2013

Thesis Proposal

The Woodley

The Pennsylvania State University
Department Architectural of Engineering
Construction Option

AE 481W – Fall 2013
Faculty Advisor – Ray Sowers

PSUAE
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Executive Summary

This proposal will describe some of the opportunities available on The Woodley construction project that could potentially increase efficiency to the building process and save the owner money. The analyses that will be conducted in the spring semester of 2014 are the off-site prefabrication of the buildings brick exterior skin using brick wall panels, implementation of a prefabrication short interval production schedule (SIPS), a prefabrication safety evaluation, and a prefabrication implementation and coordination for industry wide use by contractors.

Analysis 1: Off-site Brick Wall Panel Prefabrication
One of the major problems during the construction of the Woodley was the lagging brick masonry construction for the building's brick exterior façade. Brick exterior skin was significantly running behind schedule for the planned duration of one year from November 2013 to November 2013 and became a risk to meeting substantial completion in early March of 2014. Therefore, this analysis will focus on the implementation of off-site prefabrication using brick wall panels to shorten the construction schedule and yield potential cost savings to the owner. Prefabrication has been proven to save time and money when used effectively on projects in the construction industry. It reduces the amount of on-site work required to install a particular scope of work and provides a more productive and safer construction sequence.

Analysis 2: Prefabrication SIPS
A SIPS has also been proven to shorten a project schedule for a given scope of work and produce cost savings by increasing worker productivity with a repetitive and efficient work flow sequence. They are most advantageous when used for repetitious buildings such as residential high-rises, apartments and prisons. The repetitive nature of The Woodley's exterior façade welcomes the use of a SIPS, especially when used in conjunction with the installation and erection of prefabricated brick wall panels proposed in the first analysis.

Analysis 3: Prefabrication Safety Evaluation
The Woodley's jobsite has very tight site constraints that presented the project team with safety concerns during construction. A safety evaluation will be performed to prove the safety benefits of prefabrication over the traditional masonry construction methods used. A matrix scoring system will be developed to evaluate which method is safer and therefore more beneficial to the project. In addition, an erection and installation specific safety plan will be developed which will uphold and improve upon current OSHA standards.

Analysis 4: Prefabrication Implementation and Coordination Plan
There can be many unforeseen challenges associated with the implementation of prefabrication that can potentially outweigh its benefits for a project team. In-depth research will be conducted to assist in developing an implementation and coordination plan for prefabrication that can be used as a standard by contractors in the construction industry to address these unforeseen challenges.

All of these above analysis topics have the potential to improve the construction process for The Woodley. Through research and analysis next semester these topics will be tested for their viability as applicable solutions for the specific conditions associated with the construction of The Woodley.

Table of Contents

Project Background

The Woodley a is new construction building located in the Woodley Park neighborhood of Northwest Washington, DC, located only block from the Woodley Park-Zoo Metro station. This JBG Companies owned project is an eight-story mid-rise luxury apartment building featuring 212 high-end apartment units with 288,500 square feet of residential space and a two story below grade parking garage with 272 parking spaces. The building will also include a fitness center, clubroom lounge, library, outdoor courtyard with a country club style infinity swimming pool and landscaped rooftop terrace.

The project delivery method for The Woodley is a Design-Bid-Build with a negotiated guaranteed maximum price contract. Clark Construction Group, LLC was awarded the construction of building as the general contractor for a total cost of $88 million including the over 421,000 gross square feet of work, resulting in a per square foot cost of $209. This high cost per square foot can be attributed to building's high end luxurious exterior façade and residential unit finishes.

The construction schedule for The Woodley is approximately 23 months long, with construction starting June 16, 2011 and substantial completion set for March 14, 2014. The building's eight-story structure is made entirely of cast-in-place concrete and two-way post-tensioned concrete slabs. The building's exterior skin consists of hand laid brick, prefabricated Indiana limestone and cast-stone. The construction phase of exterior skin masonry is a driving force for the project's schedule and will be the main focus of this thesis proposal, specifically the exterior brick masonry. The total duration for the exterior skin construction of the building is approximately one year spanning 252 working days. The below Figure 1 shows a rendering of The Woodleys looking at the Northeast corner of the building.

