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Project | Crystal Plaza II

Location | Arlington VA

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Technical Report III | Alternative Methods Analysis

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Executive Summary

The focus of this technical report is to provide potential topics for thesis research through investigation of alternative methods, value engineering, and schedule compression. Each component of this report provides information about a given area of potential research with the first three sections presenting information acquired through interviews. The next two sections outline problematic conditions, issues, and situations encountered on the site and descriptions of potential research topics with their respective technical analysis methods.

The first section deals with topics discussed with a project engineer, project manager, and site superintendent at Crystal Plaza II. It focuses on the three large areas of potential research and provides an opportunity for those individuals on the project to look back and give their thoughts on the challenges, scenarios, and topics they made decisions on over the past months

The first of these topics is constructability challenges, where the individuals were asked to respond to questions about unique and challenging constructability issues on the project, as well as what was done to keep the project going. The surprising part of this section was that each individual thought someone else could answer it better, however all interviewed parties gave similar answers. The major constructability issues were narrowed down to renovation, reconfiguration, residential curtain wall, and required delivery. The pure nature of a renovation evokes difficulties in itself, but coupled with a reconfiguration of interior space for a different use, the challenges become monumental. Add to this the unique façade system and the limited time for delivery that in itself proves to be a complicated situation of phased occupancy, and the challenge of completing the project becomes outstanding.

The next topic describes the initial and current critical path of the project, along with the largest risk to completing the project on schedule. It also provides thoughts and strategies for accelerating the schedule that have both occurred and have the possibility to occur. The current critical path is depicted with the largest risk being the completion of the lobby for turnover.

The final topic in this section is value engineering. This is where areas of value engineering are described, how and if they were implemented, and their correlation to the owner's goals. This also provides a comparison to the educational description of value engineering to that of the industry as many of the responses actually resembled cost cutting rather than value engineering. However, many ideas were presented that provide areas for research to meet the owner's expectations of a high end finish while still providing a low cost. The area of notice is within the LEED section of this topic.

The final sections provide problem identification and technical analysis methods for possible thesis research topics. After several problematic issues are presented, the means to research alternates and provide obtainable deliverables is discussed. Areas of problems are consolidated into groups of research topics including sustainability, work flow management, alternate power sources, and redesign of intensive systems.

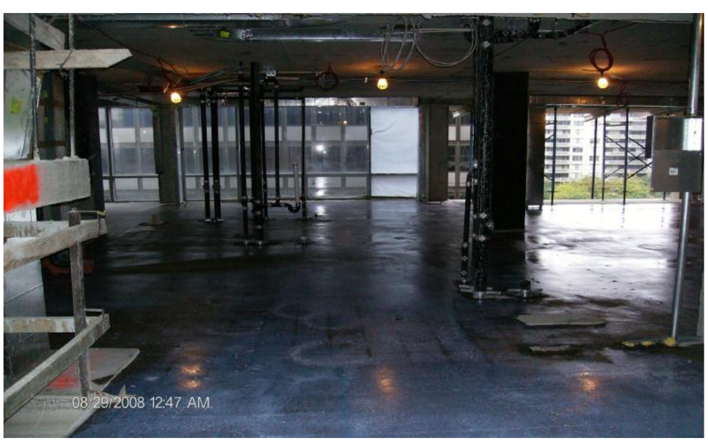
Constructability Challenges

The uniqueness of construction provides many challenges that must be overcome for a successful project. Matching estimates to budgets, quality work to tight schedules, and constructing on a site that may offer unknown conditions such as rocks, existing utilities, insufficient soils for bearing, and other unforeseen conditions are only a few of the challenges project managers, superintendents, and project engineers deal with on a daily basis. In fact, they make it their job to deal with uncertainty and risk. At Crystal Plaza II, all of these challenges have occurred, along with others associated with the type of project, the location, and the owner.

Renovation

The largest of these constructability issues is the project type and the age of the structure. The project is a renovation and addition to an existing, 12 floor, office building that transforms it into a 20 story, high-end apartment complex with commercial space on the street level. The existing building was constructed over 40 years ago and has many deficiencies that have accrued over time. The most notable of these issues is with the concrete superstructure. The existing slab is a 10”, two way reinforced, flat plate style that has started sagging from the long term loading of the previous tenant and failures to the Walker duct system. The sagging is noticeable and requires an intensive and time consuming floor leveling process. This process must be fitted into an already tight schedule, with preference of this activity before any framing begins, but after slab core drilling is complete. Also with the concrete, there are concerns over deterioration. The concern is heightened in areas requiring modification for structural uses, such as anchor points for the curtain wall and reinforcement around enlarged openings.

Existing precast façade to be removed.



Slab leveling complete after installation of risers creating constructability issues.

Rendering of finished project.

