Steel City High-Rise

Technical Report 3

Senior Thesis

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Project Location: Pittsburgh, PA

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Executive Summary

The following technical report relates to the methods and challenges of the construction of the Steel City High-Rise in Pittsburgh, Pennsylvania. This $100 million structure will be located in the heart of downtown Pittsburgh, Pennsylvania and will offer retail space, office space, a parking garage, and hotel amenities. This report will cover an analysis of the project schedule, value engineering opportunities, constructability challenges, BIM practices, critical industry issues, and potential research options.

The critical path of the project is heavily dependent on the structural steel of the building. The systems within the building are fairly simple and the majority of the building is core and shell, so the fabrication and steel erection are the primary drivers of the schedule for the duration of the project. The schedule was arranged around sequences of steel and translated to splitting the building according to occupancy type, as well as per floor.

Being that this is a high profile project that will be prominent landmark in the Pittsburgh skyline, Value Engineer was considered only when the quality and aesthetics were not compromised. The owners were very money conscientious and made sure that they thoroughly understood what the gains and losses were for every decision and potential change for all aspects of the project. The value engineering discussions not only focused on the upfront costs of products and materials, but also the lifespan effects and schedule impacts as well.

Building Information Modeling (BIM) is a tool that becomes more widely used each day in the construction industry. There are a variety of opportunities and strengths that BIM can offer a project before, during, and after construction; however, the project team for Steel City High-Rise was unable to take advantage of this opportunity. Despite the project being unable to implement BIM in the project, this technical report investigates the benefits that could be gained from using BIM on such a project.

Critical industry trends are constantly evolving and developing with each passing year. At the annual PACE roundtable, there were several opportunities to discuss the new leading trends that are most common throughout the construction industry as a whole. This report will go into details regarding the sessions that covered the implementation of innovative design and sustainability in the global community.

Schedule Acceleration Scenarios

Critical Path

The critical path of a project is always a crucial part of the planning for both the schedule and budget of the project. Turner Construction recognized the risk of delays in the project schedule, so they initially planned for a completion two months prior to the required turnover date in order to give them a cushion if any part of the critical path were to fall behind schedule. The most critical element for maintaining the schedule is the structural steel, closely followed by the weather.

With regards to the steel, there was a lot of stress revolving around the time it was taking to fabricate the major structural elements for the building. The foundations team managed to fast-track their work prior to steel arriving on site; however, the structural designer was not able to design and

detail the steel members fast enough for their fabrication to be completed at the time of the foundation work completion. There was approximately 1.5 months between the completion of foundations and the first 4 sequences of steel arriving on site, so that time was supplemented with various utilities and site work instead.

Upon the arrival of the steel, significant progress was made with the erection of the podium (the first 3 floors) which included the first 7 sequences of steel as detailed by the erector/fabricator (Amthor Steel). Unfortunately, Amthor Steel was working around the clock with two of its shops dedicated solely to the fabrication for this project and they were still unable to keep a steady flow of fabricated steel deliveries. Luckily, this did not set the project back by much and it is still set to be completed prior to the date originally suggested.

During this time, weekly subcontractor meetings with the General Contractor were held as well as Owner-Architect-Construction Manager meetings. A reoccurring topic was always how to accelerate the schedule which remaining cost-effective and not sacrificing the quality or the safety of the project. It was suggested that manpower be added to the project in order to fast track the parking garage and office portions of the building. The team ended up deciding that this was not an effective solution because those areas of the building were core and shell; therefore, the cost to accelerate those portions of the building wouldn't actually save time or money in the end. The hotel is a large part of the critical path with very detailed and specified finishes and interior work, so it was determined that it would be more effected to have additional manpower at the end to accelerate the finishes trades.

Another problem with the fabrication of the steel resulted in the structural engineer being in another state. The distance made it difficult to communicate and stress the importance of having the steel detailed for certain dates to maintain the schedule and it was not always easy to coordinate phone calls and meetings between the engineer and the rest of the project team. At one point there were issues with the load bearing walls and stairs being detailed and designed incorrectly. Correcting these mistakes caused a delayed in the fabrication and erection, as well as the drawings and details not being released early enough for the anticipated schedule.

