FINAL REPORT

U.S. GENERAL SERVICES ADMINISTRATION HEADQUARTERS MODERNIZATION PHASE I

1800 F ST. NW, WASHINGTON, D.C.

RAMUEL HOLGADO

FINAL REPORT

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APRIL 3, 2013

General Services Administration Headquarters Modernization

1800 F St NW, Washington, D.C.

Overview

Owner: General Services Administration
General Contractor: Whiting-Turner/Walsh JV
Construction Manager: Heery International
Architects: Gensler & Shalom Baranes Associates, PC
Civil Engineer: A. Morton Thomas Engineering
Structural Engineer: Thorton-Tomasetti Group
MEP Engineer: Syska

Project Cost: $200,000,000
Total Stories: 9
Size: 858,000 SF
Construction Dates: 9/15/10 to 5/20/13
Delivery Method: Design-Bid-Build

Architecture

Renowned for its role in the architectural development of the federal office building type and its neoclassical style

Floor plan was designed similarly to the letter "E" due to the technology restraints of cooling systems at the time of its original construction in 1917

Mechanical System

Air distribution system is comprised of multiple variable volume air handler units

100% outside air units will contain an energy recovery coil

A water heat exchanger and three water-cooled chillers will be located in the basement

Fire suppression system consists of a combined wet pipe and dry pipe sprinkler system

Construction

Project consists of 2 phases

Phased occupancy will be required as the building will remain fully functional and partially occupied throughout the project

Structural System

Cast in place concrete was primarily used for the construction of the New Addition, slab on grade, grade beams, and foundation walls

The existing structure is composed mainly of structural steel framing consisting of the original I beams from 1917

Electrical System

Primary power is distributed by three 3000A, 480/277V, 3-phase, 4-wire substations and a 4000A, 480/277V, 3-phase, 4-wire substation

A 1500/1875 kW/kVA, 480/277V diesel driven standby generator serves as the emergency system

Ramuel Holgado | Construction Management
http://www.engr.psu.edu/ae/thesis/portfolios/2013/rgh5029/index.htm

EXECUTIVE SUMMARY

The purpose of the Final Report is to review the research and potential solutions of the four analyses that were performed on Phase 1 of the General Services Administration (GSA) Headquarters Modernization. Located in Washington, D.C., Phase 1 of the project consists of nine total stories at approximately 362,000 square feet with an additional 67,000 square feet of new office space positioned in the building's East Courtyard. These four analyses will focus on problematic areas relating to schedule, cost, and constructability concerns.

ANALYSIS 1: NEW ADDITION FAÇADE REDESIGN

The first analysis explores the possibility of downsizing the curtain wall on the south façade of the New Addition and measuring the outcomes. The designed 78-foot truss columns created various issues in terms of delivery and coordination. Downsizing the overall size of the curtain wall and truss columns resulted in $2,856,085.85 in savings. Furthermore, this alternate design resulted in three days of acceleration and eliminated concerns with delivery. An acoustical breadth was completed within this analysis to examine the alternate façade's performance.

ANALYSIS 2: NEW ADDITION FOUNDATION SYSTEM

The second analysis proposes the idea of using an alternate foundation system for the New Addition. The current system is composed of caissons that total $1.56M, or roughly 30 percent of the structural system. In contrast, the existing foundation is composed of spread footings, which will serve as an alternate design for the New Addition. Implementing spread footings resulted in a $1,551,142.22 in savings as well as 12 days of acceleration. A structural breadth was completed in conjunction with this analysis.

ANALYSIS 3: THREE-DIMENSIONAL (3D) LASER SCANNING IMPLEMENTATION

The third analysis considers the implementation of 3D laser scanning as the current as-built drawings contain outdated and inaccurate information. Introducing the Leica ScanStation C10 and the Leica Cyclone 3D point cloud processing software on the project may provide assistance in terms of coordination concerns, which could improve production in the field and lower the overall cost. The process costs a minimum of $217,200 to administer on the project and takes 19 days to scan and process the entire building.

ANALYSIS 4: OPERATION AND MAINTENANCE OF ENERGY

The fourth analysis examines the industry issue of the operation and maintenance of energy during the operational phase. Utilizing Building Dashboard by Lucid Design Group would enable occupants to receive feedback on their resource consumption information and allow them to share and compare their data amongst their coworkers. Energy reductions may reach as high as 56 percent with the implementation of Building Dashboard during the operation phase.

ACKNOWLEDGEMENTS

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Justin Purcell – Heery International Project Engineer

PACE Industry Members

Family and Friends

TABLE OF CONTENTS

PROJECT OVERVIEW

PROJECT DESCRIPTION

Figure 1: Rendering of the GSA Headquarters from E Street NW – Courtesy of the Whiting-Turner/Walsh Joint Venture

The GSA Headquarters, located on 1800 F Street NW in downtown Washington, D.C., was originally built in 1917 and updated in 1935. It is renowned for its role in the architectural development of the federal office building type and its neoclassical style. Primarily used as an office building, the existing structure includes five primary wings and nine stories at approximately 724,000 square feet, with an additional 134,000 square feet of new office space located in the building's courtyards. The new infill structures will be composed of glass curtain walls, while the rest of the existing structure will contain salvaged limestone from the original construction. This project includes the replacement of interior finishes, preservation of historic features, and upgrade of all building systems.

The project is composed of two phases. Phase 1 consists of the eastern half of Wing 0, Wing 1, and Wing 2, while Phase 2 includes the western half of Wing 0, Wing 3, and Wing 4. Phase 1 of the project was awarded to the Whiting-Tuner/Walsh Joint Venture on September 15, 2010. Construction began on March 10, 2011 with Final Closeout expected to be finished on May 20, 2013. Phased occupancy will be required as the building will remain fully functional and partially occupied throughout the construction of the project. Although Phase 1 of the project is funded by the American Recovery and Reinvestment Act, funding for Phase 2 is currently unavailable and therefore does not have a projected start date for construction.

Figure 2: Pouring of the roof slab of the New Addition – Photo Taken by Ramuel Holgado

Cast-in-place concrete was primarily used for the construction of the New Addition. Common in Washington D.C., this method was used for the slab on grade, grade beams, and foundation walls. In addition, the columns, walls, and deck for each floor were poured with concrete. Wooden formwork and a pump truck were used to frame and pour all concrete on the project. Figure 2 shows the pouring of concrete for the roof slab of the New Addition.

The mechanical system consists of an air distribution system that is comprised of multiple variable volume air handler units. The 100 percent outside air units will contain an energy recovery coil. In addition, a water heat exchanger and three water-cooled chillers will be located in the basement. The fire suppression system is composed of a combined wet pipe and dry pipe sprinkler system. Primary power is distributed by four substations ranging from 3000 to 4000 amps. A diesel driven standby generator serves as the emergency system.

The GSA Headquarters Modernization is contracted to achieve a LEED Gold Rating and meant to act as the showcase project for the General Services Administration. Some of the high performance green building features of the project include green roofs, photovoltaic installations at the roof and skylights, radiant floors in the atria, energy recovery, daylight harvesting, and greywater and condensate recycling systems. Figure 3 illustrates the green roofs and photovoltaic installations on the GSA Headquarters. In addition, the project will include rapidly renewable materials, regionally manufactured materials, and regionally extracted, harvested, or recovered materials.

Figure 3: Rendering of the GSA Headquarters exterior – Courtesy of the Whiting-Turner/Walsh Joint Venture

The project utilized a design-bid-build project delivery system. This delivery system provided a competitive bidding process that allowed a better opportunity for value engineering during the design phase. The GSA is contracted directly with Shalom Baranes Associates, Heery International, and the Whiting-Turner/Walsh Joint Venture, all of which are Lump Sum contracts. Shalom Baranes Associates, which is the Designer Consultant, has Lump Sum contracts with all the engineers on this project, including The Syska Hennessy Group and Thornton-Tomasetti Group. The Whiting-Turner/Walsh Joint Venture, which is the General Contractor, was awarded the project after submitting the lowest bid. In turn, they too have Lump Sum contracts with all the subcontractors. Heery International, which is the Construction Management Agency, acts as the GSA's representative and do not own any risk with the schedule.

CLIENT INFORMATION

The General Services Administration is an independent agencey of the United States government that manages and supports the basic functioning of federal agencies across the nation. They supply products and communication for governernment offices and provide transportation and office space to federal employees. Furthermore, they develop cost-minimizing policies for the government. Therefore, budget management is a major priority in relation to the renovation of their headquartes in Washington, D.C.

Figure 4: The GSA Logo – Courtesy of the GSA

The modernization of the U.S. General Services Administration Headquarters was initiated for a number of reasons. Built in 1917 and later updated in 1935, the building was due for a major renovation. Due to financial constraints, the General Services Administration sought to modernize the building rather than build a new one. Additionally, although funding for Phase 2 is currently unavailable, Phase 1 is funded by the American Recovery and Reinvestment Act. Enacted in 2009, the primary purpose of this act was to save and create jobs immediately in order to stimulate the economy. Finally, the project is to serve as the showcase project for the General Services Administration and will include numerous high performance green building initiatives, as it is designed to achieve a Gold rating under the LEED Rating System.

Cost and quality are two critical factors on this project. As mentioned above, this building will serve as the showcase project for the General Services Administration. Therefore, the standards for the quality of the finished product may be nothing short of outstanding. Quality of construction was monitored closely throughout the project by a detail-oriented quality control effort. With that said, the project budget must always be kept in mind, as aforementioned. Funding for Phase 2 is currently unavailable, and funding for Phase 1 is tight. Therefore, it is imperative that the project remains on schedule. The estimated final completion is scheduled for May 20, 2013. At that approximate date, the Owner will be looking to fill 400,000 square feet of office space with occupants.

Phased occupancy will be required as the building will remain fully functional and partially occupied throughout the project. While Phase 1 is under construction, the area designated for Phase 2 will remain occupied. For this reason, safety and sequencing will remain a top priority at all times. Whiting-Turner/Walsh Joint Venture will be given the highly important task of protecting the public and construction workers, as well as the Owner's employees. In order to do so, temporary walls will be constructed in the building to separate the occupied space from the construction areas. Moreover, all personnel entering the site must comply with the safety standards, including wearing hard hats, safety glasses, safety vests, and boots. In conclusion, the keys to completing the project to the Owner's satisfaction are to meet all the standards on cost, quality, schedule, sequencing, and safety.

PROJECT DELIVERY SYSTEM

Design-Bid-Build is the project delivery system for the General Services Administration Headquarters Modernization. The Owner, which is the General Services Administration, decided this was the best approach to this project because they could have control over the design as well as have direct communication with the Designer Consultant, General Contractor, and Construction Manager. Due to the size of the project, this delivery system is appropriate because it provides a competitive bidding process and a better opportunity for value engineering during the design phase.