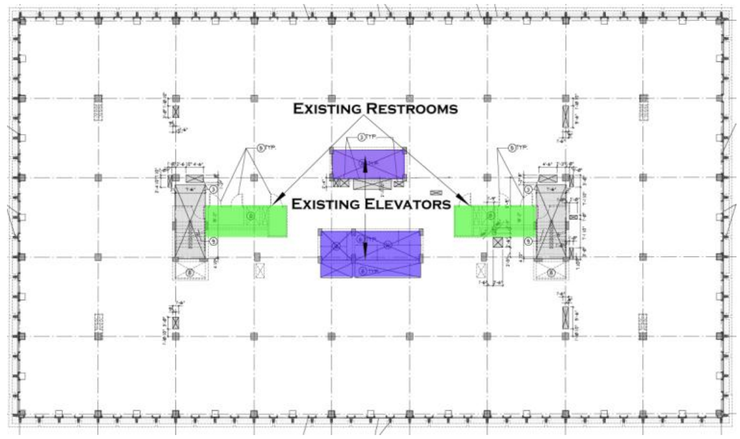
As for the nature of the project, renovations provide challenges not usually found in new construction. Uncovering unforeseen conditions during demolition poses a difficult challenge. Unforeseen conditions at Crystal Plaza range from the sagging slabs and asbestos insulation missed during abatement process to broken drainage pipes in the underground parking area. The issues of sagging slabs and asbestos insulation were part of the pre-construction planning, however, the degree of sagging and unknown areas of asbestos that were missed needed to be dealt with in the beginning to prevent delays in the schedule as these activities took precedence over others. Also the sheer amount of demolition required to be completed in a short amount of time proved challenging. Some of the ways that the general contractor overcame these challenges was to install a temporary drainage and roof system on the 11^{th} floor to allow the removal of the top floor and roof without causing water problems on site. Another tactic was to have the demolition subcontractor work six day weeks and install the tower crane, provided by the concrete subcontractor, two months ahead of schedule. This allowed for the work to be accelerated. The use of the tower crane proved invaluable as it allowed removal of the precast concrete skin in addition to the mobile cranes and could maneuver into the tight locations where the mobile cranes could not reach or would require multiple relocations and setups. The result of this action allowed the new floors to begin construction earlier, accelerating the concrete operation by three weeks.

Also, since the project had no excavation, superstructure construction of the additional floors and interior work on the existing could begin immediately, whereas with a typical new construction project there is time to review the submittals and shop drawings as the excavation and foundations are under construction. This drastically shortened the review time for submittals and shop drawings so work would not be delayed, but increased the need for correctness and review so construction mistakes and disputes could be eliminated.

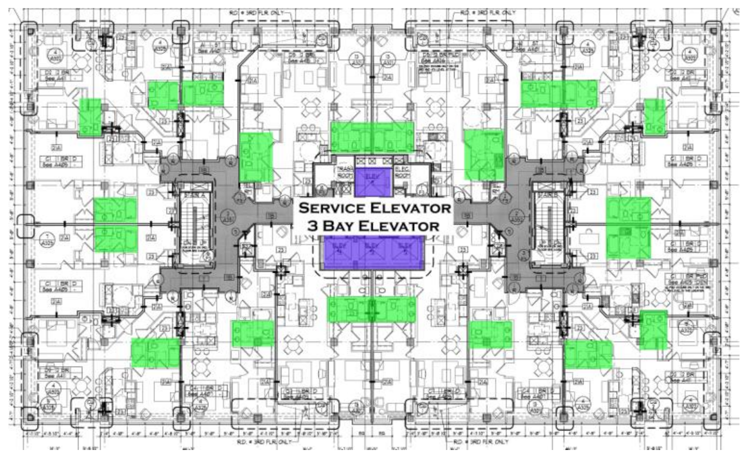
Reconfiguration

The second issue directly ties into the renovation topic described above and is due to the new building use. The existing building functioned as a commercial office building, supporting offices and open floor space for cubicles with centrally located mechanical and plumbing equipment. The electrical system was contained within a Walker duct system integrated into the concrete slab. The retrofit of these building systems for the new residential use, and the reconfiguration of the interior spaces, such as stair wells and elevators shafts, proved to be a large constructability issue.

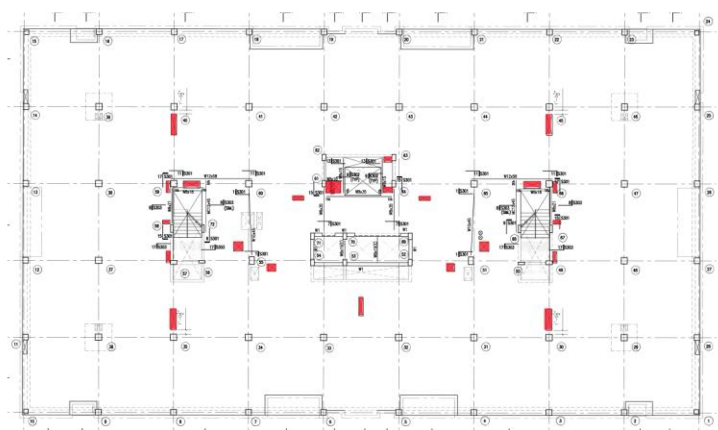
As for the mechanical, electrical, and plumbing (MEP) systems, new riser spaces were needed to supply the individual apartment units. New pipe and duct risers needed cut and cored through the existing slab while detailed information about the removed pieces was needed to calculate the amount of additional structural reinforcing. Approximately 25 new slab openings for duct risers and about 300 slab penetrations for plumbing were required. Electrical distribution via bus duct required slab cuts, but not nearly as many as the system remained centralized. A floor plan of slab cuts for ductwork and bus duct can be seen at right. These openings required a large amount of coordination as the slab cuts, mechanical and plumbing core drillings, and electrical core drillings were all performed by different subcontractors. The sequencing was also a difficult challenge in that work below the cutting and coring operation was limited and the operation needed to be suspended multiple times because of the storage of curtain wall below the active slab.