In addition to the steel largely impacting the schedule, the weather is a huge concern. Pittsburgh winters can be unpredictable and difficult to work in. Unfortunately this project is scheduled to have much of the erection and structural work to be ongoing throughout the winter months. This can potentially cause major delays because it is not safe for the erection crew to be out in the bitter cold or if ice were to accumulate on the steel it would be a safety hazard.

Value Engineering

The construction industry is typically driven by cost, quality, and safety and can often times be difficult to achieve the desired goals for all three of those components. Throughout the planning for the Steel City High-Rise various types of value engineering were discussed and many of them were implemented as well. The main item that were considered, but ended up not being in the beset interest for the project as a whole included the deletion of window washing buttons for the window washers. The owner ended up feeling more comfortable and safe with keeping the buttons in place for the caution and well-being of the window washers.

The value engineering items that were implemented related to MWBE participation, the swimming pool, storm tank, wall bases, decorative walk finishes and materials, and drop ceilings. In

regards to the MWBE participation, it was determined that it was necessary to deleted the requirement from all but 4 bid packages. The owner decided that he could meet his MWBE requirements with 4 of the subcontractors and saved money by removing the requirement from the rest of the subcontractors. By eliminating this requirement the owner saved by not having to pay as much for the premium required for MWBE participation.

An additional VE item was the removal of the swimming pool in the hotel portion of the building. The owner's decided that the occupants staying in downtown permission would not use the pool frequently and the space could be better served for other purposes. This elimination ended up saving the owner approximately $80,000. Additionally, in order to earn a LEED point on the project it was initially designed to have a storm water tank that was to filter the storm water away from the building and sift it down through the earth again. The tight footprint of the building and close proximity of the surrounding buildings made this a huge risk factor as the storm tank could potentially cause flooding in the basements of the old surrounding buildings. The team was able to remove the tank without losing the LEED Silver rating by tapping into existing manholes in the street and they paid a fraction of the price to get permission from the local water authority to have permission to eliminate the tank.

Another opportunity for value engineering came from changing the fine wood bases that were designated for level 2 and replacing them with a mock rubber base instead. This ended up saving money in both the material and installation costs for the base. Similarly, it was decided that the exterior walks on the roof and around the footprint of the building would be changed from rustic terrazzo to a broom finished concreted to save nearly $20,000. Finally, the last of the value engineering opportunities that was implemented included the removal of the drop ceiling and batt insulation on level 11 of the parking garage. It was replaced with 3.75" of closed cell foam and 1.25" of URE-K spray insulations. This change was able to provide a similar quality and performance, while saving on the material and installation costs.

Constructability Challenges

As expected with any construction project there were numerous constructability challenges that the project team was tasked with overcoming. Among these challenges were site congestion/limited footprint, incorrect details for the exterior wall, and drawing discipline discrepancies.

With regards to the congestion and tight footprint, the new structure is going into a very congested area in the heart of the city. The footprint was surrounded by buildings on 3 of the 4 sides and the fourth side was abut with a street known for both pedestrian and car traffic. Another complication with the site footprint was that the surrounding buildings were not perpendicular to the footprint which caused the designers to reorient and redesign many of the exterior walls in order to coordinate with the existing structures. This resulted in there being a maximum egress width of 5 feet around the building. Not only did this cause complications with site traffic and equipment, but it made finishing the exterior of the building difficult and in some cases impossible for the original finish plans.

Of the exterior detail complications, one of the main ones resulted in the redesign of the fire protection plans for an exterior brick wall. Along what the drawings denote as 11-line, there are plans for block to be laid up to the beams at that location. The beam is detailed to be wrapped with spray-on fireproofing; however, there is not enough space between the beam and the neighboring building to

have both block and spray-on fireproofing. The solution to this constructability issue resulted in the block and spray-on fireproofing to be replaced with a bent plate that was capable of achieving the desired fire ratings.