The General Services Administration is contracted directly with Shalom Baranes Associates, Heery International, and Whiting-Turner/Walsh Joint Venture, all of which are Lump Sum contracts. Shalom Baranes Associates, which is the Designer Consultant, has Lump Sum contracts with all the engineers on this project, including Syska and Thornton-Tomasetti Group. Whiting-Turner/Walsh Joint Venture, which is the General Contractor, was awarded the project after submitting the lowest bid. In turn, they too have Lump Sum contracts with all the subcontractors. Heery International, which is the Construction Management Agency, acts as the Owner's representative and do not own any risk with the schedule. However, since the Owner is the General Services Administration and the project is for their headquarters, they have the personnel to make the final decision on all financial items, such as change orders. The Project Organizational Chart can be seen on the following page in Figure 5.

In terms of the bonds required, since it is a government project, the General Contractor is required to have payment and performance bonds. Additionally, the government requires the General Contractor to procure this protection. Therefore, it is required that all subcontractors provide payment and performance bonds for contracts greater than $250,000.

Insurance requirements generally include Workers' Compensation Insurance, Commercial General Liability Insurance, and Automobile Liability Insurance. In addition, the General Contractor is required to provide the Contracting Officer proof that it has obtained insurance required by the contract in the form of certificates of insurance.

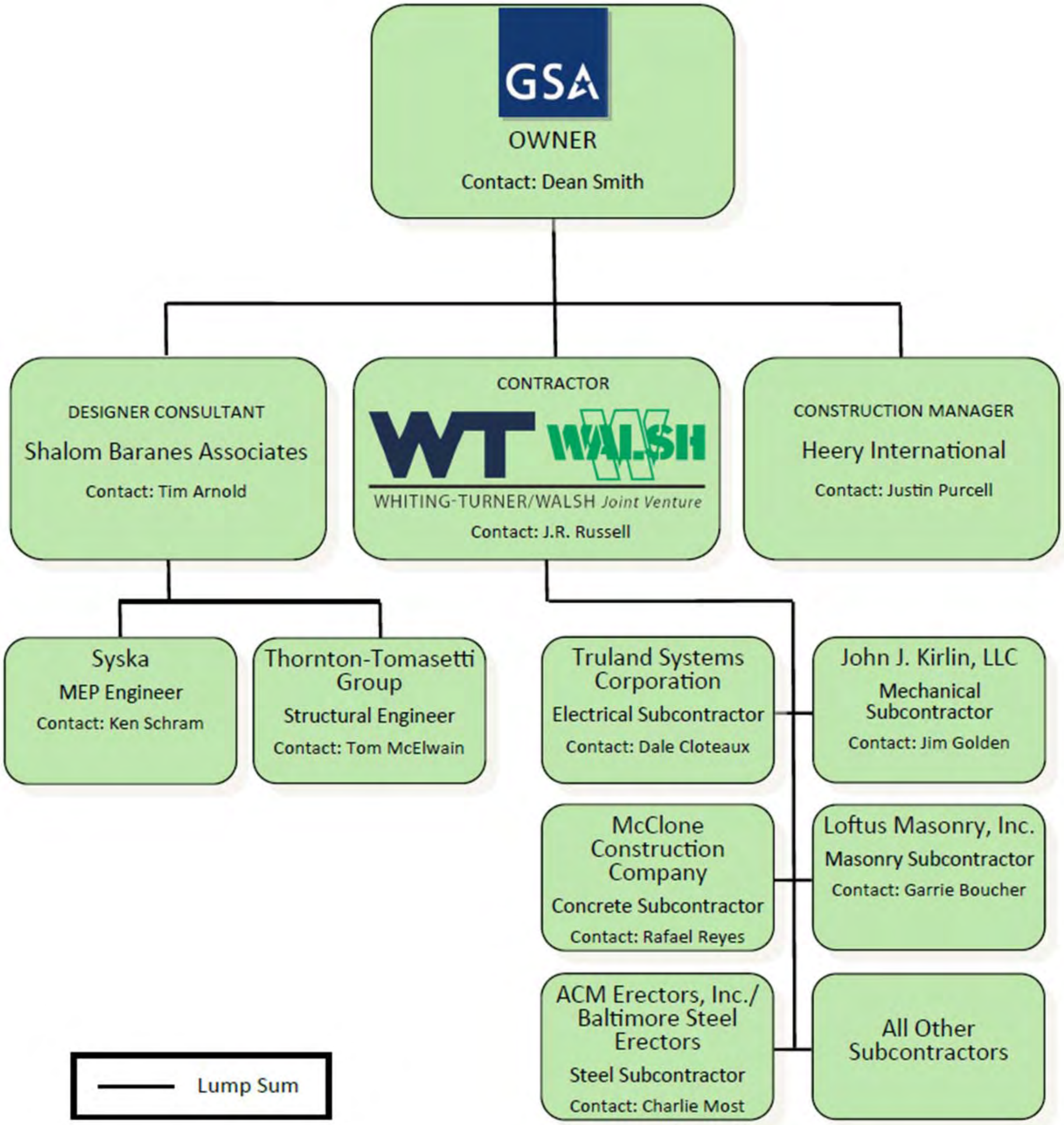

Figure 5: Project Organizational Chart – Developed by Ramuel Holgado

STAFFING PLAN

The staffing plan for the U.S. General Services Administration Headquarters Modernization can be seen in Figure 6. Since the project is a joint venture, the staffing is divided among Whiting-Turner and Walsh employees. Due to the size and complexity of the project, this project utilizes a Senior Project Manager, Project Manager, Senior Superintendent, Superintendent, Quality Control Manger, and Safety Manager, along with multiple MEP Coordinators, Assistant Project Managers, and Project Engineers. However, only the Superintendents are on site at all times, while the Senior Project Manager is on the project a few days a week. In addition, the Project Managers report to their superiours of their respective companies. Overall, Whiting-Turner and Walsh crafted a versatile and experienced staff for this challegning project.

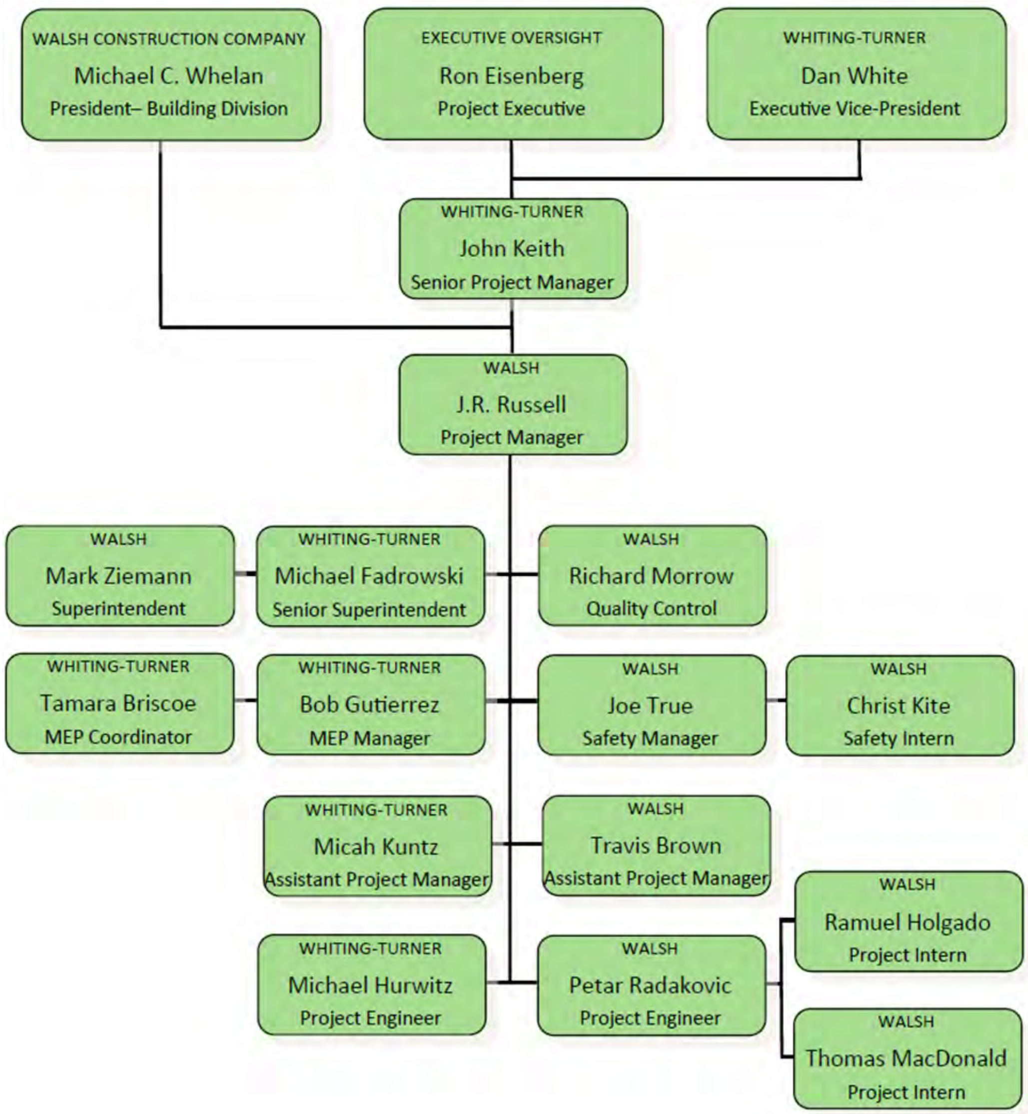

Figure 6: Staffing Plan – Developed by Ramuel Holgado

DESIGN OVERVIEW

BUILDING SYSTEMS SUMMARY

OVERVIEW

Table 1: Building Systems Checklist – Developed by Ramuel Holgado

Workscope	Yes	No
Demolition Required	X	
Structural Steel Frame	X	
Cast in Place Concrete	X	
Precast Concrete		X
Mechanical System	X	
Electrical System	X	
Masonry	X	
Curtain Wall	X	
Support of Excavation		X

The Building Systems Checklist shown in Table 1 summarizes the building systems used in the U.S. General Services Administration Modernization. The following items describe each of these critical building systems in more detail.

Figure 7: Demolition in the East Courtyard - Courtesy of the Whiting-Turner/Walsh Joint Venture

DEMOLITION

For Phase 1 of the U.S. General Services Administration Modernization, a total of four buildings in the East Courtyard were demolished. Figure 7 shows the demolition of one of these buildings. Additionally, a significant amount of items in the existing Wing 0, Wing 1, and Wing 2 were demolished. This extensive list includes radiators and pipes, mechanical equipment, cabinetry and shelving, elevator shafts, stairwells, security equipment, plumbing fixtures and toilet accessories, ceramic floor tiles and cement floor toppings, and insulation board from walls and ceiling. In general, the existing HVAC, electrical, plumbing, communication, and fire and life safety systems were all demolished and replaced.