Figure 1: View of The Woodley. Courtesy of JBG Companies.

Analysis 1: Off-site Brick Wall Panel Prefabrication

Problem Identification

One of the major problems during the construction of the Woodley was the lagging brick masonry construction for the building's brick exterior façade. Brick accounts for 52% of the building's exterior skin envelope at approximately 76,225 SF of the total 147,450 SF. Although the windows were installed prior to exterior skin masonry, which eliminated brick from the construction schedules critical path, brick exterior skin was significantly running behind schedule for the planned duration of one year from November 2013 to November 2013 and became a risk to meeting substantial completion in early March of 2014. Brick masonry is typically a slow moving construction activity for any building's exterior due to the high level of craftsmanship and physical intensity of putting the material in place. Furthermore, many buildings in the Washington, DC metro area, in particular residential apartment buildings and high-rises, call for brick exterior facades in their designs. Consequently, this has become a major challenge in general for project teams to maintain their construction schedules with the known problems of keeping the activity up to speed.

Background Research Performed

Preliminary background research was performed to evaluate if prefabricating the building's brick exterior skin off-site was a viable solution to study as a technical analysis.

In order to remedy the risk that exterior brick masonry construction presented to substantial completion and to reduce the schedule time it took to complete this scope of work, this analysis will investigate the implementation of an off-site prefabricated brick wall panel system in lieu of the original laid in-place brick construction. Prefabrication is a construction technique that is being used more prevalently in the industry today, however, being still relatively new as a means and methods it presents a project team with challenges when establishing an unfamiliar construction sequence and logistical plan.

The owner's intended goal and the architect's design strictly required that a high level of luxury and specific architectural style be maintained to satisfy the desires of future tenants and the historic integrity of Woodley Park. Consequently, choosing an alternative brick wall panel system for the original hand laid brick that matches the ascetic goal of the building's exterior façade design is absolutely prudent.

Prefabricating the building's brick exterior skin off-site using brick wall panels and then transporting these panels to the project site to be erected into place for installation potentially may save a significant amount of schedule time and yield a reduction in the cost of labor. Furthermore, these and some additional benefits of prefabrication consist of the following:

- Increase in Labor Productivity and Quality
  - *When constructing the brick wall panels off-site in a prefabrication shop that has a climate controlled environment workers have the ability to better perform their work with comfortable working heights and more accessible material, equipment and tools. They are also not subjected to the elements often faced during typical construction helping improve quality of work and productivity.*

- Decreased On-site Installation Time
  - *Materials are assembled off-site and arrive at the site ready for installation. This only then requires the moving or in the case of this analysis the erection of the preassembled material into place and final tie-in.*

- Improved Safety
  - *When considering prefabrication for a building's exterior facade, project safety improves by having a cleaner site with less staging of materials when using an off-site staging area. Also, installation of prefabricated panels in the case of this analysis eliminates the need for scaffolding with worker's being inside the building when tying in to the building's structure.*
  - *Safety is also improved while working in a prefabrication shop or facility closed off from the elements and other trades.*

- Reduction in Material Use and Waste
  - Through prefabrication all site waste for the most part is eliminated, which in the case of brick masonry construction can be an advantageous benefit knowing how much waste is produced via brick and mortar scrap. As far as material, mortar is completely eliminated from the equation as an on-site material need for this scope of work.

One of the key considerations when implementing prefabrication is transportation of the prefabricated material to the jobsite. The logistics of transporting large prefabricated material can be challenging from the standpoint of establishing an approved route to the jobsite. Local jurisdiction often limits the allowable routes that can be taken when transporting the large and often hazardous loads associated with delivering prefabricated assemblies. This logistical challenge will be an important factor of investigation for this analysis knowing the heavy commuter traffic of the Washington, DC and the restrictions in place in and around the Woodley Park neighborhood.

Another consideration for off-site logistics is the possible acquisition of an off-site staging area or yard to house prefabricated material before reaching the jobsite. Although an additional cost will be incurred when purchasing or renting a suitable location for off-site staging, conversely, there may be potential cost savings when reducing the travel time to the jobsite and the increased amount of prefabricated material being built and stored before installed on-site. Prefabrication of a chosen scope of work can often start off-site long before the planned start of installation on-site, therefore, the use of an off-site staging location can further increase the amount of prefabricated constructed and ready for installation. Furthermore, this allows for uninterrupted and quick installation of the prefabricated material when its actual on-site construction starts.