Existing floor layout with elevators in blue and restrooms in green.



New floor layout with elevators in blue and restrooms in green.



New slab cut locations for ductwork only. All plumbing fixtures require penetration.

The other large openings posing issues were the new stairs and elevator shafts. After demolition of the existing stairs, the opening was enlarged and shifted to center the stair towers. The demolition included removal of upturned and regular concrete beams, thus requiring the need for additional structural support by means of W steel shapes, as seen below. The steel needed to be placed prior to the demolition and thus the need for proper sequencing becomes vital. The necessary process for installation of steel, inspections, demolition, and reconstruction needed to be detailed so as to not create a possible hazard or delay. A similar process was required for the elevator shafts.

Demo of existing stair tower.

Structural steel reinforcing around stairs and elevator. Piece on lower left to be installed

Stored and installed curtain wall panels.

Residential Curtain Wall

The third constructability issue was the use of curtain wall on a residential building. Typically curtain wall is used on commercial projects that have centrally located mechanical systems and require no need for balconies or operable windows. The curtain wall on Crystal Plaza II has both, and because the entire façade is curtain wall, it provides no vertical surface area for exhaust or intake vents for the mechanical system, much like a commercial office building.

The curtain wall for Crystal Plaza II is custom designed to include operable windows and spandrel panels to cover exterior bay columns. Also included is the need to integrate doors for use of the designed balconies. These details create issues of interface and weatherproofing and must be taken care of in the submittal review process. The long lead time for the curtain wall, especially due to its custom nature, and the location of the manufacture not only present an issue, but put the curtain wall on the critical path. Also, as part of a renovation, the lower levels required field measurements of the structure to ensure a proper fit of the curtain wall panels.

As for mechanical exhaust and intake, all required duct work must go through or come from the roof, thus requiring more duct risers to preserve the continuous look of curtain wall on the façade. The operable windows help with maintaining a good indoor environment but increase the fabrication time of the wall panels.

Required Delivery

A final issue is from a discussion with the Project Superintendent and merits presentation. The project has a phased delivery of floors that requires multiple inspections and detailed coordination between all parties. However, of highest importance to the owner is the core and shell turnover of the first three floors. The challenge for the superintendent is to turnover three operable, occupancy allowable floors with the remaining floors to turnover within the following two months. This requires that all life safety components for the entire project be complete and online for the first turnover even with construction not complete on the upper floors. The plan of action was to “buy out” the electrical subcontractor for testing of the bottom half of the building early. This places an additional cost on the fire alarm panel reconfiguration once the whole building is online. However, this allowed the system to be tested early and to correct issues before the turnover. Also, with the early turnover, only three months of schedule was between finished framing on the top floors and the turnover. This left little time for completion of core and shell activities. The idea to solve this problem was to keep the floor cycle time the same, 10 days for framing, 10 days for rough in of each trade, and start all the subcontractors on the next floor five days into the cycle. This required larger crews, more supervision, and more coordination to avoid trade stacking, but allowed framing to be complete with 4 ½ months of schedule time to complete the core and shell activities

Schedule Acceleration Scenarios

The necessity to accelerate the schedule is often times employed on construction projects. Whether for unforeseen conditions that cause delays, extra time to complete complicated construction sequences, or bonuses for early finish the schedule is what finds itself at the forefront of the construction team's minds. Every discussion seems to revolve around the cost and effects to the schedule. Some material or sequence may be cheaper, but is it still cheaper when the effects to the schedule are taken into account? At Crystal Plaza II a clear critical path is present for construction, and it is not the same as that planned in preconstruction. The following discussion with the Project Manager and Project Superintendent show how the schedule has evolved throughout the project to its current state.

Preconstruction Critical Path

At the beginning of the project the critical path was though the fabrication and delivery of the curtain wall and glass package. This package was provided by a smaller company located 400 miles away in Buffalo, NY. The material had a four month lead time and could only be manufactured in groups because of the size of the order. The next activity on the critical path was the building dry in, or enclosure. This again deals with the curtain wall but also includes the waterproofing and roofing for a water tight structure. The need for dry in was to begin the interior trade work to meet the next goal on the critical path, final inspection and commissioning for occupancy. This activity is challenging as mentioned before due to the phasing required by the owner. The necessary inspections must occur seven times, once for each turnover to the owner.

Construction Critical Path

Not long after demolition began on Crystal Plaza II the project was placed on hold by the owner for four months. During this time the glass fabrication continued, thus allowing it to drop from the critical path. However, because of the delay, more activities became part of the critical path, especially after meetings with the owner discussing the finishing of the project.