Since the building was originally constructed in 1917, asbestos and lead-based paint became primary issues during the demolition phase. Each floor of every wing was closed off so that these hazardous materials could be removed before any work could begin. In addition, all hazardous materials were typically removed at night and according to OSHA regulations.

STRUCTURAL STEEL FRAME

Although the New Addition is constructed of cast-in-place concrete, the existing structure is composed mainly of structural steel framing consisting of the original I beams used from 1917. However, the new elevator shafts in the existing building will consist of W10's with lightweight concrete poured on composite steel decking near the openings. Additionally, the new penthouse to be constructed near the south end of Wing 2 will be composed of W8's, W12's, and light gage steel stud walls as the existing roof at this location will be removed.

The New Addition will have seven 60-foot built-up truss columns consisting of HSS 5x5x3/8 members that are connected to roof trusses. A seated connection will attach the roof trusses to the concrete beam on the seventh floor of the New Addition. The atrium steel will be erected by a 90-ton hydraulic truck crane that will be situated on E Street NW.

CAST-IN-PLACE CONCRETE

Cast-in-place concrete was primarily used for the construction of the New Addition. Common in Washington D.C., this method was used for the slab on grade, grade beams, and foundation walls. In addition, the columns, walls, and deck for each floor were poured with concrete. Wooden formwork and a pump truck were used to frame and pour all concrete on the project. Figure 8 shows the pouring of concrete for the roof slab of the New Addition.

Figure 8: Roof slab of the New Addition – Photo Taken by Ramuel Holgado

MECHANICAL SYSTEM

The central plant is located in the basement of Wing 0 and is adjacent to mechanical equipment and electrical rooms. The air distribution system used will be comprised of multiple variable volume air handler units that are spring-mounted throughout the nine stories of the building. In addition, the seventh floor will contain several 100% outside air units that will contain an energy recovery coil and serve the rest of the building.

The hot water system will consist of a steam to water heat exchanger and multiple plate and frame heat exchangers located in the basement. Three water-cooled chillers will be placed in the basement as well. In addition, three 1,105 ton cooling towers will be on the roof of the New Addition. Hot and chilled water will be distributed through several fan coil units located on each floor of the building.

The fire suppression system for the project will be comprised of a combined wet pipe and dry pipe sprinkler system.

ELECTRICAL SYSTEM

The primary power for the electrical system will be supplied by Pepco and distributed by three 3000A, 480/277V, 3-phase, 4-wire substations and a 4000A, 480/277V 3-phase, 4-wire substation. A 1500/1875 KW/KVA, 480/277V diesel driven standby generator will serve as the emergency system.

MASONRY

The existing building contains non-bearing salvaged limestone on the entire façade with brick masonry backup and a salvaged granite base. The basement walls of Wing 1 are composed of 7-5/8" CMU and solid CMU with steel angle bracing. The New Addition will consist of only cast-in-place concrete, curtain wall, and structural steel in the atrium.

CURTAIN WALL

Since the existing building is constructed of limestone on the exterior, the only curtain wall will be located on the New Addition. It will consist of a majority of the north and south façades, rising to a maximum of six stories. The curtain wall facing south will be located at the atrium and will contain motorized operable awning windows and sun shades, as seen in Figure 9. It will be supported by the steel tubes of the built-up

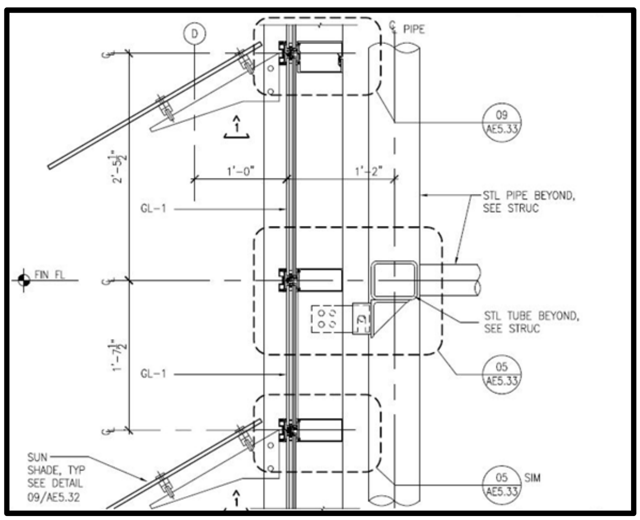

Figure 9: South Curtain Wall Partial Section - Courtesy of the Whiting-Turner/Walsh Joint

truss columns.

GREEN BUILDING PROJECT FEATURES

The U.S. General Services Administration Modernization was designed to achieve a LEED Gold Rating. However, with the LEED Platinum Rating within reach, efforts by the project team have increased to attain this new goal. High performance green building features on this project include green roofs, photovoltaic installations at the skylights and roof, radiant floors in the atrium, daylight harvesting, energy recovery, additional monitoring and controls, and greywater and condensate capture and reuse.

PROJECT COST EVALUATION

- ***To view the RSMeans Square Foot Cost Estimate, please reference Appendix A-1.***
- ***To view the RSMeans MEP Assemblies Cost Estimate, please reference Appendix A-2.***

OVERVIEW

The purpose of this evaluation is to understand the costs associated with the U.S. General Services Administration Headquarters Modernization by completing a number of estimates and cost comparisons. The RSMeans takeoffs did not take into account that the project was a renovation and therefore, all costs were projected as new construction.

CONSTRUCTION COSTS AND TOTAL PROJECT COSTS

Table 2: Actual Project Costs – Developed by Ramuel Holgado

Parameter	Existing Building
Construction Costs (CC)	$ 76,672,613.00
CC/SF	$ 178.31
Total Project Costs (TC)	$ 87,069,000.00
TC/SF	$ 202.49

Table 2 displays the Actual Project Costs. The Construction Costs shown exclude general conditions, sitework, permitting, and contractor fees. The total square feet of the building used in this section and all estimates was 430,000.

BUILDING SYSTEMS COSTS

Table 3: Building Systems Costs – Developed by Ramuel Holgado

System	Construction Cost	CC/SF	% of CC
Aluminum Entrances/ Curtainwall/Glazing	$ 5,350,000.00	$ 12.44	7.0%
Concrete	$ 3,647,530.00	$ 8.48	4.8%
Demolition/Abatement	$ 5,600,000.00	$ 13.02	7.3%
Drywall/Plaster	$ 4,909,007.00	$ 11.42	6.4%
Electrical	$ 11,509,228.00	$ 26.77	15.0%
Fire Protection	$ 1,025,000.00	$ 2.38	1.3%
Mechanical/Plumbing	$ 23,640,000.00	$ 54.98	30.8%
Roofing	$ 1,485,000.00	$ 3.45	1.9%
Sitework	$ 610,000.00	$ 1.42	0.8%
Stonework	$ 2,175,000.00	$ 5.06	2.8%
Structural Steel	$ 1,660,000.00	$ 3.86	2.2%

Table 3 is a summary of the Construction Costs of the major building systems. An emphasis should be placed on the Mechanical/Plumbing and Electrical systems, which account for 30.8% and 15.0% of the building Construction Costs, respectively. This is due to the fact that the project contained many high performance green building initiatives such as a greywater and condensate recycling system and storm water capture system.

RSMEANS SQUARE FOOT COST ESTIMATE

Table 4: Square Foot Estimate Summary – Developed by Ramuel Holgado

	% of Total	Cost/SF	Cost
Substructure	4.80%	$ 6.25	$ 2,685,500
Shell	32.20%	$ 42.06	$ 18,086,000
Interiors	19.10%	$ 24.93	$ 10,718,000
Services	43.90%	$ 57.32	$ 24,646,500
Subtotal			$ 56,136,000.00
Contractor Fees	7.00%	$ 9.14	$ 3,929,500.00
Architectural Fees	7.00%	$ 9.78	$ 4,204,500.00
TOTAL BUILDING COST		**$ 149.47**	**$ 64,270,000**

Table 4 shows a summary of the RSMeans Square Foot Cost Estimate, which was completed by using MeansCostWorks. For the complete RSMeans Square Foot Cost Estimate, please reference Appendix A-1. As stated in the Overview, although the project is a renovation, the RSMeans projected all costs for new construction. Additionally, since a cast in place building type was not an option, a reinforced precast concrete panel building type was selected. All other building parameters, such as story count and height, floor area, and labor type, were accurately entered.

RSMEANS MEP ASSEMBLIES ESTIMATE

Table 5: MEP Assemblies Estimate Summary – Developed by Ramuel Holgado

	Actual Construction		RSMeans Assemblies		
System	Construction Cost	CC/SF	Construction Cost	CC/SF	% Difference
Mechanical/Plumbing	$ 23,640,000.00	$ 54.98	$ 13,079,012.86	$ 30.42	-44.7%
Electrical	$ 11,509,228.00	$ 26.77	$ 11,964,370.70	$ 27.82	4.0%
Fire Protection	$ 1,028,000.00	$ 2.39	$ 1,500,147.50	$ 3.49	45.9%
TOTAL	$ 36,177,228.00	$84.13	$ 26,543,531.06	$61.73	-26.6%

Table 5 displays a summary of the RSMeans MEP Assemblies Estimate. To view the complete RSMeans MEP Assemblies Cost Estimate, please reference Appendix A-2. This estimate examined the building's MEP systems to a higher degree and includes systems that can be found on the actual project. For any parameters that were specified on the project, but not listed in RSMeans, the closest possible match was assumed and selected for the purposes of the estimate. Table 5 also provides a percent difference between the Assemblies Estimate and the Actual Construction Costs.

COMPARISON OF ESTIMATES AND ACTUAL PROJECT COSTS

The RSMeans Square Foot Estimate was $64,270,000 or approximately 16.2% below the Actual Construction Costs. This is due to the limiting options within RSMeans, which did not include demolition/abatement, structural steel, curtain wall, or any of the high performance green building initiatives. Additionally, since RSMeans only accounts for new construction, it is more difficult to get a more accurate estimate for a renovation.

The MEP Assemblies Estimate total was $26,543,531.06 or approximately 26.6% below the Actual Construction Costs of the MEP systems. Although the Electrical systems estimate was relatively accurate, the Mechanical/Plumbing systems estimate was significantly lower than Actual Construction Costs. The reason for this is the same reason as listed for the RSMeans Square Foot Estimate. Not all of the Mechanical/Plumbing systems specified on the project were on RSMeans. Some of the more significant systems missing include the greywater and condensate recycling system, storm water capture system, and solar water heating equipment. Additionally, the parameters in RSMeans may not have matched perfectly with the systems on the project. With these issues aside, the RSMeans MEP Assemblies estimate seemed to be a fairly reasonable assessment of the actual systems specified on the project.