Problem Solutions

Following this analysis being performed the potential solutions that could occur are as follows:

- Prefabrication of the building's brick exterior skin is not feasible due to cost escalation and inadequate schedule acceleration improvements; therefore, it will not be implemented.
- Prefabrication of the building's brick exterior skin detracts from the aesthetics of the intended finished product to the extent that its implementation is undesirable to the owner.

- Prefabrication of the building's brick exterior skin saves money and time and should be implemented.
- The requirement of transporting and delivering the prefabricated brick wall panels to the jobsite is not logistically and financially feasible for implementation.

Methodology

In order to successfully complete this technical analysis the following deliverables must be completed:

- Research case studies of similar projects that implemented prefabrication for a building's exterior envelope to obtain productivity rates.
- Perform a detailed estimate to obtain costs for the original method of constructing the brick exterior skin and its associated productivity rates.
- Examine the building's exterior envelope design and determine the most feasible and efficient breakdown and construction sequence for installing the brick wall panels.
- Evaluate how this developed breakdown and construction sequence for brick wall panels will affect worker productivity rates.
- Calculate the costs incurred from off-site prefabrication or purchasing of brick wall panels, an off-site staging location and trucking cost for deliveries.
- Develop site utilization plans per elevation for the on-site staging, erection and installation of the prefabricated brick wall panels.
- Compare the total cost and duration of the original method of constructing the brick exterior skin to the total cost and duration of implementing prefabricated brick wall panels.

Expected Outcome

Prefabricating the brick exterior skin envelope of The Woodley using brick wall panels will result in significant cost savings. The majority of the anticipated savings will result from a shortened on-site construction schedule due to the reduction of on-site labor required to erect and install the prefabricated brick wall panels. Additionally, an increase in worker productivity with a simpler and faster construction sequence will also contribute to a shortened on-site construction schedule.

Analysis 2: Brick Exterior Skin SIPS Implementation

Problem Identification

The problem for this analysis is the same problem addressed in first proposed analysis where brick exterior skin masonry construction was a risk to the project meeting substantial completion due to the activity's lagging pace of production. As mentioned before brick accounts for roughly 52% of the building's exterior envelope square footage and has construction schedule duration of approximately one year, starting in November 2012 and ending in November 2013. Finding a way to shorten the construction schedule and increase worker productivity for this activity would be very beneficial to the success of the project.

Background Research Performed

In order to increase productivity and shorten the construction schedule for brick exterior skin masonry this analysis will propose the use of a short interval production schedule (SIPS). A SIPS breaks down a construction activity or sequence of work into greater detail than a typical project schedule. It will achieve this through defining a set duration for the given activity(s) and the crew size needed for completing the work within the established timeframe. The scope of work is also broken down into construction zones to develop a specific work sequence. These construction zones should be approximately the same size and share a similar design so that a trade or team the same amount of time to complete each zone. In doing this a SIPS allows for very efficient allocation of manpower, as well as providing a detailed schedule for trades involved in the scope of work. This amount of detail allows tradesmen to always know what they should be performing up to the hour or even minute at any point through the work day.

A SIPS is typically used for projects that are highly repetitive such as precast parking garages, residential high-rises, apartment buildings and prisons. Projects such as these with repetitive layouts or repeating scopes of work allow for application of the construction zones stated earlier. In case of The Woodley, it will be an applicable project for a SIPS with the repetition present throughout design the building's exterior skin envelope. Establishing a repetitive workflow will especially be applicable when developing a SIPS for the proposed implementation of prefabricated brick wall panels for first analysis.

Problem Solutions

Following this analysis being performed the potential solutions that could occur are as follows:

- Using a SIPS is beneficial for brick exterior skin masonry construction by increasing productivity and reducing schedule time and should be implemented.
- Using a SIPS is beneficial for brick exterior skin masonry construction by increasing productivity but does not offer a reduction in schedule due to a higher cost incurred through its implementation and therefore should not be used.
- Using a SIPS for brick exterior skin masonry construction is not feasible based on the building's exterior envelope design. Therefore, it should not be implemented.
- Using a SIPS for the current laid-in place method for brick exterior skin masonry construction is beneficial to the project but its use for the proposed prefabricated brick wall panel method is not feasible. Therefore, a SIPS should not be implemented in conjuncture with the first analysis.

