. As with any project time constraints led to fast fixes that were not the most efficient or cost effective. Further research on the main building issues could be done to streamline the construction process and maximize savings to the project team and the owner.

Constructability Challenges

There were three main constructability challenges on the Westinghouse Building 4 project. The first challenge came in the design review before the building even got under way. The **original façade** was deemed too plain by the owner thus a new system had to be designed and approved. Secondly, once a new façade was agreed upon it was up to the constructor and architect to design a method of **attaching the new façade**. Hanging this new façade brought with it several of its own challenges that had to be overcome. Lastly, after the project was underway the owner decided they wanted a secondary set of **telecommunication lines** to come into the building in case the primary lines were severed.

Original Façade

Westinghouse Building 4 was constructed just a hundred yard from the main headquarters. The initial conceptual design that the architect put together and was agreed upon, called for a less elaborate façade than the other buildings in the complex. It called for an all brick and glass façade with no real design twists. This was the design that Turner Construction budgeted for and bid on. Later, when the building design went before the design review board the initial façade design was deemed too simple. The board felt that the building would stand out as an aesthetic eye sore compared to the surrounding buildings. Buildings 1, 2, and 3 all incorporated layers of metallic panels in their facades, which added to the luster of the buildings. The board wanted to change Building 4's façade so that it more closely mimicked these surrounding building façade's.

Figure 2: Shows the additional aluminum fascia along the top of the building and a small accent strip in the middle above the entrance.

When Turner and the architect went back to the drawing board another issue came up. Deciding who would pay for this added cost was a huge decision because the material cost of such panels would be around $120,000. Turner decided they would not try to charge the owner for this design change because they are a good client of theirs. Because Turner would be eating the extra cost, they wanted to minimize the cost of the materials as much as possible. The two entities agreed that non-insulated metal panels would both add flare to the building and not be cost prohibitive. In order to add enough character to the building two separate layers of metal panels had to be added to the building. A metal panel parapet was placed around the top of the building and another layer of panels would be placed between the second and third floor.

These panels would be approximately 3 feet tall and stretch 6 feet across in length. Approximately 10 of these panels would be placed along each of the 60 foot section of the long north and south walls of the building while only the parapet would wrap all the way around all four sides. In their decision of non-insulated panels over insulated ones, Turner managed to save around $30,000 and got the material cost down to around $70,000 for the whole system.

Attaching the New Façade

Because the original façade was self supporting, a special design now had to be made to support the metal panels off of the building structure. The architect came up with a system that called for studs to extend out from the building structure, cantilevering the metal panels. These support studs provided a simple solution to the hanging of the panels, but they also caused a serious design challenge because they had to penetrate the building's continuous vapor barrier. The constructability challenge that this penetrating developed was how to seal around the supports to an acceptable level so that no water associated damages would occur within the walls of the building.

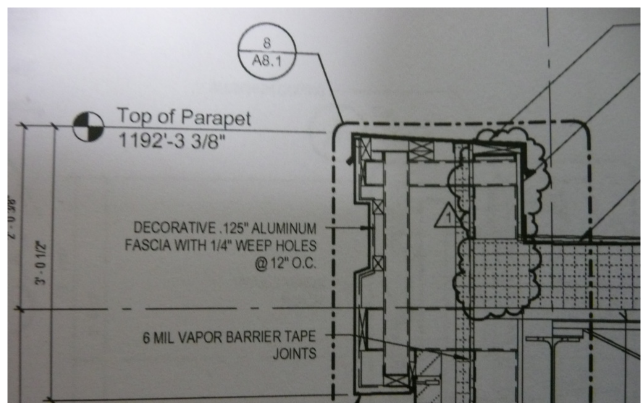

Figure 1: Is the detail drawing of the connection between the aluminum fascia and the structure of the building.