GENERAL CONDITIONS ESTIMATE

- ***To view the General Conditions Estimate, please reference Appendix B.***

The General Conditions Estimate for the General Services Administration Headquarters Modernization can be broken down into three cost categories:

- Personnel
- Site Expenses
- Miscellaneous Costs

The Personnel category of the General Conditions estimate includes all members of the Project Team for the Whiting-Turner/Walsh Joint Venture. Included in the Site Expenses category are all costs associated with the site office, jobsite operations, and temporary utilities. The Miscellaneous Costs category is comprised of insurance, bonds, and labor escalation. Exclusions from the estimate include home office overhead. A General Conditions Estimate Summary can be found in Table 6.

Table 6: General Conditions Estimate Summary – Developed by Ramuel Holgado

Cost Category	Total Cost	Cost/Week	Percentage of GC Cost
Personnel	$ 2,609,488.88	$ 25,091.24	47.67%
Site Expenses	$ 1,495,487.68	$ 14,379.69	27.32%
Miscellaneous Costs	$ 1,368,905.09	$ 13,162.55	25.01%
TOTAL	$ 5,473,881.65	$ 52,633.48	

The General Conditions Estimate was created using rates from RSMeans; however, known actual rates were used for line items instead of estimated rates when available. The General Conditions Estimate of $5,473,881.65 was approximately 9.97% lower than the actual General Conditions cost of $6,079,893.00.

The difference between the estimated and actual General Conditions costs may be due to the fact that the estimated weekly rates of the Personnel may not have matched the actual rates. In addition, the quantities for the line items were all estimated and may not reflect the actual quantities used on the project. Furthermore, the percentage costs of the General Liability and Builders Risk Insurance and the Payment and Performance Bonds were estimated using RSMeans and adjusted to better match the actual rates, but still may vary from the actual costs on the project.

In conclusion, the weekly cost for the General Conditions Estimate is $52,633.48. As seen in Figure 10, the Personnel costs account for a majority of the General Conditions costs, at 47.67%, while the Site Expenses and Miscellaneous Costs amount to 27.32% and 25.01%, respectively. Overall, the General Conditions are estimated to cost approximately 6.33% of the $86,412,506.00 project, which is about average with a typical construction project. Although renovation projects may typically have higher percentages of General Conditions costs when compared to new construction projects, the relatively average General Conditions percentage on this project may be due to the construction of the New Addition as well as the expensive and advanced MEP system to be installed. With that said, it is crucial to understand the importance of keeping up with project schedule to avoid any added expenses.

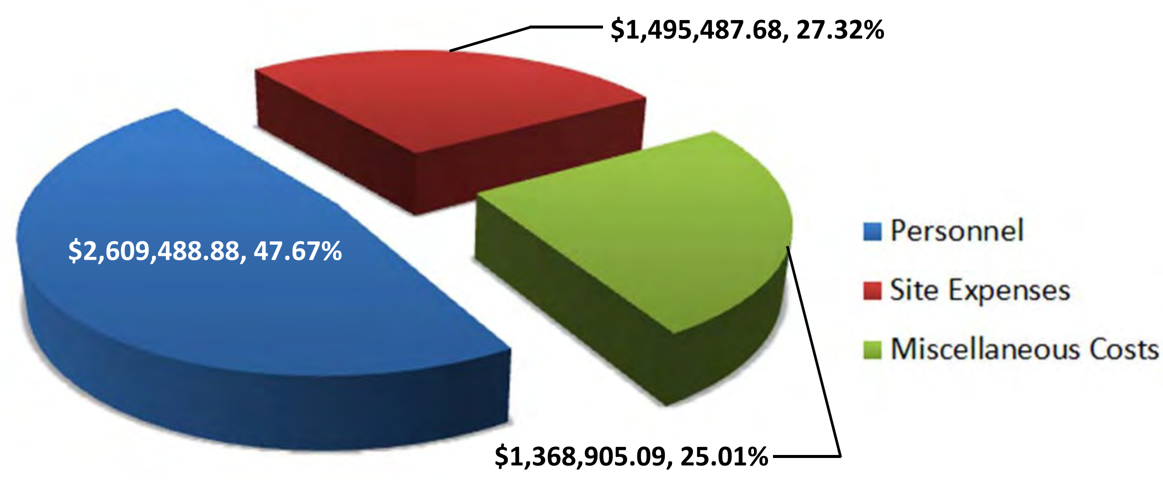

Figure 10: General Conditions Estimate by Percentages – Developed by Ramuel Holgado

CONSTRUCTION OVERVIEW

EXISTING CONDITIONS

- ***To view the site plan for the Existing Conditions, please reference Appendix C-1.***

The U.S. General Services Administration Headquarters was originally constructed in 1917 and is located on 1800 F Street NW, Washington, D.C., which is right outside of George Washington University's Campus and a couple blocks west of the White House. Shaped like the letter "E" with five main wings, its footprint takes up an entire city block, as seen in Figure 11. Buildings that surround it include the National Science Foundation, American Institute of Architecture Students, Octagon Museum, and a couple of George Washington University dormitory halls.

Due to these tight conditions, space became a primary issue on the project. The General Contractor's office was placed on the seventh floor of Wing 4 of the occupied side, while the Subcontractors' offices were placed along the ground floor of Wing 1 of the construction side. The site can be entered only from E Street NW and access doors guarded by security on the ground floor of Wings 1 and 2 between the occupied side and construction side. Construction entrance gates are located in front of the East Courtyard tunnel, adjacent to the West Courtyard tunnel, and in the West Courtyard along Wing 2.

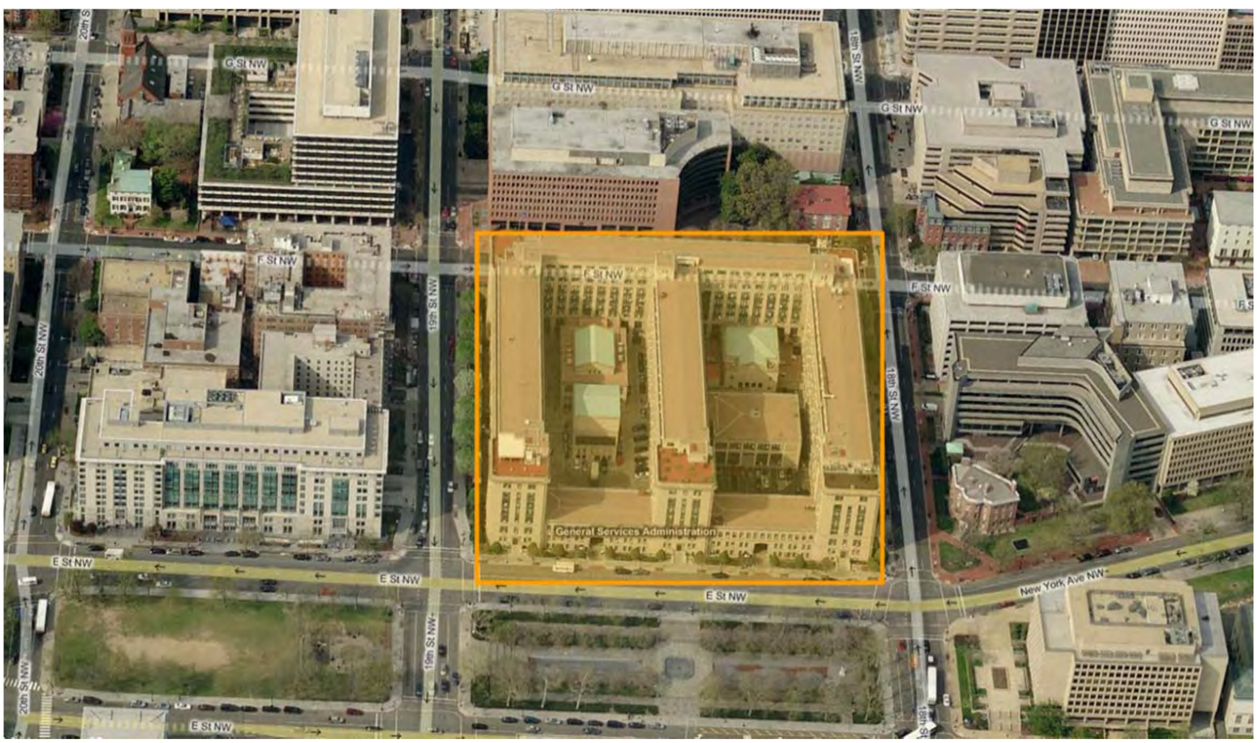

Figure 11: Existing Site of the U.S. General Services Administration Headquarter – Courtesy of Google

The New Addition will be located in the East Courtyard and will have the same number of stories above grade as the Existing Building. All of the existing structures in the East Courtyard, with the exception of the auditorium, will be demolished.

For a complete summary of the Local Conditions, which includes construction parking and soil and subsurface water conditions, please refer to Page 17.

For a complete Existing Conditions Site Plan, which includes building footprints, existing utilities, and vehicular and pedestrian traffic flow, please refer to Appendix C-1.

SITE LAYOUT PLANNING

- ***To view the site plan for the Foundation for the New Addition, please reference Appendix C-2.***
- ***To view the site plan for the Superstructure, please reference Appendix C-3.***
- ***To view the site plan for the Finishes, please reference Appendix C-4.***

OVERVIEW

Phase 1 of the U.S. General Services Administration Modernization consisted of a multitude of different phases of construction throughout the project. This summary of the Site Layout Planning will review three of these critical phases: the Foundation for New Addition Phase, Superstructure Phase, and Finishes Phase. Although a variety of different equipment and manpower were used throughout each phase, the site remained generally unchanged in terms of traffic flow, construction entrances/exits, and laydown areas, among other items.

FOUNDATION FOR NEW ADDITION PHASE

The Foundation for New Addition Phase began immediately after the initial sitework, which included the demolition of four buildings in the East Courtyard. Since the East Courtyard was on the same elevation as the basement of the existing building, minimal excavation was required. The foundation consisted of grade beams and foundation walls. Shortly after they were constructed, the underground plumbing and electric rough-in began. Then, the slab-on-grade was prepared and poured.

Due to the limited amount of space on site, the offices for the General Contractor, Construction Manager, and all the Subcontractors were placed in the existing building. The General Contractor's office was placed on the seventh floor of Wing 4 on the occupied side of the building, facing F Street NW. The Construction Manager's office was located on the ground floor of Wing 0 on the occupied side. Finally, all of the Subcontractors' offices were located along the ground floor of Wing 1 on the construction side. This office layout remained the same for the rest of the project.