Methodology

In order to successfully complete this technical analysis the following deliverables must be completed:

- Research SIPS and its use for exterior brick façade masonry on similar projects for both traditional laid laid-in place traditional construction and prefabricated brick wall panels.
- Obtain information regarding current crew sizes and productivity rates that were estimated for laid-in place brick masonry construction for the building's exterior skin.
- Obtain information regarding crew sizes and productivity rates associated with erecting and installing prefabricated brick wall panels.
- Examine the architectural layout of the building's exterior skin divide it into similar construction zones for both the current laid-in place brick masonry construction and the implementation of the proposed prefabricated brick panels from the first analysis.
- Produce a SIPS for both the current laid-in place method and the proposed prefabricated brick wall panels for brick exterior skin masonry construction with set durations, the most efficient work flow sequence and crew sizes.
- Compare the SIPS developed for the current laid-in place method to the SIPS used for the proposed implementation of prefabricated brick wall panels to determine which method and SIPS is more beneficial to the project.

Expected Outcome

The use of a SIPS will accelerate the construction schedule of brick exterior skin masonry construction of the building by a significant amount of time. The development of SIPS will particularly be beneficial when used in conjuncture with the prefabricated brick wall panel construction proposed in the first analysis, which has a more repetitive work flow sequence by nature relative to the traditional laid-in place method used for the brick exterior skin. The fact that workers will know exactly where they need to be throughout the construction sequence and the timeframe in which they have to perform their work will increase their productivity, reducing delays due that result from lack of coordination and information that can occur with a typical project schedule. A SIPS will also help the general contractor's field staff drive the schedule and evaluate progress based on the greater amount of detail available with durations establish for the work flow sequence. Ultimately, the use of a SIPS, in particular for the proposed implementation of prefabricated prick wall panel construction in the first analysis, will save money and facilitate a more productive work force that completes the intended scope of work in shorter amount of time.

Analysis 3: Prefabrication Safety Evaluation

Problem Identification

Maintaining safety throughout the construction of any building is always of the upmost importance to any owner and builder. Ensuring a safe environment and construction sequence for an unfamiliar construction method such as prefabrication is especially important and an essential goal for a general contractor. In the case of The Woodley's construction, the congested and tight existing site created challenges as far as material deliveries, staging and scaffolding space. Knowing this the anticipated implementation of prefabricated brick panels for the building's exterior skin will present the general contractor with the logistical problem of ensuring safety when managing additional site traffic and equipment, as well as allocating more staging and erection space.

Background Research Performed

One of the main challenges that contractors face in the field is installing material or assemblies that are not designed with enough attention to safety, specifically safety associated during installation. In the case of The Woodley's brick exterior skin, the masonry construction of laying brick itself is not overly hazardous but the congested and tight work spaces at high elevations on scaffolding platforms present safety risks. Also, falling debris from exterior skin masonry work is another hazard that must be considered to ensure a safe work environment for trades on the ground of a jobsite.

These factors of brick masonry construction for a building's exterior could be avoided with the safer installation techniques associated with the implementation prefabricated brick wall panel. The decision to use prefabrication during design can increase safety during installation when a project is under construction. Although erection of panels needs to be carefully coordinated to ensure safety, the actual installation process is safer knowing that workers will be inside the building when tying in the panels to the buildings structure. This eliminates the safety risks entailed with workers being on scaffolding during installation during traditional laid-in place brick masonry construction. Another consideration when analyzing on-site safety for prefabricated material are the logistics of associated with staging and erection. Delivery and erection of prefabricated panels can produce additional site traffic and dynamic equipment activity around the site, requiring more space to ensure safety.

These benefits and challenges regarding on-site safety when implementing prefabricated brick wall panel construction will need to be researched and understood before the process can be used. Current OSHA requirements and the most common incidents with prefabricated brick wall panel construction will also need to be investigated to develop a safe work flow sequence.