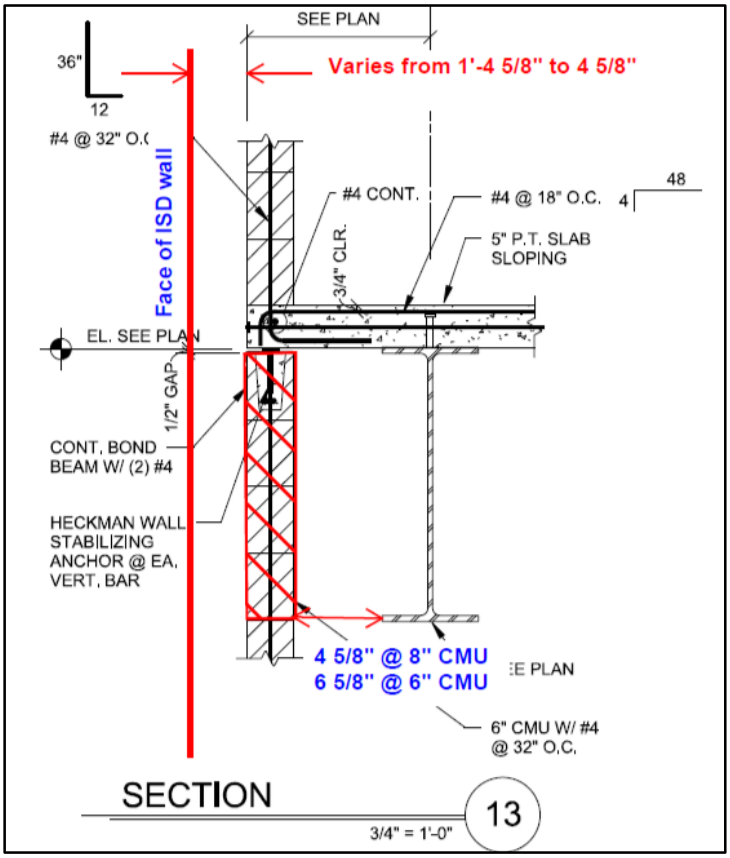

Figure 1 : RFI Limited Space for SFP by Turner Construction

Additionally, along the exterior walls there were joints and sill conditions at windows that did not allow for the joints to be serviced. This issue was discovered during a meeting between the subcontractors and designers and it was determined that a submittal regarding the matter would be issued. The conflicts were resolved by redesigning the details for the metal panel and curtain wall joint details.