The material and equipment storage/laydown area was located in the East Courtyard. Items such as the portable toilets, waste dumpsters, temporary power transformer, and personnel and material hoists remained at the same locations throughout the project. All waste and recycled material, demolished concrete, and unneeded soil were hauled offsite when necessary. Equipment for this phase included an excavator, concrete truck, dump truck, and sheepsfoot compactor.

Considering all of the conditions of the extremely tight site, the site layout plan for the Foundation for New Addition Phase functioned very well. Since safety was a main priority on the project, the project team did an excellent job of managing traffic and directing pedestrians away from the site. In addition, due to the well-thought site plan, the flow of construction was unhindered and the project was able to remain on schedule.

SUPERSTRUCTURE PHASE

The Superstructure Phases consisted of the framing, reinforcing, and placement of the concrete deck, columns, and walls of the New Addition, which is nine stories tall. It also included the erection of the atrium steel, which contain built-up truss columns that are approximately 60 feet in length. Framing for the photovoltaic panels and skylights were also installed during this phase of construction.

The material and equipment storage/laydown area remained in the same location as in the Foundation for New Addition Phase. However, due to the increasing number of deliveries, an additional laydown area was located on E Street NW while another dumpster was placed in the East Courtyard. A 5-ton tower crane was used during this phase of construction to help deliver materials to the New Addition. Additionally, a 90-ton hydraulic truck crane was used to erect the atrium steel in their proper locations. Other equipment used for this phase included a concrete pump truck, concrete truck, and dump truck.

Overall, this phase of construction was much more congested than the previous. However, the project team did a great job of keeping the site safe through the thoughtful placement of the cranes. Deliveries to the site increased and became more difficult, especially with the 60-foot built-up truss columns. While these items were being delivered, E Street NW was shut down to vehicular traffic due to safety concerns. Certified flaggers helped redirect traffic down 18th Street NW. With that said, no significant changes could be made to improve the site layout planning for this phase.

FINISHES PHASE

The Finishes Phase included all the rough-ins and finishes for the existing Wing 1 and Wing 2, as well as the New Addition. This phase also contained the exterior renovation for Wings 1 and 2, which included the restoration of the masonry and salvaged limestone.

The material and equipment storage/laydown area in the East Courtyard and on E Street NW increased in size due to the increased number of deliveries. Both the tower crane and the hydraulic truck crane were removed from site upon the completion of the Superstructure Phase. Additionally, suspended scaffolds were located along Wings 1 and 2 for the exterior renovation. The suspended scaffolds both started in the East Courtyard and sequenced along the perimeter of their respective wings. Equipment used for this phase of construction included telescopic handlers and a dump truck.

Even with the increased work during this phase in Wing 1, Wing 2, the New Addition, and the East Courtyard, the construction team did an outstanding job managing the flow of construction. The combination of a safe and efficient site layout plan allowed all work to be completed according to the schedule. Overall, minimal changes could be made to any of the site layout plans to make significant improvements on the project.

LOCAL CONDITIONS

PREFERRED METHODS OF CONSTRUCTION

Washington, D.C. is a densely populated city with heavy traffic throughout the week. Additional challenges to construction include a generally high water table, strict zoning regulations, and a strenuous permit process. The local conditions therefore make cast in place reinforced concrete a preferred method of construction in the area because of tight streets, ease of transportation, and the Heights of Buildings Act of 1910, which restricts the height of buildings according to the width of the road it is built on.

CONSTRUCTION PARKING

Due to the nature of the location of the project, construction parking at the U.S. General Services Administration Headquarters is extremely limited. The General Contractor utilized space in the East Courtyard and along E Street for deliveries, lifts, cranes, and construction vehicles, such as excavotors and skid-steer loaders. Construction workers and members of the project team, including the Project Managers and Superintendents, were not allowed to park on site. Instead, they were required to find parking in the local parking garages or on the surrounding streets, which had two-hour parking limits. Figure 12 illustrates the construction parking along E Street NW.

Figure 12: Construction Parking along E Street NW - Courtesy of the Whiting-Turner/Walsh Joint Venture

WASTE REMOVAL

In order to help obtain the LEED goals for the project, the handling of waste and recyclables became an important issue. Expectations were for the project to receive one point for recycling 50% of the waste. However, constant early efforts enabled the project to recycle over 95% of the waste. This contributed three points towards the projected LEED Gold Rating. Additionally, recycling was included with the dumpster fees, which was approximately $350 to $400 a pull.

Soil and Subsurface Water Conditions

The geotechnical report showed that the natural residual materials encountered on site were generally consistent with the regional geology and soils information. The natural soils encountered typically consisted of clay, silty sand, clayey sand, poorly-graded sand, poorly-graded sand and gravel, and clayey sand and gravel. Residual soils were encounted at approximately 55 to 60 feet below grade and typically became more dense with depth.

The water table was encountered at approximately 20 to 30 feet below basement elevation. Due to all these conditions, caissons were drilled until they hit bedrock, which was approximately 75 feet below grade.

Local Bylaws and Permitting

Building Permits are required by law for construction in Washington, D.C. The following is a list of items where a Building Permit is needed:

- New construction and foundations
- Additions, alterations, or repair of existing buildings
- Demolition
- Razes
- Construction of retaining walls, fences, sheds, or garages
- Erection of signs or awnings

In addition, a Public Space Permit is required by law for the use or installation of structures on public space, which is the area between the building or property line and the curb. The following list contain of few examples of work that require a Public Space Permit:

- Dumpsters in public space
- Sidewalk construction and repair
- Sidewalk cafes
- Front patios
- Flag poles, planter boxes, retaining walls, and fences in public space

These permits will expire if the authorized work in question has not begun within one year of the issuance of the permit or if the authorized work has been abandoned for a period of one year after it has begun.

The items where Building Permits and Pubic Space Permits were required for the General Services Administration Headquarters Modernization included demolition, razes, and fences in public space.

DETAILED PROJECT SCHEDULE

- ***To view the Detailed Project Schedule, please reference Appendix D.***

OVERVIEW

The Detailed Project Schedule, which is available in Appendix D, illustrates the major phases of construction for the General Services Administration Headquarters Modernization. Included in the schedule are key milestones and phasing relationships. The schedule summary contains three main stages of the project:

- Design & Preconstruction Phase
- Construction Phase
- Final Closeout

DESIGN AND PRECONSTRUCTION PHASE

The Design and Preconstruction Phase consists of 708 days and includes activities such as the Administrative Notice to Proceed and the Demolition/Abatement Plan. The project was awarded to Whiting-Tuner/Walsh Joint Venture on September 15, 2010. Additionally, the Procurement of Construction Services lasts 533 days and overlaps into the Construction Phase before ending on November 14, 2012.

CONSTRUCTION PHASE

The Construction Phase is broken down into five phases of work, which overlap each other throughout the project. These phases are the New Addition, Wing 1, Wing 2, Exterior, and Final Sitework. Since Wing 1 and Wing 2 are mainly being renovated in the interior, the Initial Sitework/Demolition is listed under the New Addition. The schedule for the New Addition also contains the erection of the Structure, Rough-Ins, Finishes, Chiller Plant, and Loading Dock.

Wing 1 and Wing 2 contain the Rough-Ins and Finishes as well as the construction of the Elevators, Steam Plant, and the Electric, Mechanical, and Communication Rooms. The New Addition and both Wings were worked on simultaneously. The durations of Wing 1 and Wing 2 are 238 days and 288 days, respectively.

The other phases of the Construction Phase include the Exterior and Final Sitework. The Exterior phase consists of the Exterior Renovation and Rooftop Work. Activities under the Exterior Renovation include the restoration of masonry and salvaged stone as well as the stripping and priming of the windows and window frames. The Exterior lasts 310 days to complete, while the Final Sitework lasts 97 days.

FINAL CLOSEOUT

The Final Closeout takes 35 days for the General Services Administration Headquarters Modernization. Included in this phase are the Trade and Building Final Inspections and Final Punch List. The Substantial Completion for the project is on April 15, 2013, while the Final Completion is set for May 20, 2013. The Project Schedule Overview can be seen in Table 7.

Table 7: Project Schedule Overview – Developed by Ramuel Holgado

	Duration	Start Date	Finish Date
Design & Preconstruction Phase	708	3/8/2010	11/14/2012
Construction Phase	547	3/10/2011	4/5/2013
New Addition	543	3/10/2011	4/1/2013
Initial Sitework/Demolition	184	3/10/2011	11/22/2011
Structure	239	11/23/2011	10/15/2012
Rough-Ins	155	5/14/2012	12/12/2012
Finishes	204	6/20/2012	4/1/2013
Wing 2	288	2/28/2012	3/28/2013
Rough-Ins & Finishes	288	2/28/2012	3/28/2013
Wing 1	238	5/5/2012	3/28/2013
Rough-Ins & Finishes	238	5/5/2012	3/28/2013
Exterior	310	11/1/2011	12/31/2012
Exterior Renovation	187	4/20/2012	12/31/2012
Final Sitework	97	11/22/2012	4/5/2013
Final Closeout	35	4/2/2013	5/20/2013
TOTAL	836	3/8/2010	5/20/2013

ANALYSIS 1: NEW ADDITION FAÇADE REDESIGN

- ***To view the Atrium Takeoffs and Calculations, please reference Appendix E.***

PROBLEM IDENTIFICATION

The main challenges of the New Addition Façade include the delivery of the trusses and the coordination of the 5-ton tower crane with the 90-ton hydraulic truck crane, which was brought on site solely for the erection of the truss columns. Due to the nature of the tight and congested streets of downtown Washington, D.C., the delivery of the 78-foot truss columns was somewhat difficult. The portion of E Street NW behind the building was shut down when the truck deliveries arrived once a day, which contained one truss column and one roof truss. A certified flagger would then direct oncoming traffic and pedestrians away from the delivery and toward 18th Street NW. The hydraulic truck crane would then lift each individual truss off the truck bed and place it safely on site before erecting them on the atrium. Since the hydraulic truck crane was situated next to the tower crane during the erection of the trusses and had overlapping swing radii, coordination between the cranes was absolutely crucial.

BACKGROUND INFORMATION

The curtain wall system on the south façade of the New Addition of the GSA Headquarters, as seen in Figure 13, rises over 78 feet in height and spans the entire length of the atrium. It is composed of seven 78-foot built-up truss columns consisting of HSS 5x5x3/8 members that are connected to 27-foot roof trusses. A 90-ton hydraulic truck crane, which will be located on E Street NW, will erect the atrium steel into place.

RESEARCH GOAL

An alternate design will be researched and developed in order to improve cost, schedule, and constructability all without significantly altering the architectural aesthetics of the façade.