Problem Solutions

Following this analysis being performed the potential solutions that could occur are as follows:

- The change to prefabricated brick wall panels in lieu of the current laid-in place method for the buildings brick exterior skin offers a safer means of construction and should be implemented.
- The safety concerns associated when changing to prefabricated brick wall panels out weight the current laid-in place method. Therefore, prefabrication should not be implemented.

Methodology

In order to successfully complete this technical analysis the following deliverables must be completed:

- In-depth research will be performed for case studies of similar projects that used prefabricated brick walls panels regarding safety challenges and concerns.
- Research will also be performed to understand the current OSHA requirements for brick wall panel erection and installation and possible areas for improvement.
- A matrix scoring system will be developed to compare safety advantages and disadvantages of the current laid-in place method and the implementation of prefabrication for the building's brick exterior skin. A totaled score will establish which method is safer based on their respected safety for on-site construction.
- Using the matrix scoring system, improvements and possible solutions will be proposed for both methods for brick exterior skin construction.
- An erection and installation specific safety plan will be developed for the implementation of prefabricated brick wall panel construction proposed in the first analysis using current OSHA safety requirements and applicable improvements.

Expected Outcome

Through the matrix scoring system developed in this analysis, prefabrication of the building's brick exterior skin using brick wall panels will result in a safer method of construction than the current laid-in place process. The anticipated advantages associated with erection and installation of brick wall panels will provide increased safety knowing workers will be inside the building during installation while relying on a crane to erect the panel into place. Also, it will eliminate the need for scaffolding, avoiding possible safety violations and accidents associated with work being performed on congested scaffolding platforms at high elevations.

Analysis 4: Critical Industry Issue – Prefabrication Coordination & Implementation

Problem Identification

Prefabrication is being implemented on projects more prevalently in the construction industry today. However, there are still many unforeseen challenges associated with its use that project teams must overcome. As proposed in the first analysis, off-site prefabrication of brick wall panels for the building's exterior skin envelope will be investigated for its ability to reduce schedule time and produce cost savings. Yet, without proper coordination with the owner, architect, structural engineer and masonry trades as a general contractor early on in construction and even during design or preconstruction, prefabrication can easily become unsuccessful in its implementation.

Background Research Performed

There can be many challenges to overcome as a general contractor when convincing a project team to use prefabrication for a scope of work. Cost and quality are two of most critical factors when proposing its use. Owner's usually will be cooperative when they consider the reduction in time for the project schedule but it is often difficult to have them accept the potential cost escalation that can occur when implementing prefabrication. The design team, including the architect and engineer, must be effectively convinced that prefabrication will not detract from both the quality of work put in place, engineered performance and the intended aesthetic appearance of the original design. The involved trades in the chosen scope of work to be prefabricated also must be on board early on during construction. Establishing a realistic and achievable work flow sequence and schedule will require their input. Also, coordination with involved trades can become an issue if union subcontractors and tradesmen will be involved during the prefabrication process. These issues with union labor can affect not only the prefabrication process itself but also delivery, staging, erection and installation.

Problem Solutions

Following this analysis being performed the potential solutions that could occur are as follows:

- The development of a detailed prefabrication implementation and coordination plan will be beneficial to the general contractor as an aid to effectively convincing the owner, design team, and involved trades of to support the use of prefabrication.
- The prefabrication implementation and coordination plan is not effective as a means of guidance for a general contractor when convincing the project team to use prefabrication.

Methodology

In order to successfully complete this technical analysis the following deliverables must be completed:

- In-depth research will be performed on similar projects and case studies where the use of prefabrication presented a general contractor with implementation and coordination issues,
- A detailed prefabrication implementation and coordination plan will be developed in anticipation for its use as a standard for guidance to a general contractor.

- This implementation and coordination plan will include the following elements:
  - Coordination
    - Owner Coordination
    - Architect Coordination
    - Engineer Coordination
    - Subcontractor/Prefabricator Coordination
    - Trucking Company Coordination
  - Transportation Logistics
  - Site Logistics
  - Inspection requirements
  - Off-site staging
  - Conclusive Advantages and Disadvantages

Expected Outcome

The developed prefabrication implementation and coordination plan proposed in this analysis will be an effect means of guidance for a contractor either considering or choosing to use prefabrication for a scope of work on a project.