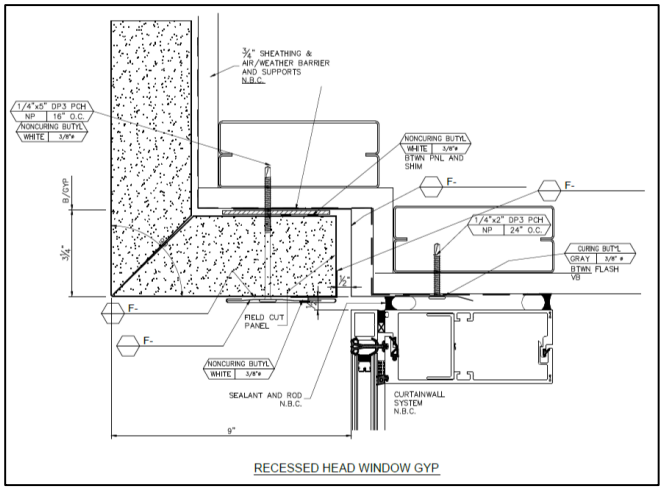

Figure 2: Submittal 0005 - 074213 – 0 Turner Construction

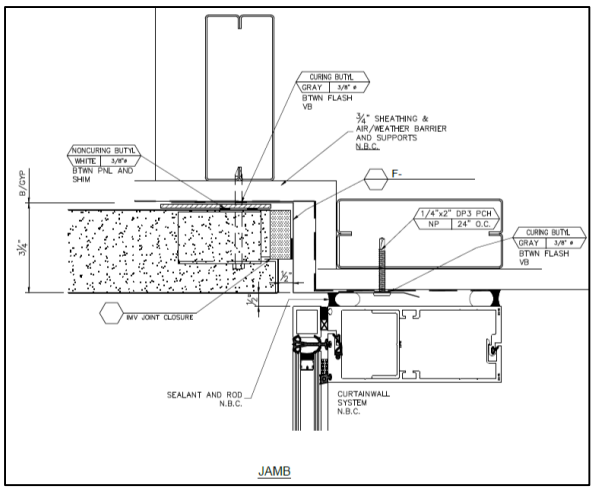

Figure 3: Submittal 0005 - 074213 – 0 Turner Construction

A final constructability challenge for the project was the reoccurring discrepancies between the structural drawings and the architectural drawings. This was due in part to the lead architect changing in the middle of the project, as well as miscommunication as to where elements of the building were to be dimensioned according to structural components versus the architectural finishes. After RFIs and meetings between the architect and the structural engineer, the drawings were corrected and the construction continued.

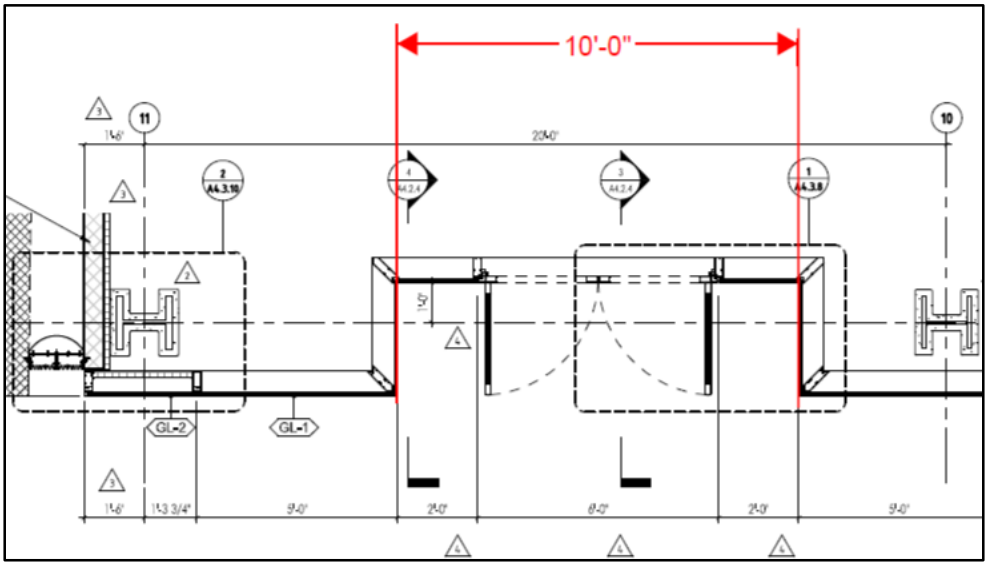

Figure 4: RFI 166 - Conflicting Structural and Architectural Dimensions on Entrance Returns – Turner Construction