In order to support the weight of the panels, two supports were needed every 12 inches on center. This created a ton of holes that needed to be sealed, which made the risk of leaks quite severe. After going back and forth with the architect for over a month, closed cell foam was finally selected to be used to seal up the holes created by the panel supports. Because the vapor barrier was compromised, closed cell foam had to be used instead of open cell foam. Open cell foam provides good thermal insulation, but cannot be fully entrusted against moisture leakage. Since non-insulated panels were chosen, the entire cavity behind the panel would be filled with the closed cell foam.

Also, since the top row of bricks was now substituted out for much thinner metal panels a gap was formed between the roof and panels. This gap was created where not only horizontal water infiltration was a problem, but also vertical. Extra flashing was required to seal this gap and the same closed cell foam was sprayed in the entire panel cavity. This system was deemed sufficient by all parties to protect the building against moisture infiltration and thermal lose from within the building.

Telecommunication Lines

Building 4 was originally only designed with one set of communication lines feeding into it. The owner was concerned that damage or interruption of these lines would seriously cripple the ability of the employees in the building to do their work. The solution to this was adding a secondary set of communications lines that would feed into the building from a different side of the building. A serious challenge with this was the confusion in communication between the owner and the constructor. It was hard for the project manager to determine exactly what the owner wanted in this issue. They knew in concept what they wanted, but had no idea how their communications infrastructure was actually set up. The project team was responsible for identifying the communications vendors, the utility providers, and the connection point for this second set of lines.

The construction team decided that in addition to the communication lines coming from Westinghouse Building 1 they would bring a set of lines in from Cranberry Woods Drive. Cranberry Woods Drive is a road located just a couple hundred yards from the building and has communication lines running along it that feed the rest of the Cranberry Woods Business Complex. These secondary lines had to be brought into the building and mated with the original set in the IDF room. The additional trenching, conduit, and hook-up fees were again consumed by Turner because good relations with the owner were held at the utmost of importance.