Analysis Weighting System

The following weighting breakdown for the four proposed analyses will be used as a scoring system to determine a final grade for the final report in the spring semester of 2014. The scoring system being proposed can be referenced below in Table 1.

Table 1: Analysis Weighting System Breakdown

Analysis Description	% of Final Grade
Analysis 1: Off-site Brick Wall Panel Prefabrication	35
Analysis 2: Prefabrication SIPS	25
Analysis 3: Prefabrication Safety Evaluation	20
Analysis 4: Prefabrication Implementation and Coordination Plan	15

Conclusions

This proposal defined some of the opportunities available on The Woodley building construction project that could increase labor productivity; reduce time on the overall construction schedule and save the owner money. The analyses that will be performed in the spring semester of 2014 are the prefabrication of the brick exterior skin using brick wall panels, implementation of a prefabricated brick wall panel short interval production schedule (SIPS), a prefabrication safety evaluation, and the creation of a prefabrication implementation and coordination plan for the future use of industry contractors.

Prefabrication has been proven to save time and money when used effectively on projects in the construction industry. It reduces the amount of on-site work required to install a particular scope of work and provides a more productive and safer construction sequence. A SIPS will be used in conjuncture with prefabrication. SIPS has also been proven to shorten construction schedules and increase worker productivity, in turn, decreasing the cost of construction for a scope of work. The Woodley's jobsite has very tight site constraints that presented the project team with safety concerns. A safety evaluation will be performed to prove the safety benefits of prefabrication over traditional masonry construction methods. In addition, an erection and installation specific safety plan will be developed which will uphold and improve upon current OSHA standards. Lastly, there can be many unforeseen challenges associated with the implementation of prefabrication that can potentially outweigh its benefits for a project team. In-depth research will be conducted to assist in developing an implementation and coordination plan for prefabrication that can be used as a standard by contractors in the construction industry to address these unforeseen challenges.

All of the above analyses have the potential to save the project owner time and money. Through the research and analysis performed during the spring semester of 2014 these topics will be tested for their viability as applicable solutions for the construction of the Woodley.

Appendix A

Breadth Topics

In order to complete the all the required components of senior thesis, two breadth areas in options other than construction must be demonstrated. The different options within the Architectural Engineering Department at Penn State are construction (the focus option for the proposed analyses), mechanical, structural and lighting design. Firstly, a structural breadth will be performed that will focus on the design an anchoring system to tie the prefabricated brick wall panels to the buildings structure. Secondly, a mechanical breadth will be conducted to evaluate the thermal performance of the prefabricated brick wall through thermal gradient calculations for different environmental conditions of the Washington, DC area.

Structural Breadth

A structural breadth will be performed to analyze the anchoring system that will be used to tie in the prefabricated brick wall panels proposed in the first analysis. An anchoring system will be chosen through determining the range of different loads expected to be placed on the building's exterior studs and concrete slabs by the prefabricated brick panels when tied in. The installation techniques required with this chosen anchoring system will also be examined.

Mechanical Breadth

A mechanical breadth will be performed to evaluate the thermal energy performance of the chosen prefabricated brick wall panel system used in the first proposed analysis for the off-site prefabrication of the building's brick exterior skin. Thermal gradient calculations will be used to evaluate the energy performance of the panels in the most typical weather conditions throughout the year for the Washington, DC area. This breadth will ensure that the chosen brick wall panel system maintains the required quality per the original design of the building's exterior envelope and if needed the reselection of a product that is adequate.

Appendix B

Proposed Senior Thesis Spring Work Schedule

Reference the following page for the proposed schedule.