Figure 13: Interior rendering of the atrium showing the curtain wall system – Courtesy of the Whiting-Turner/Walsh Joint Venture

POTENTIAL SOLUTION

A potential solution would be to downsize the overall size of the curtain wall system. Using truss columns that are four-stories high rather than six-stories high may eliminate many constructability concerns. First off, the delivery and erection of multiple truss columns and roof trusses a day may be possible, which could accelerate the schedule. Shorter trusses would equate to using a smaller crane than the 90-ton hydraulic truck crane, which may lead to less coordination issues with the tower crane. In addition, incorporating less glazing may improve the acoustics for the open office floor plans of the New Addition, which may be an important concern considering the urban location of the GSA Headquarters.

METHODOLOGY

- Interview the Whiting-Turner/Walsh Joint Venture Project Team and ACM Erectors, Inc./Baltimore Steel Erectors in regards to the constructability issues of the current façade
- Redesign façade
- Research alternate crane sizes for the erection of the shorter truss columns
- Measure the impact on atrium steel delivery, cost, constructability, and schedule acceleration for installing a smaller curtain wall
- Measure the changes of the acoustics on the open office floor plans due to the reduced window surface area

RESEARCH RESOURCES AND TOOLS

- Industry Professionals
- The Pennsylvania State University Architectural Engineering Faculty
- The Whiting-Turner/Walsh Joint Venture Project Team
- ACM Erectors, Inc./Baltimore Steel Erectors
- Applicable Project Documents
- AE 202 – Introduction to Architectural Engineering Concepts
- AE 309 – Architectural Acoustics
- AE 372 – Introduction to the Building Industry
- AE 472 – Building Construction Planning and Management
- AE 473 – Building Construction Management and Control
- AE 475 – Building Construction Engineering I
- AE 476 – Building Construction Engineering II

EXPECTED OUTCOME

The expected outcome of downsizing the curtain wall system to about two-thirds its original size may reap several benefits. First and foremost, the delivery and erection of multiple truss columns and roof trusses in a single day may be possible, which could accelerate the schedule. Secondly, a smaller hydraulic crane might be possible, which could potentially reduce coordination issues with the tower crane. Less surface area of curtain wall glazing, shorter truss columns, and a smaller crane will also result in cost savings. Additionally, the reduced surface area of glass may positively impact the acoustical performance of the New Addition.

ORIGINAL FAÇADE DESIGN

The original façade assembly is located at the south façade of the New Addition in the East Courtyard, as seen in Figure 14. The atrium steel contains seven 78-foot built-up truss columns consisting of HSS 5x5x3/8 members that are connected to 27-foot roof trusses. A seated connection will be used to attach the roof trusses to the concrete beam on the Seventh Floor of the New Addition. A 90-ton hydraulic truck crane, which will be located on E Street NW, will erect the atrium steel into place. When fully erected, the lower 16 feet of the truss columns will be encased in concrete with stainless steel cladding and enclosed by the curtain wall system.

Figure 14: Exterior rendering of the atrium showing the curtain wall system of the New Addition in the East Courtyard – Courtesy of the Whiting-Turner/Walsh Joint Venture

The curtain wall system is composed of an in-fill atrium exterior vertical glazing made of 1 3/16" clear, insulated argon, laminated, low-emissivity glass and an in-fill atrium horizontal glazing made of 1 5/16" clear, insulated, laminated, low-emissivity, fritted glass. The vertical glazing also consists of sunshades and motorized operable awning windows located along both the top and bottom of the curtain wall. The horizontal glazing contains operable windows at the skylights, extruded aluminum gutter assemblies with galvanized steel grating, and electrochromic glazing light sensors, which can automatically control the amount of light and solar energy that can pass through the glazing. The total surface area of the vertical glazing is approximately 9,575 square feet, while the total surface area of the horizontal glazing is about 3,600 square feet.

The current schedule appropriated one truss column and one roof truss to be delivered and erected each day for a total duration of seven days. The approximate lead time for the atrium steel was four to six months due to site measurements, coordination, and painting. The curtain wall was allotted 20 days in the schedule. In reality, it took roughly 35 days as some of the belt courses needed to be notched out because they protruded into the curtain wall. Framing for the skylights took about 15 days while setting the skylights took an additional 10 days. Overall, the current atrium took a total of 67 working days to complete.

Including all material, labor, and equipment, the total cost of the atrium totaled to roughly $8.65M. The original contract for the atrium steel with Baltimore Steel Erectors, LLC came to $2.5M. GPR Inc.'s original contract for the curtain wall summed up to $5.35M. The skylights were furnished and installed by two separate contractors. The original contract with Super Sky Products, Inc. reached $225,000, while the original contract with McCoy Associates, Inc. came to $575,000 for a total amount of $800,000 for the skylights.

ALTERNATE FAÇADE DESIGN

As mentioned previously, a potential solution would be to downsize the overall size of the curtain wall system. The current assembly uses 78-foot built-up truss columns that stand six-stories tall along with over 9,500 square feet of vertical and horizontal glazing for the curtain wall. Downsizing the built-up truss columns to 51 feet tall, which would be from the first floor up to the fifth floor, would reduce the total glazing to 5,400 square feet. Since the actual footprint of the atrium will remain the same, the size of the skylights will also remain the same at approximately 3,600 square feet.

Since the proposed atrium would only ascend three stories above the first story as opposed to five, the remaining two stories will be constructed similar to the existing limestone building façade. The typical wall section will include salvaged limestone on the exterior with brick masonry backup and 2-1/2" rigid insulation. The windows will be constructed with 1-1/16" clear, insulated, laminated, low-emissivity glass with an aluminum frame that matches the existing windows. A rendering of the alternate south-facing façade of the New Addition may be seen in Figure 15.

Figure 15: Exterior rendering of the proposed alternate atrium showing the curtain wall system of the New Addition in the East Courtyard – Rendering Edited by Ramuel Holgado – Original Rendering Courtesy of the Whiting-Turner/Walsh Joint Venture

ALTERNATE FAÇADE IMPLEMENTATION

By using Autodesk Quantity Takeoff and comparing totals to the original design, takeoffs for the alternate design were able to be completed. The original curtain wall, which is five stories high, contains a total of 9,575 square feet of glazing. The alternate curtain wall, which is proposed to be three stories high, would contain 5,400 square feet of glazing, or approximately 56.4 percent of the original. As mentioned previously, the actual footprint of the atrium will not change. Therefore, the square feet of horizontal glazing, which is about 3,600 square feet, will remain the same for both the original and alternate system. The linear feet of the original atrium steel, including the built-up truss columns and roof trusses, totaled to about 730 linear feet. The alternate design will only require approximately 536 linear feet, which is about 73 percent of the original total. The proposed limestone wall and windows on the fifth and sixth floor of the south façade of the New Addition were taken off by using the East Courtyard south elevation of the fifth and sixth floors of Wing 0, which would be identical to the alternate design. Quantities for the limestone wall and windows came out to be 1,890 and 1,332 square feet, respectively.

Since the curtain wall system, skylights, and atrium steel used on the actual atrium is very unique to the project, unit costs were found for the current system and applied to the proposed façade. At $5.35M and 9,575 square feet, the unit cost for the curtain wall is $558.75 per square foot. Using this value, the cost of the alternate system will be just under $3.02M. Since the total square feet for the skylights will remain the same, the total price of the alternate skylights will remain $800,000. The original atrium steel cost a total of $2.5M and contained about 730 linear feet for a unit cost of just under $3,425 per linear foot. Using this rate, the alternate atrium steel will account for roughly $1.83M. Unit prices for the limestone wall and windows were taken from RS Means CostWorks. The unit cost for the limestone wall, which includes the rigid insulation and brick masonry backup, added up to $56.18 per square foot. Therefore, the limestone wall would cost just over $106,000. Since there were no window sizes in RS Means CostWorks that matched the size used on the alternate design, the closest size was picked and the cost per square foot was determined. This rate, which is $28.06 per square foot, was then applied to the windows on the alternate façade. The total for the 16 windows on the fifth and sixth floors came to about $37,000. Overall, the total cost of the alternate façade summed up to over $5.79M.

Similarly to the cost estimate, due to the unique components of the atrium, the durations for the different components of the alternate system were calculated as percentages of the original durations by comparing the sizes of each component. It must be noted that these figures may not be completely accurate as they disregard factors such as learning curve. Since the curtain wall of the alternate system was about 56.4 percent the size of the original system, it is estimated that the duration of the alternate system will be roughly 56.4 percent of the original 35-day duration, which would come out to 20 days. Since the skylights and horizontal glazing will remain the same size, the duration for the alternate system will remain at 25 days. For the original atrium steel, one built-up truss column and one roof truss was delivered and erected each day. With a built-up truss column that is nearly two-thirds the height of the original, it is estimated that two truss columns and two roof trusses can be delivered and erected each day for a total duration of four days. Finally, durations for the limestone wall and windows were determined by using the previously mentioned takeoffs and RS Means CostWorks. Durations for the limestone wall and windows were nine and six days, respectively. In total, the alternate atrium schedule will take 64 working days to complete.

The current rental crane is a Grove TMS900E 90-ton hydraulic truck crane from W.O. Grubb Crane Rental out of Portsmouth, Virginia. Since the largest item of steel that the alternate system will have is 51 feet long as opposed to the original 78 feet, smaller cranes may be considered. However, it is important to keep the boom length in mind. The crane will be situated on E Street NW approximately 80 feet away from where the truss columns will be erected. The crane must lift the 51-foot truss columns a safe distance over the 27-foot section of Wing 4. Therefore, the crane should have a boom length of at least 130 feet to ensure that it can safely lift the truss columns 20 feet over the top of Wing 4. The W.O. Grubb Crane Rental Product Guide shows that the only hydraulic truck crane that can satisfy this need is the current Grove TMS900E. Figure 16 shows a diagram of the crane situation.