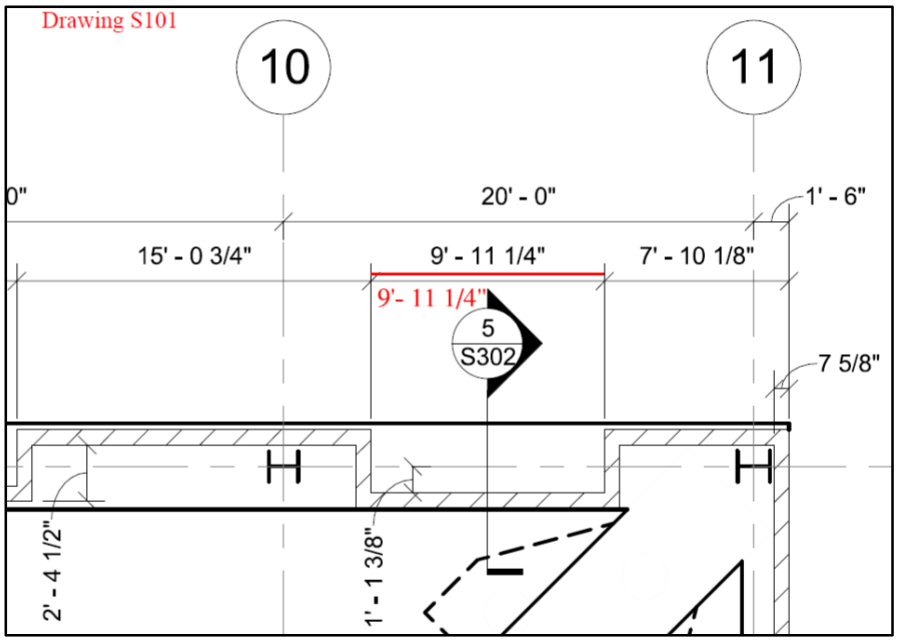

Figure 5: RFI 166 - Conflicting Structural and Architectural Dimensions on Entrance Returns – Turner Construction

BIM Use Evaluation

For the Steel City High-Rise, there was no BIM plan established or utilized. The MEP was all contracted as a design build where much of the design was finalized after the structure drawings were sealed and released for construction. Additionally, much of the building is core and shell due to the retail spaces and offices waiting for tenant fit-outs, as well as the parking garage requiring minimal building systems. While BIM was not critical for this project in particular, the implementation of BIM is becoming more and more beneficial and common throughout the industry. The main reasons in which a project may use a BIM execution plan would include coordination and clash detection between various trades that will have systems in the building, quality control, safety plans, and for tracking progress through 4D modeling.

If I were to develop a BIM Execution Plan, I would choose to focus on site utilization planning, 3D coordination, phase planning (4D Modeling), and existing conditions modeling.

X	PLAN	X	DESIGN	X	CONSTRUCT	X	OPERATE
	PROGRAMMING		DESIGN AUTHORING	✓	SITE UTILIZATION PLANNING		BUILDING MAINTENANCE SCHEDULING
	SITE ANALYSIS		DESIGN REVIEWS		CONSTRUCTION SYSTEM DESIGN		BUILDING SYSTEM ANALYSIS
		✓	3D COORDINATION		3D COORDINATION		ASSET MANAGEMENT
			STRUCTURAL ANALYSIS		DIGITAL FABRICATION		SPACE MANAGEMENT / TRACKING
			LIGHTING ANALYSIS		3D CONTROL AND PLANNING		DISASTER PLANNING
			ENERGY ANALYSIS		RECORD MODELING		RECORD MODELING
			MECHANICAL ANALYSIS				
			OTHER ENG. ANALYSIS				
			SUSTAINABLITY (LEED) EVALUATION				
			CODE VALIDATION				
	PHASE PLANNING (4D MODELING)	✓	PHASE PLANNING (4D MODELING)	✓	PHASE PLANNING (4D MODELING)	✓	PHASE PLANNING (4D MODELING)
	COST ESTIMATION		COST ESTIMATION		COST ESTIMATION		COST ESTIMATION
✓	EXISTING CONDITIONS MODELING	✓	EXISTING CONDITIONS MODELING	✓	EXISTING CONDITIONS MODELING	✓	EXISTING CONDITIONS MODELING

Figure 6 : BIM Uses from bim.psu.edu

Site Utilization Planning

Site utilization planning is a BIM process that is used to represent both permanent and temporary facilities on site throughout the duration of construction. These are typically graphically represented and are most beneficial when linked to the project schedule to help with sequence planning as well. The benefit to using this for the Steel City High-Rise would be great due to the fact that the footprint is very limited and the site will quickly become congested. By utilizing this BIM resource it would allow the team to quickly identify and avoid any issues that could arise from time and space constraints as well as coordinating deliveries, various trades, equipment, and material storage. Effectively planning these components of the project ultimately can help increase the safety around the site as well.