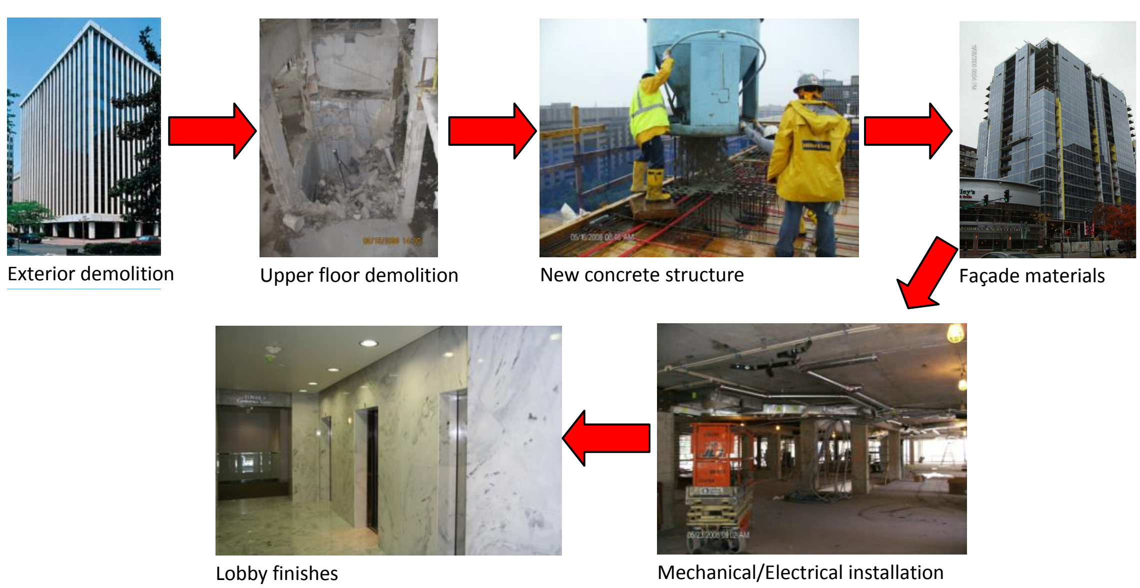
The first activity now on the critical path is demolition. The demolition of the exterior and top floors must be completed before construction can begin. This is where the use of the tower crane, having been installed two months early, to assist in removing components greatly helps. Following the completion of exterior demolition, concrete is next on the critical path. The interior demolition has some float due to the need of the existing stairs and the available area for trades to begin work, so it is not on the critical path. The concrete structure from floor 12 to 20 needs to be complete in order for curtain wall installation and interior framing and rough in to begin. The need for re-shoring and formwork storage limits the pace at which the other trades can move. Creation of a repetitious floor cycle of approximately four days helps this activity. The two primary risks with the concrete are proper placement of the stressing cables and imbeds as drilling will not be allowed because of the post tension cables, and the weather. A setback due to multiple days of bad weather can have a large impact on the schedule.

Following concrete is the installation of the curtain wall and weatherproofing systems for the building to be water tight. To expedite this activity, overhead protection was erected to begin installation of the curtain wall on the lower floors. The largest risk for this activity is the curtain wall itself. The ability for the manufacturer to keep up with construction is first on the list. The other risk is damage to the components because while many are repetitious, the curtain wall is a custom system.

Following water tight is two activities. The first of which is to complete electrical installation to allow the next item on the critical path, permanent elevator service, to occur. The other activity is heating. The need for the heating system to be online is crucial since expected completion for water tight is near to the winter months and the interior work requires a stable, controlled environment. To accelerate these activities additional crew were required onsite. For the electrical rooms required on each floor, a larger crew and overtime helped accelerate the schedule. Also with the electrical rooms, the use of mold resistant drywall was implemented, and while at a higher cost, allowed the electrical rooms to be completed prior to the water tight milestone. Because the need for the mechanical system was realized early on, a crew of eight workers was able to work overtime for approximately two months to finish the system.

The next activity on the critical path is the lobby. The required finishes, their lead times, the intricate systems to be installed, and the design revisions place the lobby as the largest risk to the project. The linear process for construction in the lobby is not helped by the long lead times for the materials or the design changes. The lead time for the interior stone is about four months. To overcome this limitation the stone work was released early without the framing complete for field measuring. The layout due diligence of the general contractor will be the key to the success of this activity. The millwork will be on hold until framing is complete to allow field measuring, but may need to be accelerated by the manufacturer through overtime during fabrication and installation. Overall, the lobby activities may need to be accelerated if some of the discussed issues become problems. To do this, the general contractor plans to work overtime on site and possibly create a trade stack situation in which the next trade will be allowed to start their work as soon as possible, forcing multiple trades to work in the same space.

Visualization of critical path



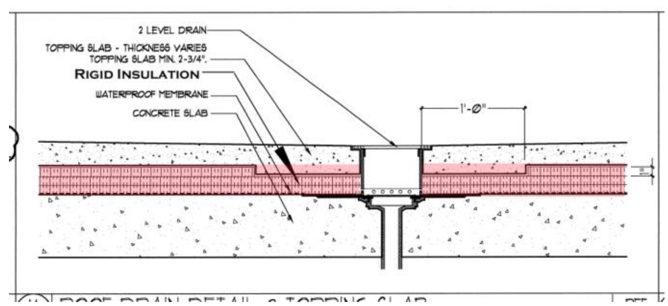
Value Engineering Topics

Crystal Plaza II provided a unique situation for value engineering during the four month suspension period that allowed the general contractor, designers, subcontractors, and owner to evaluate components of the project to find the best possible solution for the owner and their goals. Even after this suspension period, more ideas were presented by subcontractors as they submitted ideas that would help them in installation but not detract from the overall value of the project. Many of these submissions are still pending and are for smaller amounts of cost savings. The items of larger savings and influence on the project are presented in this section, broken into their respective discipline.