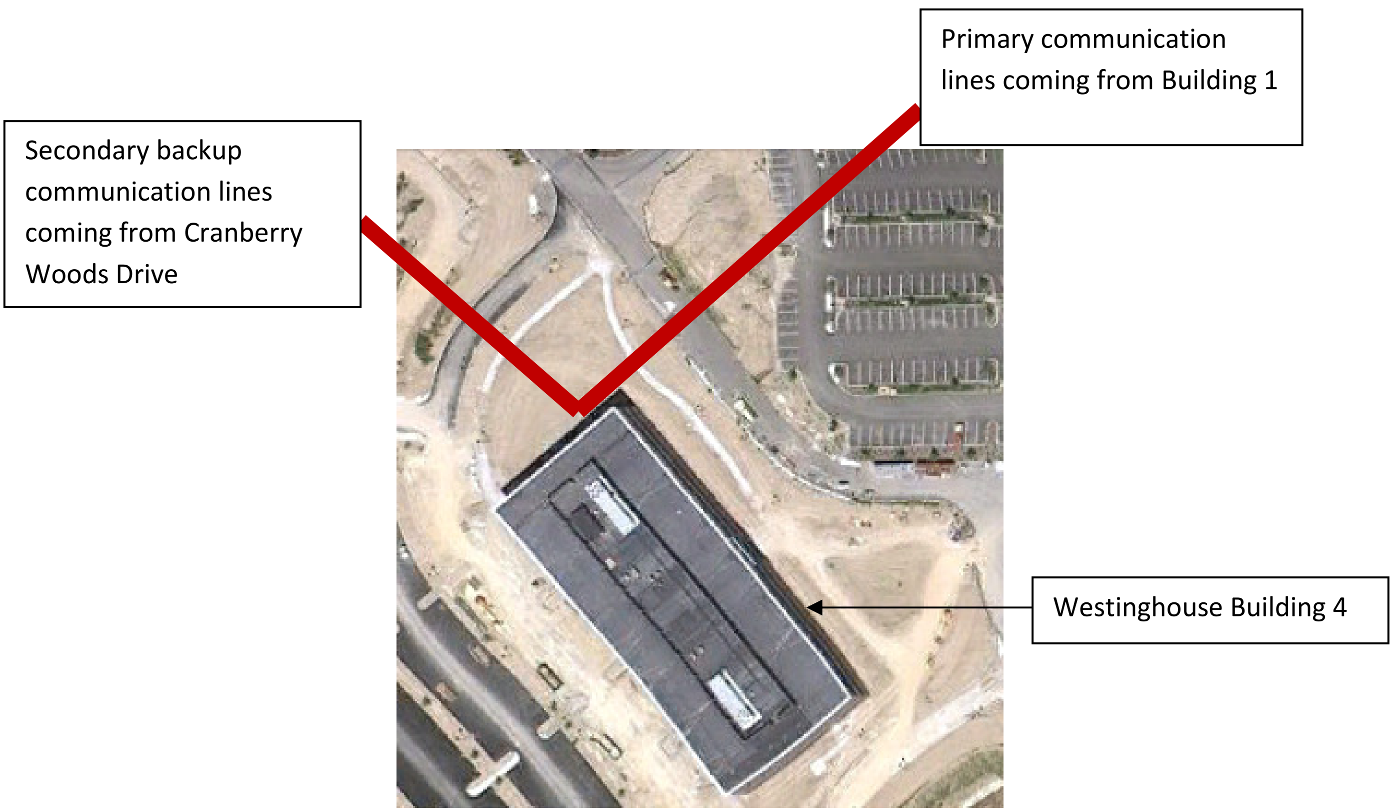

Figure 3: Shows the Location of the primary and secondary communication lines that enter Westinghouse Building 4.

Schedule Acceleration Scenarios

The critical path of the schedule started with the notice to proceed and ended with the owner turnover. Along the critical path there was one major hold up in the beginning and then two major acceleration scenarios that inevitably lead to the building being completed 2 months ahead of schedule.

The first stage in the critical path was obtaining the notice to proceed and breaking ground, which should have occurred on October 1st, 2009. Due to issues with funding and easement agreements the Westinghouse Building 4 ground breaking did not take place until Oct. 15th. This put the project a little over two weeks behind and put Turner at risk of eating the $5,000/day in liquidated damages associated with late delivery of the building. To speed up production on the project and get it back on schedule the project team worked the concrete and steel subcontractors on overtime and weekend shifts. The overtime ended up costing an additional $25,000, but it set a fast pace and established a sense of urgency within all of the later parts of the project.

To gain a little extra time the project manager also had the steel erection start early. When the slab on grade was just 75% complete the steel started going up. Accelerating these two early critical path activities led to other critical activities being able to start early later down the road. For example, because the steel started early, the exterior framing was able to start early, which led to façade and roofing activities starting early as well. A unique quality of this project's critical path is that it shifted around as these activities started in a staggered pattern. An example of this shifting was when the critical path shifted from concrete to steel and then back to concrete. Since the steel started early, the slabs on deck were ready to be poured when the structural steel was 75% complete, which shifted the critical path back to the concrete. The critical path switched again from concrete to roofing when the slabs on deck were 50% complete. Once the roof was completed the critical path stopped switching and became more regular.

Once the roof was completed, the critical path shifted to the structural studs, then masonry and glazing, then interior finishes. Within the interior finishes activities such as dry wall, flooring, and MEP, which all went in pretty much simultaneously. The main opportunity for accelerating the schedule was to staggered the start of certain activities along the critical path as other activities were far enough along to allow them to proceed. This opportunity was exploited on this project and helped the project not only get back on schedule, but end early.

The risks to the project mainly had to do with the repercussions of the late notice to proceed. Subcontractor scheduling becomes more complicated when the project gets 2 weeks behind. Luckily on this project the project team had plenty of lay down area, which meant deliveries did not have to be rescheduled due to the late start. The earthwork on the project included moving 200,000 cubic yards of material total and that activity came first so any hold ups on that activity would have been devastating to the project. Working the concrete and steel overtime eliminated most worries of risks to the schedule because it got everything back on track.

The techniques of accelerating this project specifically were working contractors overtime and staggering the starts of critical path activities. The project manager did not feel that these actually accelerated the schedule as much as they just got the project back on track.