3D Coordination

3D coordination planning is a process that allows a project team to determine field conflicts and clash detection by combining the various building system 3D models. By determining these clashes and conflicts in the model, it saves the schedule and the budget of the project by preventing these issues from arising in the middle of the installation and construction of the systems. If these conflicts were not caught early enough it could cause major delays and change orders to redesign the systems, to remove in-place systems, to change the sequencing, or any combination of the three. Additionally, it can reduce the number of RFIs and bulletins on a project and in some cases it may actually reduce the cost or duration of the project by showing how productivity can be improved and increased.

Phase Planning (4D Modeling)

Phase planning is the merger of a 3D model with the schedule of the project to give a 4-dimensional model of the project. It is used to aid in the planning and sequencing of a project, while adhering to the requirements and space available for the construction site. The phase planning can be beneficial to all parties involved in the project from the design team to the construction manager, to even the owner or future occupants. Having a tool that can visually relay the details and constraints of the project allows the various groups to have a better understanding of the decisions that are made and why the schedule is organized the way that it is. It has all of the benefits of the 3D coordination, but it also adds in the space constraints as the schedule progress and new trades are present on site. It ultimately allows the site to be readily operable and well maintained from start to finish.

Existing Conditions Modeling

Existing conditions modeling is used to model the existing conditions and facilities of the site in 3-dimesions. This model is good preparation prior to the demolition of the site to best predict and coordinate where old utilities and tie-ins will exist. For the Steel City High-Rise there were several utilities that were found during the demolition phase that were too old to have ever been properly documented, so this would have been beneficial to have in order to update the existing conditions throughout the construction process. It also can be implemented in the future 3D and 4D models and used for the lifespan of the building and building maintenance over time as well. In fact, one of the most useful aspects of this model may be that it helps with both pre-disaster and post-disaster planning that the site could potentially encounter.

Critical Industry Issues

As previously mentioned, of the many discussions that were offered at the annual PACE roundtable, I personally attended the sessions that covered the implementation of innovative design and sustainability in the global community.

During the first session there was a large focus on the international successes and failures that the United States has the opportunity to learn from. This is an occurring phenomena in various industries and not just the construction world, but the United States seems to be slow in adapting to some of the successful foreign policies. This question of why the United States is slow to implement these practices sparked the question of what environment for a project team tends to spark innovation.

In a previous discussion that day, Ken from Southland Industries discussed new tactics for how they develop innovation on their projects. Southland Industries is putting a new focus on chemistry between the various parties on a project team, rather than allow cost alone to drive the people chosen for the project. From there they then have occasional meetings that exclude the project manager and superintendents and instead get the field team together to brainstorm new innovative ideas for how to improve the schedule, the quality, the processes, and any combinations of the two. By doing this they are removing the people from the conversation that tend to handle these situations in the way that they are familiar and comfortable with and that often prevents any chance of innovation occurring. Many of the attendees at PACE were alarmed by this method because they saw this as a weakness to not have a distinct leader present for these conversations and decisions; however, I saw their hesitation despite Southland's success as proof of how engineers can see innovation as a risk and limit themselves. Ironically, those people who saw Southland's idea as radical were showing how being set in our ways really does stifle innovation. After all, some people say without risk there can be no reward.

Additionally, incentivizing innovation and encouraging a design charrette were discussed as potential ways to increase innovation in the construction industry. A charrette can vary slightly from project to project, but the overall idea is to have sessions in which a group of designers and team members get together to collaborate and brainstorm potential ideas and solutions through dialogue. The general consensus of the group felt that this was best achieved through the collocation of the project team. Steel City High-Rise was the perfect example for whether or no collocation can actually make a real impact on the success of a project. The majority of the project team was collocated with the exception of the structural engineer and the architect and those were the only two disciplines or areas in which there were issues with coordination, communication, and expectations.