Mechanical Value Engineering

This discipline provides the largest area for value engineering at Crystal Plaza II. Many of the ideas and submissions from subcontractors involve changing the design or specified product to better suite their installation style or preference. This allows them to work with what they know and to potentially utilize new technology on the project. Some common, low cost savings and lost interest ideas included changing piping systems (rejected due to necessary redesign and excessive cost of redesign), using standard mixing valves over electronic valves (pending), and removing other components.

The first large item for value engineering is the change from R30 rigid insulation to R20 rigid insulation on the roof slab. The original design specifies R30, however during the submittal review process the subcontractor noted on their submission that R30 insulation would be thicker than that shown on the drawings for around the pool area, thus causing a conflict with the topping slab elevation. After review it was suggested to change to R20 insulation throughout as it met the required elevation and allowed for a significant cost savings, $20,000. After review by the designer, the request was accepted because the R20 insulation will not drastically reduce the buildings ability to perform.



Detail showing designed roof insulation.

Another large value engineering item is the removal of insulation and heat tracing on apartment supply pipes from the recirculation risers. Original design has insulation and heat tracing to provide nearly instantaneous hot water to all fixtures, no matter the distance from the risers. After consulting with the owner, it was decided that the longer wait for hot water was acceptable and a cost savings of $175,000 was available. This may seem like cutting cost, but because the system did not require the heat tracing, there was no required electrical work and by not installing insulation, the plumbing crew saved time. Also, this allowed the plumbing branches to be installed before the building was water tight and did not hold up “close in” while they were heat traced and insulated.

Finishes Value Engineering

The finishes value engineering accounts for a large portion of the estimated cost savings on the project. Given the owner's goals of a high end apartment, the finishes required are of the highest caliber and require skilled trade's people to install. It can be easily seen why so much effort has gone into value engineering the finishes to allow for a high end look with a low price that can be installed by the standard trades.

The first value engineered item saved between $225,000 and $500,000. The original design shows stainless steel and glass balcony railings for all balconies. This setup required an imbed in the concrete and custom connection, as well as custom welding to attach the railing system. The alternative suggested was to use an aluminum and glass railing system that matched the imbed base plate, and required no special connections or welding that could not be performed by the standard trade. The selling point for the owner was the view from the street. The balconies begin on the 14th floor and from the street, it is impossible to distinguish between the two finishes. The variance in cost savings is due to the possible redesign of the system.

Another large item is the use of granite for countertops and toilet partitions in the general bathrooms and locker rooms in lieu of a cultured marble finish. The use of granite ties into the countertops in the lobby area and the individual apartments that allows economies of scale. The granite still provides a high end finish but has a lower cost than the cultured marble, both of which are important to the owner. The potential savings are about $37,000.

As for finishes within the apartments, two ideas for value engineering were presented that had high cost implications. The first was to use a painted drywall pocket/bulkhead to house the shading system for the curtain wall. This system was to replace the designed aluminum chamber and was accepted for a cost savings of $200,000. The use of a drop bulkhead from the finished drywall ceiling still provided a continuous look and met the owner's goals. The second suggestion was to replace the rolling shading system with 1" louvered blinds. The estimated cost savings would have been around $200,000 for the low tech system, but was rejected by the owner because it didn't meet their criteria.

A final value engineering idea was presented for the exterior stone façade. The 1 ¼ "exterior granite façade was suggested to be replaced with a thinner ¾ "granite cladding. While the finish remained the same, the quality and durability of the thicker system, as well as the redesign costs for proper alignment with the curtain wall and store front systems prevented the change. Also, estimated savings were only $14,000.

LEED Value Engineering

The final area of value engineering is those components dealing with LEED. Often times it seems this is the area that undergoes cost cutting rather than true value engineering. Many of the designed features for sustainability are often eliminated because higher first costs are only compared, and not life cycle costs or the effects of the product on the environment. An overall benefit to all of the components discussed is the owner's ability to market the building as green upon its completion.

The first component to be considered was the requirement of wood. LEED credits EQ 4.4 and MR 7.1 require the use of wood 100% free of urea formaldehyde, and 50% certified by the Forestry Stewardship Council (FSC), respectively. Initially, both points were considered; however, a review of the wood on site now seems to make both points unobtainable. Primary use of wood on site is in five areas: Millwork, Trim, Unit Cabinets, Pre-hung Doors, and Miscellaneous Blocking. As for millwork, it is primarily high end veneers and located in the lobby. There is no FSC certification available for these high end veneers, but there is a possibility for UF free. The trim is both FSC certified and UF free, while the unit cabinets are not FSC certified, although they are KCMA certified (a voluntary certification by the manufacturer), and may require a cost increase for UF free. The pre-hung doors are UF free but require a substantial cost increase for FSC certification. And finally, all blocking is FSC certified and UF free. Therefore the owner has decided not to pursue credit MR 7.1 due to high costs and still would like to obtain credit EQ 4.4. With the millwork certification not possible and the difficulty of using 50% certified wood, this is understandable. The cost savings on the veneer alone is $70,000. As for the EQ 4.4, the determination for continuation is dependent on the cabinets. Pending the results of the research, the credit will be dropped if there is a substantial cost increase.