Value Engineering Topics

Value engineering on the Westinghouse Building 4 project came into play in two main scenarios. The first case value engineering played a role was when the façade changed from brick to metal panels. Building 4 was designed with very similar systems and materials as the much larger Building 1. In some value engineering the project team changed the air handler size and adjusted the insulation on the vents. Also, some electrical specs from building 1 were deemed unnecessary and discarded to save money on the project.

As mentioned in the Constructability Challenges section, metal panels were required to achieve the required aesthetic look of the building, but to save money non-insulated panels were chosen over insulated panels. It was determined that it would be less expensive and more practical to spray foam the panel cavities instead of hanging insulated panels. The closed cell spray foam was chosen for the foam type to avoid additional moisture materials that would have had to have been installed if open celled foam was applied.

In Building 1, fire rated conduit was required for all electrical wiring. This was priced as part of the contract by Turner, however it was unnecessary and plenum rated cable was used instead. This change saved thousands of dollars in additional conduit cost and labor cost.

Figure 4: Shows a picture of the Trane Air Handler that was substituted on the project to save cost.

The main value engineering was exemplified in the HVAC systems of the building. The original HVAC systems that were specified were far too large and expensive for the building. Noticing this flaw, the project manager took the building design and load information to Trane and asked for advice on a smaller less expensive unit that would produce the same climate inside the building. Trane packaged their largest system and sold it to the project team. This change in air handlers ended up saving several hundred thousand dollars that the team would have spent uselessly on oversized equipment.

The ductwork of the building was another place that money was saved due to value engineering. Externally wrapped ductwork was originally specified, but by going with internally lined ductwork in most of the building the team was again able to save several thousand dollars. Everything downstream of the Variable Air Volume or VAV boxes was internally lined, but the upstream ductwork had to remain externally wrapped due to vent size stipulation. Insulation was left out all together on some of the round ductwork that extended from the square internally wrapped ductwork to the diffuser. By not putting insulation on these small sections of ductwork it was easy for Turner to save thousands of dollars of man-hours that it would have taken to wrap all of the connections. In the end about 25% of the ductwork was changed to internally lined and an additional 15% was not lined at all.

All of these changes combined ended up saving the company a few hundred thousand dollars, which more than made up for their extra costs that they absorbed in order to keep good relations with the customer.

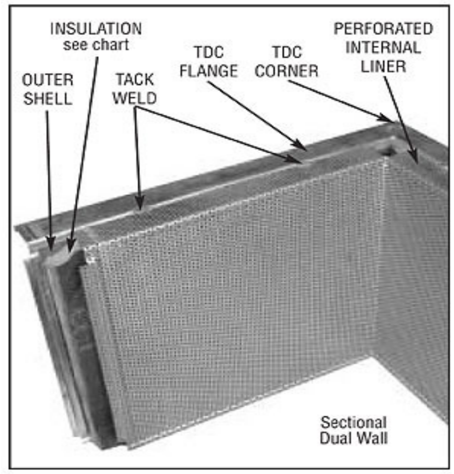

Figure 4: Shows a diagram of internally lined ductwork.

Problem Identification

Several problematic features of the Westinghouse Building 4 project were identified in the interview with the project manager. These unique problems could be investigated further in later research on the project.

Changing Façade Material

Further studies could be conducted on alternative façades. The Owner decided that an all brick façade was too plain and would be an eye sore in the Cranberry Woods complex. The owner did not specify exactly what had to be added to the building façade. A look into alternate façade systems could be done to identify something aesthetically pleasing while still in the price range of the original brick.

Hangers for Metal Panels

Once the constructor chose metal panels a method of hanging the panels off of the building had to be developed. The method they went with was problematic because it created other large problems. Investigation could be done to develop an alternative method of attaching the panels to the building.

Building Sealant

Un-insulated metal panels were chosen to add extra flare to the building. These panels had to be filled with a type of foam insulation that would both seal the building and provide adequate thermal insulation for the building. A closed cell foam had to be used to seal the building against moisture, but alternate methods of thermal insulation could have been used that might have saved time and money.