Spring 2014 Proposed Thesis Work Schedule
Timeline from January 2014 - April 2014

The Woodley

Kevin Kroener- Construction Option
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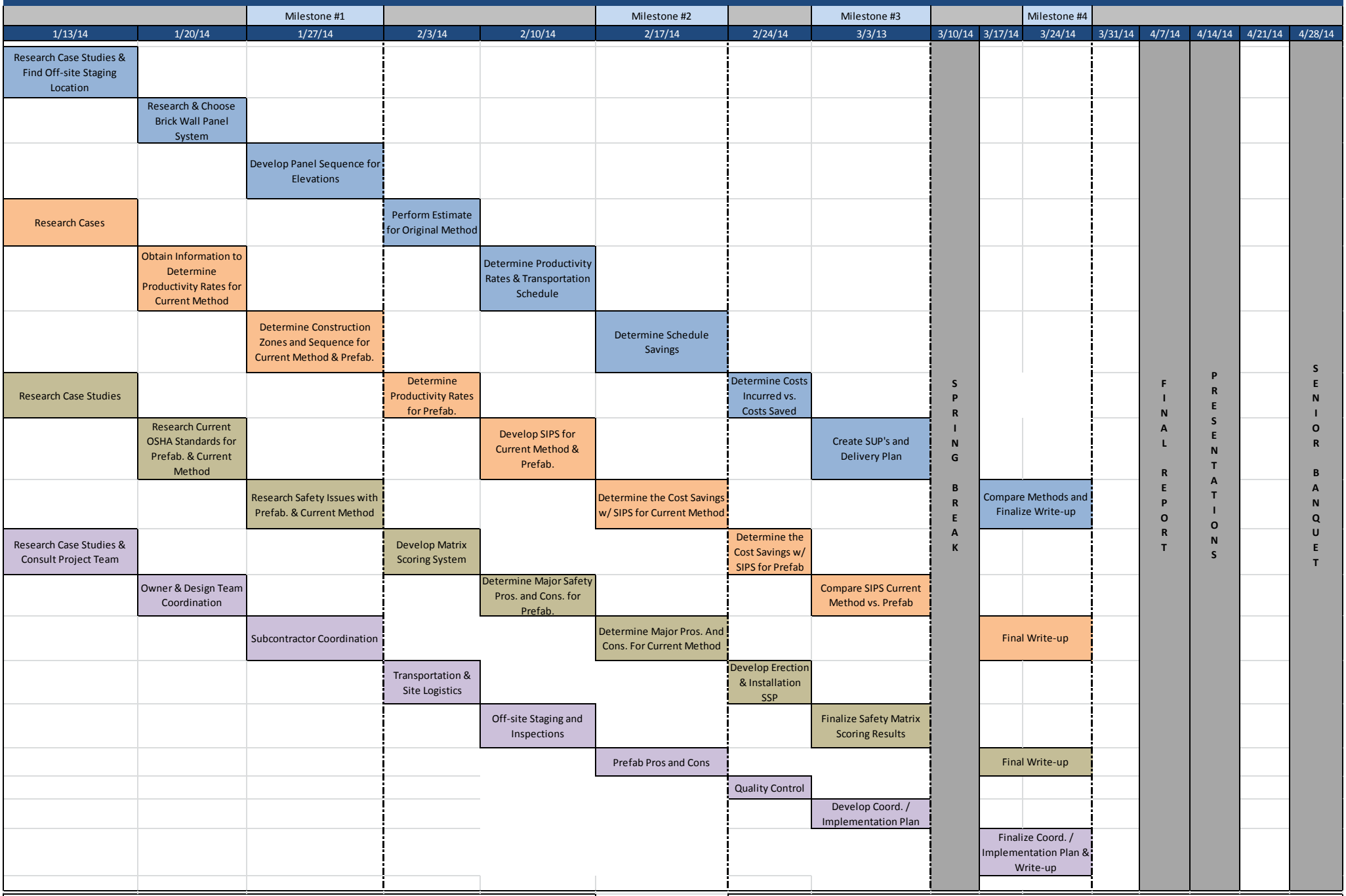

Analysis Descriptions	
Analysis #1	Off-site Brick Wall Panel Prefabrication
Analysis #2	Prefabrication SIPS
Analysis #3	Prefabrication Safety Evaluation
Analysis # 4	Prefabrication Implementation and Coordination Plan

Milestone Activity Summary	
#1	Research & Prefabrication System Selection Completed
#2	Prefabrication Schedule Savings, SIPS, Major Safety Concerns and Coordination Completed
#3	Prefabrication Logistics, Method Comparison, Safety Scoring Matrix Completed
#4	Completion of Write-ups and Presentation Practice