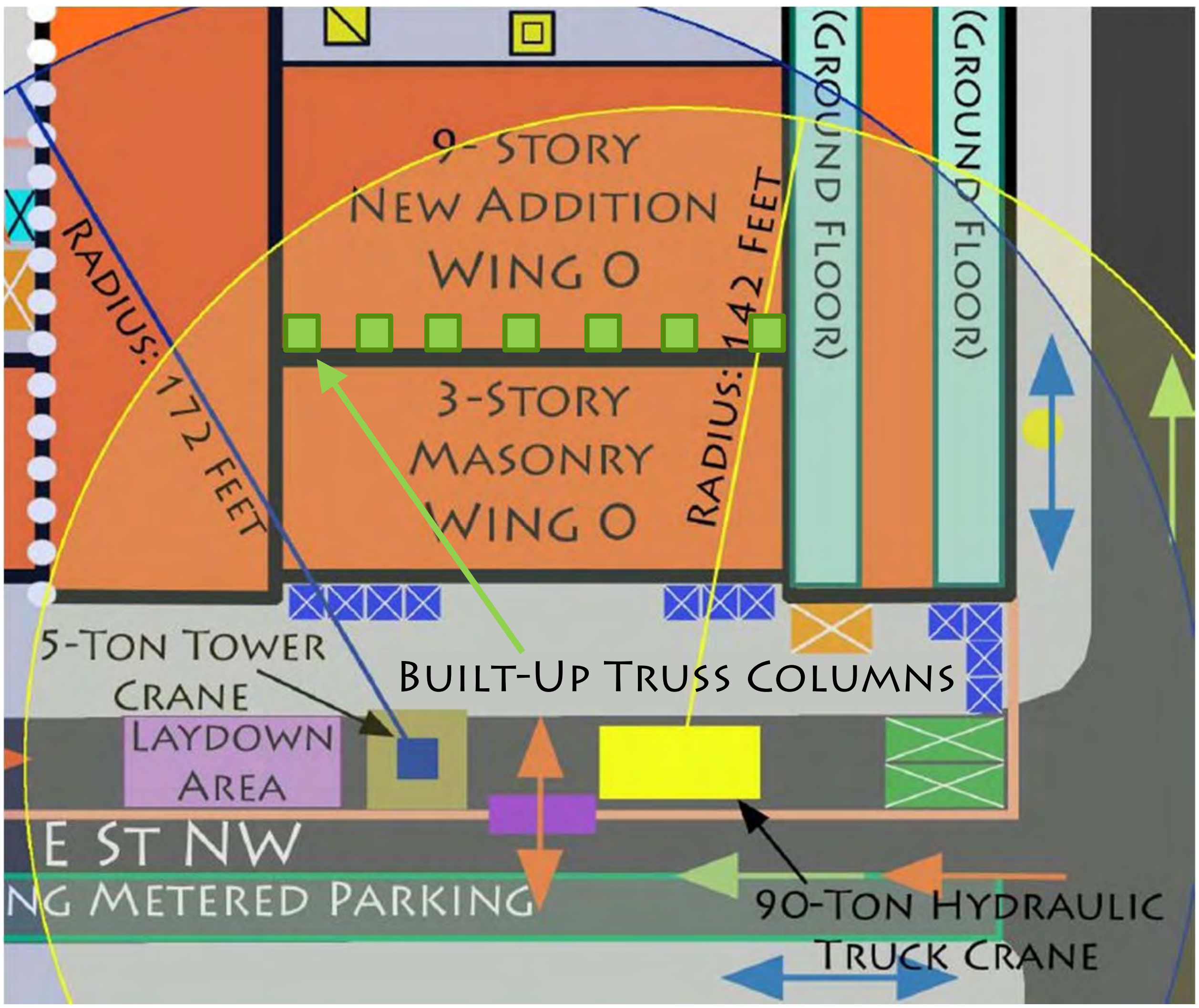

Figure 16: Diagram showing the proximity of the 90-ton hydraulic truck crane to the built-up truss columns – Developed by Ramuel Holgado

Architecturally speaking, it may be argued that the downsized curtain wall and atrium looks more aesthetically pleasing than the original design. Originally built in 1917 and updated in 1935, the General Services Administration Headquarters is renowned for its role in the architectural development of the federal office building type and its neoclassical style. A curtain wall that consumes the entire south elevation of the New Addition looks somewhat disproportionate. Downsizing the curtain wall so that two stories of limestone and windows may run across the fifth and sixth floor of the New Addition preserves its neoclassical style while still maintaining a modern look.

It should be noted that downsizing the atrium will eliminate the walkway located at the south end of the New Addition from Wing 1 and Wing 2. That being said, the walkway on the north end of the New Addition will still be available. So although it may disrupt the flow between Wings 1 and 2 on the fifth and sixth floors, occupants will still have a means to travel through the New Addition.

COST IMPACT

A breakdown of the alternate system cost estimate can be seen in Table 8. Unit costs of the original system were calculated and used to estimate the total cost of the alternate design. The cost of the limestone wall and windows, which were not part of the original system, were estimated by using RS Means CostWorks. These items were taken off by using the East Courtyard south elevation of the fifth and sixth floors of Wing 0, which is duplicated in the alternate design.

Table 8: Alternate System Cost Estimate – Developed by Ramuel Holgado

Alternate System Cost Estimate							
System	Design	Unit	Quantity	Actual Cost	Actual Cost/Unit	TOTAL Estimated	Estimated Cost/Actual
Curtain Wall	Original	SF	9575.0	$5,350,000.00	$ 558.75	$ -	N/A
	Alternate	SF	5400.0	$ -	$ -	$3,017,232.38	56.4%
Skylights	Original	SF	3595.7	$ 800,000.00	$ 222.49	$ -	N/A
	Alternate	SF	3595.7	$ -	$ -	$ 800,000.00	100.0%
Atrium Steel	Original	LF	730.3	$2,500,000.00	$ 3,423.20	$ -	N/A
	Alternate	LF	535.5	$ -	$ -	$1,833,125.66	73.3%
Limestone Wall	Original	SF	0.0	$ -	$ -	$ -	N/A
	Alternate	SF	1890.0	$ -	$ 56.18	$ 106,180.20	N/A
Windows	Original	SF	0.0	$ -	$ -	$ -	N/A
	Alternate	SF	1332.0	$ -	$ 28.06	$ 37,375.92	N/A

Table 9 compares the original cost against the alternate cost estimate. The total cost of the alternate façade, which includes the downsized curtain wall, skylights, atrium steel, limestone wall, and windows, came to $5,793,914.15. The total cost of the original design, which only contained the full-sized curtain wall, skylights, and atrium steel, summed up to $8,650,000. Therefore, by downsizing the atrium so that the built-up truss columns are four stories in height rather than six stories in height, the total savings for the New Addition façade redesign would amount to $2,856,085.85.

Table 9: Atrium System Cost Comparison – Developed by Ramuel Holgado

Atrium System Cost Comparison						
System	Curtain Wall	Skylights	Atrium Steel	Limestone Wall	Windows	TOTAL
Original	$5,350,000.00	$ 800,000.00	$2,500,000.00	$ -	$ -	$8,650,000.00
Alternate	$3,017,232.38	$ 800,000.00	$1,833,125.66	$ 106,180.20	$ 37,375.92	$5,793,914.15
SAVINGS						$2,856,085.85

SCHEDULE IMPACT

Table 10 shows a quick overview of the atrium system schedule comparison. As previously mentioned, the original system will take a total of 67 working days to complete. The alternate system will take a total of 64 working days to complete. Therefore, although the alternate system will take less time to erect and deliver the shorter truss columns as well as install the downsized curtain wall, more time to the schedule will be added for the limestone wall and windows. A total of only three days will be saved when constructing the alternate design over the original.

Table 10: Atrium System Cost Comparison – Developed by Ramuel Holgado

Atrium System Schedule Comparison						
System	Curtain Wall	Skylights	Atrium Steel	Limestone Wall	Windows	TOTAL
Original	35	25	7	0	0	67
Alternate	20	25	4	9	6	64
DIFFERENCE						3

CONSTRUCTABILITY

The original system had many constructability issues. First off, the trusses needed to be verified that they were plumb and that the spacing was correct to ensure that the blast curtain wall would align and clip correctly to the vertical trusses. Additionally, the general contractor had to notch out some of the belt courses that protruded into the curtain wall, resulting in a delay of about 15 working days. Another concern was that it was difficult to deliver the 78-foot truss columns in downtown Washington, D.C., as seen in Figure 17. Coordination of the 5-ton tower crane with the 90-ton hydraulic truck crane also proved troublesome.

The alternate façade may not have completely fixed any of these issues, but it certainly would have helped. Less belt courses would have needed to be notched out because the curtain wall is smaller. In addition, the shorter truss columns would have been easier to deliver to downtown Washington, D.C. and it may have been possible to deliver multiple daily. Although shorter truss columns may have allowed for a smaller hydraulic truck crane, ultimately, the actual 90-ton crane must be selected due to its extended boom length.

Figure 17: Atrium Built-Up Truss Column Delivery on the intersection of 18th Street NW and E Street NW – Courtesy of the Whiting-Turner/Walsh Joint Venture

RECOMMENDATION AND CONCLUSION

Redesigning the façade by downsizing the atrium solves may potentially solve many issues. It will allow for easier delivery of the built-up truss columns to downtown Washington, D.C. and will require less notching of the belt courses that protrude into the curtain wall, which caused a delay. In regards to the schedule, the alternate design only shaved off three working days. However, the total cost saved is nearly $3M. A majority of this money was saved by reducing the size of the curtain wall which features smart glass coupled with electrochromic glazing light sensors.

All things considered, I would not recommend the redesign of the south-facing façade of the New Addition. The General Services Administration has made it clear that their headquarters will serve as their showcase project. Therefore, the amount of cost saved from redesigning the façade does not outweigh the change in architectural aesthetics or reduction of the state-of-the-art curtain wall glazing as the General Services Administration pushes to change their identity to become a leader in sustainability and high performance green building initiatives. Maintaining the full-size curtain wall as seen in the original design gives the 96-year-old building a more modern facelift. In addition, the walkways along the fifth and sixth floor of the New Addition that look down on the atrium and towards the National Mall may seem too valuable of a feature to lose, especially to the architect and the General Services Administration.

ACOUSTICAL BREADTH: FAÇADE REDESIGN ACOUSTICAL IMPACT

- ***To view the complete Acoustical Analysis Calculations, please reference Appendix F.***

INTRODUCTION

Due to its location in downtown Washington, D.C., the acoustical performance of the General Services Administration becomes an important topic, especially since it contains an office environment. This analysis will measure the acoustical performance of the areas affected by the façade redesign that is adjacent to E Street NW, including the original atrium design and the alternate design, which includes a downsized atrium and open office floor plans on the fifth and sixth floors of the New Addition.

The ultimate goal is to calculate the Noise Criteria (NC) and Room Criteria (RC) and compare these values to the NC and RC recommendations provided by the textbook, *Architectural Acoustics*, by M. David Egan. These values will help determine if the sound pressure levels are acceptable for the office setting.

ORIGINAL DESIGN ANALYSIS

The original design of the atrium has a total volume of approximately 283,460 cubic feet. In order to determine the absorption coefficient, the surface area and material of each component of the atrium was determined. The absorption coefficients were gathered from *Architectural Acoustics*, which allowed the total room absorption to be computed at the necessary center frequency octave bands. Table 11 displays the absorption coefficient and surface areas of each component of the atrium as well as the total room absorption.