The next component deals with the individual unit mechanical systems. LEED credit EA 1, Optimizing Energy Performance, was removed from the project because the mechanical units in the apartments could not meet the requirements without costly redesigns and more expensive equipment. The owner was still undeterred by the cost increase but the logic behind the removal of this credit deals with the unitized residential layout that requires more mechanical units.

In more of a design revision situation, the pursuit of LEED credit SS 7.2, Heat Island Effect Roof, was dropped. Initially the roof was to receive a white or highly reflective roofing material in non occupied areas. However, it was decided that with the pool and social areas, the white roof would be too reflective and cause glares for the residents. The cost associated with the white ballast roof had a minimum premium over the standard roofing system that replaced it.

A final LEED value engineering component deals with LEED credit WE 3, Water Reduction. The first of which was a rejection from the mechanical engineers. The plumbing subcontractor submitted a request to use standard water closets instead of the specialty dual flush type specified. The idea was to install a standard product that allowed for a high end look, but still cost less. However, the idea for the dual flush water closets was to save water, and therefore without them the water reduction credit could not be achieved. The second idea was to switch the standard fixtures for showers, lavoratories, water closets, and kitchen sinks to low flow fixtures. The same high end look was available for the low flow fixtures, but at a cost premium of about $10,000. This submission is still pending owner approval and may not include the water closets. However, if water closets are included a cost savings could lower the premium because the dual flush system may be higher in cost than the low flow system.

Problem Identification

As with all construction, issues arise, are reviewed, and a response is given as to the direction of the work. Many times this process produces solutions that may not be as well thought out or planned as they could be, and while not wrong or harmful to the project, research into alternatives could provide a better base of knowledge to respond to future situations. The review of the constructability issues in the previous sections provide background from those individuals working on the project every day. This section provides an opportunity for expansion of those ideas and presentation of others that may benefit from analysis and tools that are part of the Architectural Engineering curriculum.

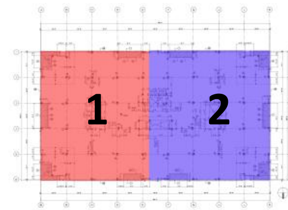
Concrete

The first area of problem identification is concrete. This includes construction of new floors, work sequence, modifications to existing floors, and any other activity dealing with concrete on the project. The problems are bullet pointed below with an explanation of the potential issue and questions for possible research.

- **Existing Slab Leveling Sequence/Schedule Timing-** This is an extremely time and area intensive process. The process was delayed until late in the game, thus causing additional issues with already framed walls, core drill holes for risers, and installed risers. By allowing other activities to begin before the floor leveling, additional time was spent because of the unlevel floor and later by the floor levelers to level around obstacles. After the start, the floor levelers worked in a sequence that had them working on half a floor every other story for three stories. This was required to allow other crews to work and for the balcony installation process that required the man/material hoist to be closed on those floors. What processes could have taken place to allow the activity to start earlier? Could the other activities have avoiding placing the obstacles or would that put them behind? What other products are available and could have been used that would make the process easier? Is there another sequence that would have prevented moving material among so many areas?

- **Concrete Pour Sequence-** The sequence utilized by the concrete subcontractor used a two pour per floor sequence. This sequence allowed for work to continue on one side as material was stored on the other. The sequence, with pictures, is on the following page. Typically floors are broken into three or more pours to allow area for work, area for storage, and an area that is being poured. While the sequence on Crystal Plaza II did allow for finish ahead of schedule, would sequence flow better with a three pour breakup? Would this allow for a better layout that could increase efficiency and not require overtime makeup if a day is missed? Would this sequence allow for concrete placing everyday instead of every other with a few days between floors?

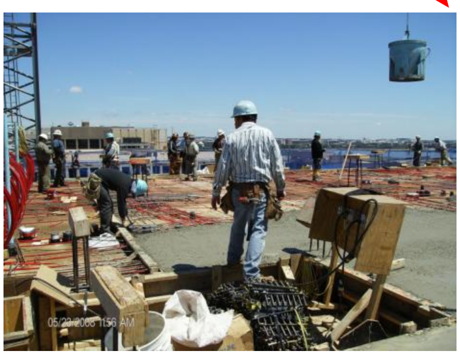
1. Form area 1, materials stored area 2 below on top of concrete
2. Continue forming into area 2, lay cables and imbeds in area 1
3. Pour area 1, lay cables and imbeds area 2
4. Pour area 2, form area 1




Step 1 Form area 1 with materials in area 2 below


Step 2 Form area 2


Step 2 Cable/imbed layout area 1


Step 3 Pour area 1, cable/imbed area 2


Step 3 Pour area 1


Step 4 Pour area 2, begin forming area 1 above

- **Coordination of Slab Imbeds-** This task proved to be critical in nature and allowed little room for error. Pre-pour inspections were necessary to ensure all imbeds, riser sleeves, and riser box outs were in place and the correct size. With the network of post tension cables, drilling or cutting the slab is not allowed. Fatal repercussions could result from damaging a stressed tendon during the cutting or drilling operation. In the case of the balcony railing system, an assumed imbed layout was used, as the balcony system had yet to be approved. This created a large issue later when the post layout did not match the layout of the imbeds. The solution is still under review.