Installing New Communication Lines

After the project was underway the owner decided there needed to be a secondary set of communication lines into the building in case the primary lines were damaged or interrupted. This late addition to the project required a scramble of utility investigation and efforts. A detailed look into alternate utility lines in the areas could be done to identify an easier connection point for the communication lines.

Subcontractor Overtime Scheduling

Early delays in the project meant that the constructor had to make up time on the front end of the project to get it back on schedule. If delays are corrected quickly it avoids rescheduling and coordination issues that may occur later in the project. Scheduling the concrete and steel subcontractors to work overtime helped to regain the two weeks that were lost in the beginning of the project. A deeper look into overtime scheduling and coordination could be done to identify more ways that the project could have been put back on track.

Project Phasing

By starting critical path activities early the project team was able to gain much more time than they actually needed. This plan was originally implemented when the project was still behind, but even after the project was back on schedule this method of activity scheduling continued. Shifting the critical path between concrete and steel was the main contributor to the project finishing three months early this year. More research could be done from a construction point of view to figure out how this type of project phasing was done and how it could have been made even better.

Air Handler Sizing Analysis

The air handlers on the Building 4 project were way over sized as they were initially specified. These original specifications came from the initial sizes of air handlers that were used on the first three building. Recognizing this immediately with his common sense, the project manager was able to have the air handlers resized, saving the project hundreds of thousands of dollars. A hand calculation could be done to determine the specific building needs and to size an appropriate even cheaper air handler.

Ventilation Insulation

To recover some cost on the Westinghouse Building 4 project, the team decided to change the duct insulation type. By changing from an externally wrapped to an internally lined insulation type the team was able to save thousands of dollars while maintaining the specified duct insulation coefficients. The new type of insulation was similar in material cost, but cost substantially less in labor costs. A study could be done to find another duct insulation method that could add extra savings. Also, certain portions of the duct system were left bare of any insulation at all because it was determined that it was not needed. A more in depth study could be done to locate other portions of the ductwork where insulation was also not required.

Sustainability Features

The Westinghouse Building 4 design calls for very little in the way of sustainable features. Certain systems such as the window systems and lighting systems were designed to save nominal amounts of electricity, but the building has real potential to utilize more green technologies. The building has a small footprint so adding features such as solar panels on the roof would not be cost prohibitive. Also, a small pond sits nearby to the building so a grey water reuse and/or filtration system could be installed to direct building runoff into the pond where it could be reused at a later time.

Technical Analysis Methods

Technical Analysis Method #1: Changing the Building Façade

As described in the sections above, the Building 4 façade caused some early design and constructability challenges early on in the project. To the project team changing the façade from brick to steel solved one problem while it created several others. In making the façade more aesthetically pleasing to the eye, the construction team created undesirable penetrations in the vapor barrier that had to be sealed. In addition, the connection between the metal panels and the roof added extra water penetration dangers to the building. In this design analysis, alternate façade systems could be researched to find an adequate material replacement to the brick while refraining from creating other constructability challenges.

This analysis will include an investigation into alternate façade systems. The panel weight in the chosen system is very important because the heavier the panels are the more hangers will be needed to distribute the weight. More hangers, in this case, means more vapor barrier penetrations. Also, insulation characteristics of the chosen replacement system will need to be analyzed. The original brick façade provided excellent thermal insulation characteristics, where the metal panels require extra foam insulation to mimic similar characteristics. Considering all of the challenges created by changing the façade system, an analysis will be done to investigate the possibility of installing the all brick façade as originally designed and then attaching the metal paneling to the brick. This would eliminate the thermal insulation concerns and do away with all unplanned vapor barrier penetrations.

To perform this analysis, research will be needed to determine the thermal insulation characteristics of the originally designed brick. Once these properties are determined alternate materials and systems can be chosen bases on their similar characteristics. By keeping the R values of the systems close, additional load calculations for the HVAC system will not be required. To investigate the possibility of keeping the original brick and attaching the paneling to it, load barring characteristics of brick masonry will need to be determined. Load barring capabilities of construction materials should already exist , and will just need to be looked up. Attaching the paneling to the brick would also require a structural analysis to make sure the hangers and brick were able to carry the vertical and lateral loads.