In the second session regarding sustainability in the global community there ended up being some overlap with the ideas mentioned in the implementation of innovative design discussion. During this session we began by identifying that the main drivers for whether or not a sustainable idea is needed or implemented relate to cost, efficiency, and time. The best way to get people on board with sustainability and new concepts is to be transparent and open about the short-term and long-term effects that the ideas may have within multiple facets of construction.

Additionally, sustainable decisions do not always have to be added costs to the project. Often times people assume that LEED and sustainability have to equal extra dollars; however, a sustainable decision can be as simple as using resources in the area and that can often times save money. For example, if the construction industry were to adapt construction and buildings to the climate and geography rather than the other way around, there would not be nearly as much money and energy spent trying to counter these forces of nature. That can be seen in simple settings such as areas of California trying to grow grass where is cannot thrive naturally.

Further discussion stemmed from various aspects of energy. Recently there has been a push to make better energy choices for the type of building and region, rather than just simply making sustainable and local material purchases. The life of a building is becoming a much more important aspect than previously considered. Fuels and energy controls can often times be very expensive, so a new push for renewable resources that allow waste to be converted into energy are drawing a lot more attention in the industry.

Another aspect of sustainability that does not immediately come to one's mind is the methods in which things are fabricated and brought to the site. More recently people are noticing the added benefits that can occur as a result of building components being prefabricated on site, rather than just locally. This overlaps with the idea of collocation where the proximity allows for collaboration and communication that can hopefully eliminate and prevent problems before they ever arise. Additionally, the prefabrication on site eliminates the fuel that would be used to transport the fabricated materials/products to the site and it saves on time and manpower while preserving quality and saving money.

After the innovation session, it was interesting to see how Turner and the Steel City High-Rise are working towards some of these new innovative construction approaches, but I also think that there is room to grow. For the most part the project has adapted the idea of collocation, but I really think that there should be more pressure for the structural engineer and the architect to better immerse themselves with the team. A lot can be said and learned from the lack of issues that have occurred between those parties that are regularly present and available to talk on site. Aside from the collocation, I think that this project could largely benefit from allowing the subcontractors to propose innovative ideas for how to complete the work. Whether or not the general contractor's team is completely removed or not is debatable. I think that the important thing would be to allow the field team to take the lead on the meeting and have the creative freedom to propose any ideas that come to mind prior to the general contractor giving an opinion on whether or not the ideas will work. This freedom to collaborate can have ideas spawn from one another and take the conversation in a really good direction that can end up having huge impacts on the project as a whole.

Unfortunately, I was limited in what I could take away from the sustainability talk and apply to the Steel City High-Rise. The tight footprint of our building really limits the amount of materials and products store on site at any given time. Additionally, the project is already striving to achieve a LEED Silver rating on the building with much of it (the retail, offices, and garage) being core and shell, so there are limited areas that can be developed with sustainable impacts prior to the tenant fit-outs. The areas that can learn from the sustainable components relate to resourcing from local businesses and making sure that the lifecycle of the MEP systems are carefully considered to see if they are having minimal negative impacts to the environment.

Feedback From Industry Roundtable

Anchoring the 22nd Annual PACE Roundtable was the opportunity to discuss the day and my thesis project with an industry member. I spoke with Bob Grottenthaler from Barton Malow. Our discussion focused largely on the idea of resiliency and standardization in construction. The Steel City High-Rise does not have much repetition or standardization throughout the structural system and I believe that there is a large risk to the schedule, sequencing, and budget of the project considering the variability of the project as a whole. If there were to be more repetition among bays or floors of the structure it would greatly help accelerate the schedule and fabrication of members, which would ultimately help the cost of the work as well. The tight footprint of the site and the other constructability issues pose enough of a risk as it is, so I think a more typical and consistent structural system would largely benefit the project. Additionally, the sequencing of work occurring on multiple floors with steel erection occurring over floors with laborers below them, can be a huge safety risk as well.