- **Design for Construction Loads-** In a height limited environment, it is necessary to utilize all possible ways to maximize usable space. To achieve this at Crystal Plaza II, the post tension slabs were designed for residential loading that required them to be 6" thick, in the typical case. Some areas did require thicker slabs. However, on the 19^{th} floor the slab for the 20^{th} floor is 16 feet above the 19^{th} floor slab, rather than the typical 10 feet. The mechanical subcontractor began to use a scissor lift to perform work and this created issues with the slab as it was not designed to support the construction load. While this should have been realized, the result of the situation caused a slight delay as the concrete was repaired and the mechanical work continued with the use of a time intensive scaffolding system.

- **Core Drilling/Slab Cutting for MEP Layout-** This issue spans into the mechanical discipline but has more impact on the structure. Due to the requirements of the layout, core drilling and slab cutting for MEP risers, the existing structure lost a majority of its reinforcing strength, and therefore required the addition of carbon fiber reinforcement (CFRP). The CFRP was already utilized on the job to strengthen critical columns to support the load of additional floors and the roof top pool. However, it is now required at select locations on the underside of the existing slabs. CRFP is very expensive and time intensive to install. While only about 6-10 pieces are required per floor, this is not enough to make it economical in the least. Also, the CFRP must be fireproofed to provide a two hour rating, which is also expensive and time consuming. Finally, on top of negative implications, installed work, such as ductwork branches and wall framing, had to be removed to install the CFRP. Is there a better way to route risers or layout the MEP system to limit the amount of slab penetrations (currently over 350 per floor)?

Curtain Wall

This section describes problematic areas dealing with the curtain wall system. Curtain wall is not a typical residential façade material, however it does add to the high end look desired by the owner.

- **Site Logistics/On-site Storage-** As mentioned earlier, the curtain wall system is provided by a smaller manufacturer located in Buffalo, NY. This presents many issues as discussed earlier, but primarily the potential for delays using just in time delivery if the delivery is late. Given the storage potential in the underground parking area, if may have been beneficial to continually deliver the curtain wall units and store them on site. This may produce issues with protection, security, and equal storage areas for other trades, but may also increase the efficiency of the installation of a material on the critical path.

- **Installation-** The current installation time for the curtain wall is long. Overlooking the current delays of the material, the installation process is tedious and difficult in itself. Single pieces are lowered into place from the floor above, attached, and then sealed. This process also requires a large amount of space for the equipment and material storage. Also of interest is the time intensive process of installing the clips in the existing concrete along its vertical surface on which to mount the curtain wall system. Would it be possible to install the curtain wall sections in small groups of two or three that are prefabricated onsite and then lowered into place? Also is there an alternative method, say placing the clips on top of the existing slab, to installing the support clips?
- **Weatherproofing-** Again, because curtain wall is not a typical residential façade material issues with flashing and weatherproofing have become noticeable. The system is water tight; however the flashing details prove to be a complicated issue to resolve. How should the system be flashed given a typical façade material has an interior space that serves as a potential backup for weatherproofing? How should the system be flashed at balconies and door ways to keep water from entering the system?

Technical Analysis Methods

This section is intended to expand on the problematic issues discussed in the previous sections into research topics. It begins to break out questions and analysis techniques to research possible alternatives to the solutions proposed during construction or to issues not yet encountered.

LEED vs. Green Globes

Currently the Crystal Plaza II project is pursuing a LEED silver rating. Material selection and construction techniques have been implemented, along with design decisions, to complete the requirements for the certification. However, as construction progresses, the general contractor, subcontractors, designers, and owner are witnessing firsthand the difficulty in building sustainably. While many of the involved parties have sustainable building experience, it is an observation that the experience with high performance buildings is not as readily available as was originally anticipated. General contractor and owner “value engineering”, as seen in an earlier section, often cuts out those components intended to make the building more sustainable. While already in the process for LEED certification, research into an alternative strategy could prove beneficial. Researching the outcome of the current condition of the project within the Green Globes assessment may provide a ranking system that allows the involved parties to eliminate some features, while still achieving a reasonable certification. While Crystal Plaza II is on track to receive some type of LEED certification, the overall picture of sustainability should be realized, and not the goal of achieving a certain level, as most often is the case. To perform this analysis a detailed breakdown of design policies and construction practices to achieve LEED points, as well as the current LEED checklist, will be required to compare and insert those results into the Green Globes system. Conversation among the owner, general contractor, and designers will be imperative to verify and access the feasibility of credits. The final product should be an in-depth look into the possibility of certification by Green Globes and/or LEED as decisions are made, a tracking log with reasoning behind elimination of sustainable features including owner comments, and feasibility of obtaining certification. This also allows a connection to graduate level studies in sustainability and a possibility for breadth in research.