Technical Analysis #2: Schedule Acceleration Threw Overtime and Phasing

Due to early delays in the project, the project manager had to develop strategies to getting the project back on schedule. The project team decided to work the concrete and steel subcontractors overtime to help recover time. In addition, the concrete and steel was alternated to further accelerate the project. These methods were developed after the project was underway so inefficiencies were present that could have been avoided, but the methods did get the project back on track and then some. An analysis could be conducted to determine a more efficient construction sequence that would get the project back on schedule, but not have to involve paying the subcontractors overtime.

This analysis will require in depth look at possible phasing that could accelerate the project. The building's steel structure and concrete floors could be alternated in such a way that the progress started on one before the previous operation was completed. Crane rates and concrete subcontractor availability would need to be determined before proceeding with this method. A deeper look into the site logistics would also have to be conducted. There would need to be ample room around the building footprint to allow for safe operation of both the crane and concrete pump truck in order to conduct this type of phasing.

Technical Analysis Method #3: <u>Air Handler Sizing</u>

The original air handler on this project was massively oversized, and hundreds of thousands of dollars were saved by changing the type of air handler that was used. It is not typically up to the project manager to size the air handler, but in this case substantial savings were accomplished because the PM recognized at a glance that the air handlers were oversized.

To perform this analysis, hand calculations would be conducted that would prove that the original air handler was way over sized. Factors such as building purpose, size, and occupancy all play a role in determining adequate volumes of air that will be required for a building. Being that Building 4 is an office building with primarily open spaces, the required CFM calculation should be straight forward and can be found in the mechanical systems section of the IBC. Once the specified air handler is deemed oversized, few additional calculations will be required to determine an appropriate replacement.

After the new air handler is sized, a manufacturer will need to be chosen. Time will be very important in choosing the new manufacturer. Since this change is taking place after the building construction started, a local manufacturer would be best. Manufacturing capabilities and delivery durations would be of utmost importance and background checks would be required on the manufacturer to determine feasibility of them accomplishing the required task. An experienced mechanical designer would be preferred because they could assist in the sizing of the new system to further guarantee that an adequate replacement system was chosen.

Technical Analysis Method #4: <u>Sustainable Features</u>

Being that the owner of Building 4 is a nuclear power plant designer, they push that their company helps to prevent global warming by eliminating greenhouse gasses. Adding sustainable features such as solar panels and grey water reuse to their building would help Westinghouse to further portray themselves as a green company. A solar array placed on the roof of the building would help in generating some of the power required by the building in its everyday activities. Storing storm water runoff in a nearby pond would be valuable to the owner because the water could be reused later in systems such as landscape sprinklers or toilets. By reusing the rainwater, the owner would be able to reduce their monthly water bill and minimize storm water runoff pollution in local streams.

To determine if these systems would be worth the investment, several analyses would need to be conducted. Firstly, a solar analysis would need to be conducted to determine how many hours of sunlight the roof of building 4 receives throughout the year. Secondly, research would need to be done to determine exactly how many square feet of roof space are available for the solar array. Once these figures are determined it should be easy to contact a company that manufacturers solar arrays and determine the amount of electricity that could be produced. Next, research would be done to determine the price of electricity in the area so that monetary savings could be determined. Time of returns would be very important due to the high upfront cost of the building. Additional research could be conducted to determine if government tax cuts or utility grants would be available to subsidize the upfront cost of these systems.

Average annual rainfall in the area would be the key factor in determining if the grey water reuse system would be worth the investment. Water could be directed from the roof to a nearby storage pond. Tests would have to be done to ensure that the runoff was not toxic because the existing pond contains live fish and is frequently visited by building occupants. The site has lush landscaping all around it that requires ample watering during hot summer months. By storing storm water runoff the owner could noticeably reduce their water consumption.