Considering my conversation with Bob and the sessions that I had attended that day, I will need to have industry contacts relating to the structural engineer, curtain wall fabricator/manufacturer, and LEED/Sustainability Consultant/Engineer. I have access to all of these contacts through Turner Construction resources, as well as professors and Bob who are familiar with the industry and sustainable ideas and programs.

The 22nd Annual PACE Roundtable

STUDENT FORM

Industry Member: Bob Greenmaker

Key Feedback:

Which research topic is most relevant to industry? What is the scope of the topic?

Resiliency + standardization of structural system to help with fabrication, schedule, cost, etc. My project has a lot of constructability issues + it is very large, so the complicated + non-typical structural system can hurt the schedule, budget, safety, etc of the project

Suggested Resources:

What industry contacts are needed? Is the information available?

- Structural engineer
- Curtain wall prefabrication/manufacturer
- LEED/ Sustainability Consultant/Engineer

Yes - have all contacts from project team.

The 22nd Annual PACE Roundtable

STUDENT FORM

Student Name Ashley Bistline

Session 1: Topic: Innovative Design

Research Ideas:

1) Innovation occurs during first 10%
Construction cost vs lifecycle - get people involved early on
→ cut schedule = cut costs, get tenants + revenue earlier
→ what environment do aspects thrive in

2) have collocation + charrettes to encourage brainstorming + innovation throughout the life of project.

Session 2: Topic: Sustainability in Global Community

Research Ideas:

1) other countries - compact, public transportation, use, recycling (fine penalties), water systems
- doesn't have to add cost to project if you accept to climate + geography rather than force it to change. - self cleaning mats

2) Better energy choices
- lifecycle for cost + environmental impact
- energy conservation + controls
- indoor air quality
- codes
- energy from waste
- transportation = fuel
- prefab on-site vs local

Session 3: Topic:

Research Ideas:

1)

2)

Level 1: BIM Execution Planning Process

Steel City High-Rise

Developed with the BIM Project Execution Planning Procedure by the Penn State CIC Research Team.
http://www.engr/psu.edu/ae/cic/bimex

BIM USES

Planning
Validate Program
Owner | Programming

Schematic Design
Author Schematic Design
Architect | Design Authoring

Schematic Design
Perform 3D Coordination
Contractor | Cost Estimation

Schematic Design
Develop Existing Conditions Model
Contractor | EC Model

Schematic Design
Create 4D Model
Contractor | 4D Modeling

Design Development
Author Design Development
Architect | Design Authoring

Design Development
Perform 3D Coordination
Architect | 3D Macro Coordination

Design Development
Develop Existing Conditions Model
Contractor | EC Model

Design Development
Create 4D Model
Contractor | 4D Modeling

Construction Documents
Author Construction Documents
Engineer | Design Authoring

Construction Documents
Perform 3D Coordination
Architect | 3D Macro Coordination

Construction Documents
Develop Existing Conditions Model
Contractor | EC Model

Construction Documents
Create 4D Model
Contractor | 4D Modeling

Operations
Compile Record Model
Contractor | Record Model

INFO. EXCHANGE

Program Model

Schematic Design
Existing Conditions Model
Architectural Model
MEP Model
Structural Model
Civil Model

Schematic Design 4D Model

Schematic Design 3D Coordination Model

Schematic Design Existing Conditions Model

Design Development
Existing Conditions Model
Architectural Model
MEP Model
Structural Model
Civil Model

Design Development 4D Model

Design Development 3D Coordination Model

Design Development Existing Conditions Model

Construction Documents (WP)
Existing Conditions Model
Architectural Model
MEP Model
Structural Model
Civil Model

Construction Documents (WP) 4D Model

Construction Documents (WP) 3D Macro Coordination Model

Construction Documents (WP) Virtual Prototypes

Construction Documents (WP) 3D Micro Coordination Model

Record Model