SIPS for Trade Workflow through Modeling Medium

The intended research into SIPS and trade workflow has direct ties to the construction management option. Given the sequence at Crystal Plaza II, it lends itself nicely to a SIPS type procedure with repetitive work in nearly repetitive areas. Using a previously created model and showing various trades and their location by solid shapes, a 4D model can show progress throughout the structure. This would have been extremely beneficial early in the project for various reasons. For example, as discussed earlier, with no excavation, interior rough in could begin in the existing structure immediately. This created some sequencing issues as one trade ran into another and then just jumped floors to find an open area to work. To avoid this situation, the model would show on a large scale where and when a crew was performing work. On a small scale, a specific trade could have a SIPS procedure for each floor for the repetitive activities. For example the plumbers could use the large scale model to locate the floor of the activities and see how they are to progress if the sequence is complicated. Then on a daily basis the can review the SIPS to stay on schedule and perform the tasks as efficiently as possible. The SIPS for the plumbers may include risers and mains, branches, and initial apartment hookup, as well as individual unit plumbing for repetitive units. The SIPS would include a visual representation that can show material storage, daily completion requirements, and traffic areas. Reasonable deliverables would be a 4D model showing “parade of trades” with SIPS procedures and visuals. The SIPS materials would be for a selected trade and would include the necessary components with background materials and discussion with that trade. This also provides a link to graduate studies within the Architectural Engineering major.

Utilizing Generator Backup to Shift Peak Demand and Produce Revenue

As part of the emergency backup system at Crystal Plaza II, a diesel generator is being placed on west side of the roof top level, between the cooling towers. The generator, currently unknown size, is designed to provide power to all emergency systems within the building. Rather than letting the paid for system remain idle until its needed, the generator could be used during times of high peak load to either supplement power from the grid, in effect lowering the demand of the building, or to sell power at a commodity rate back to the power company. Another possibility is a program called demand response in which the power company enters an agreement with a facility to buy a given amount of power, if needed, to help meet demand loads. There are differing levels and requirements available through this agreement as to amounts, times, and ability to produce. Using this installed system to produce revenue or offset cost may speed the payback period for the system. Detailed research into power rate structure and feasibility of the idea will be required. A potential best and worst case scenario for energy production would provide an acceptable deliverable. Also, researching the local availability to demand response to inform the owner of the opportunity of profitability from an otherwise idle system would serve as a goal. This topic again has direct ties to a graduate level course and a previous internship experience that can provide valuable resources. It also can provide an area of breadth for research.

Centralization of Primary MEP System

The general idea behind this topic is to expand on the issues evolving from core drilling and slab cutting for the reconfiguration of the interior space. While some of the penetrations are warranted, it seems an excessive amount have been used to simplify the system. The original design of the building at Crystal Plaza II had centralized systems in terms of distribution. The risers followed either stair tower or the elevator shafts and then branched out over the floors. However, this is common in a commercial building where large spaces are conditioned and served by the same equipment. This is also common because of the likelihood of repetitive floor plans that stack areas such as electrical closets, HVAC equipment/closets, and restrooms. This is not the case in residential construction when all the units require individual control and an individual mechanical unit. Also, the restrooms, while still having the possibility to be stacked, are much more numerous and dispersed throughout the floor area. The result of the slab penetrations is additional strengthening materials for the slab that are costly and time intensive. To avoid these costs and time delays, research into an alternative distribution system is considered. The continual use of the centralized riser areas that exist on the lower floors will be evaluated for feasibility of handling the new loads as well as a cost and time impact for the new piping layout and labor required. A direct comparison of cost and time can determine the best choice. Also, discussion with the responsible trades can produce valuable information as to the given choice of system and how issues may be avoided in future cases. Utilization of a 3D model to show the potential differences in layout and coordination required for a specific trade is also a goal. This topic allows for breadth research of mechanical systems and design.

Building Integrated Photovoltaics (BIPV)

A final area of technical review is in the developing field of building integrated photovoltaics. The idea for this topic stems from independent research conducted with Architectural Engineering and Architecture faculty. The use of an integrated photovoltaic system can have profound effects even when some surfaces receive little solar radiation. Reflection of solar radiation from light colored hardscape, adjacent buildings, and other sources often produce significant energy to create power. Given the façade material at Crystal Plaza II and its new construction nature, implementing a BIPV system within the curtain wall and roofing surfaces provides an excellent opportunity to produce energy that can be utilized in much the same way as the generator. Onsite production of energy also provides the potential to lower tenant's energy bills or even "zero out" the buildings energy use completely and earn LEED credits. Research into possible systems, their efficiency, and cost implications will be considered. A detailed breakdown of production and cost savings/earnings will also be a goal. This section can be combined with the previous section dealing with generator use into one section if time becomes an issue. The resulting topic would be titled "Demand Response and Energy Production for Profit". This topic again allows for a breadth research in sustainability, renewable energy, as well as interdisciplinary research into constructability, estimating, and scheduling as the primary medium for BIPV is the façade, which is on the critical path.