Table 11: Original Design Total Absorption – Courtesy of Ramuel Holgado

Absorption Coefficient							Total Absorption						
	Coefficients							Room Absorption					
	125 HZ	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	Area (m^2)	125 HZ	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
South Wall (1st Floor)	0.36	0.44	0.31	0.29	0.39	0.25	105.8	38.08	46.54	32.79	30.67	41.25	26.44
East Wall (1st Floor)	0.36	0.44	0.31	0.29	0.39	0.25	27.3	9.83	12.02	8.47	7.92	10.65	6.83
West Wall (1st Floor)	0.36	0.44	0.31	0.29	0.39	0.25	27.3	9.83	12.02	8.47	7.92	10.65	6.83
Windows (1st Floor)	0.35	0.25	0.18	0.12	0.04	0.04	71.6	25.08	17.91	12.90	8.60	2.87	2.87
Interior Atrium Curtain Wall	0.35	0.25	0.18	0.12	0.04	0.04	826.8	289.38	206.70	148.83	99.22	33.07	33.07
Atrium Curtain Wall	0.35	0.25	0.18	0.12	0.04	0.04	889.5	311.34	222.39	160.12	106.74	35.58	35.58
Floor	0.01	0.01	0.02	0.02	0.02	0.02	334.1	3.34	3.34	6.68	6.68	6.68	6.68
Doors	0.35	0.25	0.18	0.12	0.04	0.04	77.3	27.07	19.34	13.92	9.28	3.09	3.09
Atrium Skylights (Ceiling)	0.35	0.25	0.18	0.12	0.04	0.04	334.1	116.92	83.51	60.13	40.09	13.36	13.36
Atrium Trusses	0.05	0.10	0.10	0.10	0.07	0.02	386.6	19.33	38.66	38.66	38.66	27.06	7.73
Concrete Encased Columns	0.10	0.05	0.06	0.07	0.09	0.08	229.7	22.97	11.49	13.78	16.08	20.68	18.38
Balcony Floor (2nd Floor)	0.35	0.25	0.18	0.12	0.04	0.04	36.3	12.71	9.08	6.54	4.36	1.45	1.45
Balcony Floor (Floors 3-6)	0.01	0.01	0.02	0.02	0.02	0.02	391.3	3.91	3.91	7.83	7.83	7.83	7.83
Balcony Ceiling	0.29	0.10	0.05	0.04	0.07	0.09	427.6	124.01	42.76	21.38	17.11	29.93	38.49
Balcony Railing	0.35	0.25	0.18	0.12	0.04	0.04	143.1	50.07	35.77	25.75	17.17	5.72	5.72
People (40 Adults)	0.25	0.35	0.42	0.46	0.50	0.50	76.0	19.00	26.60	31.92	34.96	38.00	38.00
							Total	1082.89	792.03	598.16	453.28	287.89	252.36

The sound pressure levels of downtown Washington, D.C. were then estimated. Following this, the calculation for the adjoining wall between the atrium and E Street NW could begin. First, the wall, window, door, and curtain wall types and surface areas were determined. A composite transmission loss was then computed by finding the transmission loss and intensity transmission coefficients. After calculating the noise reductions, the reverberant field level of the atrium was determined. These values can be seen in Table 12.

Table 12: Original Design Reverberant Field Level – Courtesy of Ramuel Holgado

Reverberant Field Level (L_{irf} in Receiving Room)						
Octave Band (Hz)	**125**	**250**	**500**	**1000**	**2000**	**4000**
Reverberant Field Level (dB)	61	54	47	39	43	36

These levels were then inserted in the NC and RC charts, as seen in Figure 18. After comparing the values to their respective curves, it was determined that the original atrium design has an NC Rating of 46 and an RC Rating of 48. The recommended NC and RC range for a public circulation space for an office is from 40 to 45. Therefore, it may be concluded that the NC and RC ratings for the original design is slightly above the recommended range.

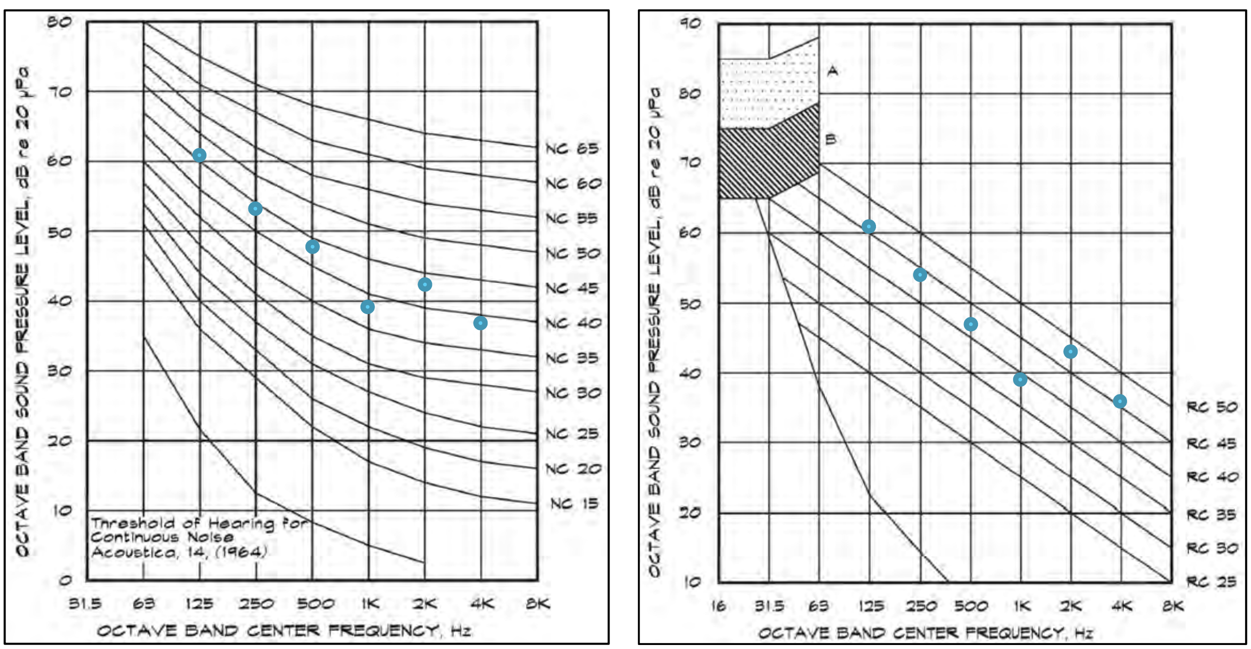

Figure 18: Original Design NC and RC Charts – Courtesy of Ramuel Holgado

ALTERNATE DESIGN ANALYSIS

The alternate design is composed of two separate entities: the downsized atrium and the open office plans of the fifth and sixth floor. The NC and RC ratings for these areas were calculated separately, but in the same manner as the original system. Focusing first on the alternate atrium, the surface area and absorption coefficient for each material and the total room absorption can be found in Table 13.

Table 13: Alternate Design (Atrium) Total Absorption – Courtesy of Ramuel Holgado

Absorption Coefficient							Total Absorption						
	Coefficients							Room Absorption					
	125 HZ	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	Area (m^2)	125 HZ	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
South Wall (1st Floor)	0.36	0.44	0.31	0.29	0.39	0.25	105.8	38.08	46.54	32.79	30.67	41.25	26.44
East Wall (1st Floor)	0.36	0.44	0.31	0.29	0.39	0.25	27.3	9.83	12.02	8.47	7.92	10.65	6.83
West Wall (1st Floor)	0.36	0.44	0.31	0.29	0.39	0.25	27.3	9.83	12.02	8.47	7.92	10.65	6.83
Windows (1st Floor)	0.35	0.25	0.18	0.12	0.04	0.04	71.6	25.08	17.91	12.90	8.60	2.87	2.87
Interior Atrium Curtain Wall	0.35	0.25	0.18	0.12	0.04	0.04	427.4	149.60	106.86	76.94	51.29	17.10	17.10
Atrium Curtain Wall	0.35	0.25	0.18	0.12	0.04	0.04	501.7	175.59	125.42	90.30	60.20	20.07	20.07
Floor	0.01	0.01	0.02	0.02	0.02	0.02	334.1	3.34	3.34	6.68	6.68	6.68	6.68
Doors	0.35	0.25	0.18	0.12	0.04	0.04	66.5	23.27	16.62	11.96	7.98	2.66	2.66
Atrium Skylights (Ceiling)	0.35	0.25	0.18	0.12	0.04	0.04	334.1	116.92	83.51	60.13	40.09	13.36	13.36
Atrium Trusses	0.05	0.10	0.10	0.10	0.07	0.02	268.1	13.41	26.81	26.81	26.81	18.77	5.36
Concrete Encased Columns	0.10	0.05	0.06	0.07	0.09	0.08	229.7	22.97	11.49	13.78	16.08	20.68	18.38
Balcony Floor (2nd Floor)	0.35	0.25	0.18	0.12	0.04	0.04	36.3	12.71	9.08	6.54	4.36	1.45	1.45
Balcony Floor (Floors 3-4)	0.01	0.01	0.02	0.02	0.02	0.02	195.7	1.96	1.96	3.91	3.91	3.91	3.91
Balcony Ceiling	0.29	0.10	0.05	0.04	0.07	0.09	231.9	67.25	23.19	11.60	9.28	16.23	20.87
Balcony Railing	0.35	0.25	0.18	0.12	0.04	0.04	81.3	28.45	20.32	14.63	9.75	3.25	3.25
People (34 Adults)	0.25	0.35	0.42	0.46	0.50	0.50	64.6	16.15	22.61	27.13	29.72	32.30	32.30
							Total	714.43	539.69	413.04	321.26	221.88	188.36

The adjoining wall for the alternate atrium is similar to that of the original atrium. The only difference is that the surface area of the curtain wall of the alternate design is about 56 percent the total surface area of the original design. The noise reduction was then determined after the composite transmission loss was calculated by finding the transmission loss and intensity transmission coefficients. That being said, the reverberant field level of the downsized atrium is similar to the full-sized atrium with only slightly lower levels at the 500 Hz and 2000 Hz octave bands, as seen in Table 14.

Table 14: Alternate Design (Atrium) Reverberant Field Level – Courtesy of Ramuel Holgado

Reverberant Field Level (L_{lrf} in Receiving Room)						
Octave Band (Hz)	125	250	500	1000	2000	4000
Reverberant Field Level (dB)	61	54	46	39	42	36

The NC and RC charts for these values can be found in Figure 19. As expected, these ratings were nearly similar to the original ratings. The alternate atrium design has an NC and RC rating of 46 and 47, respectively. As mentioned previously, the recommended NC and RC range for a public circulation space for an office is from 40 to 45. As a result, these ratings are also slightly above the recommended range and may not seem suitable for the space.

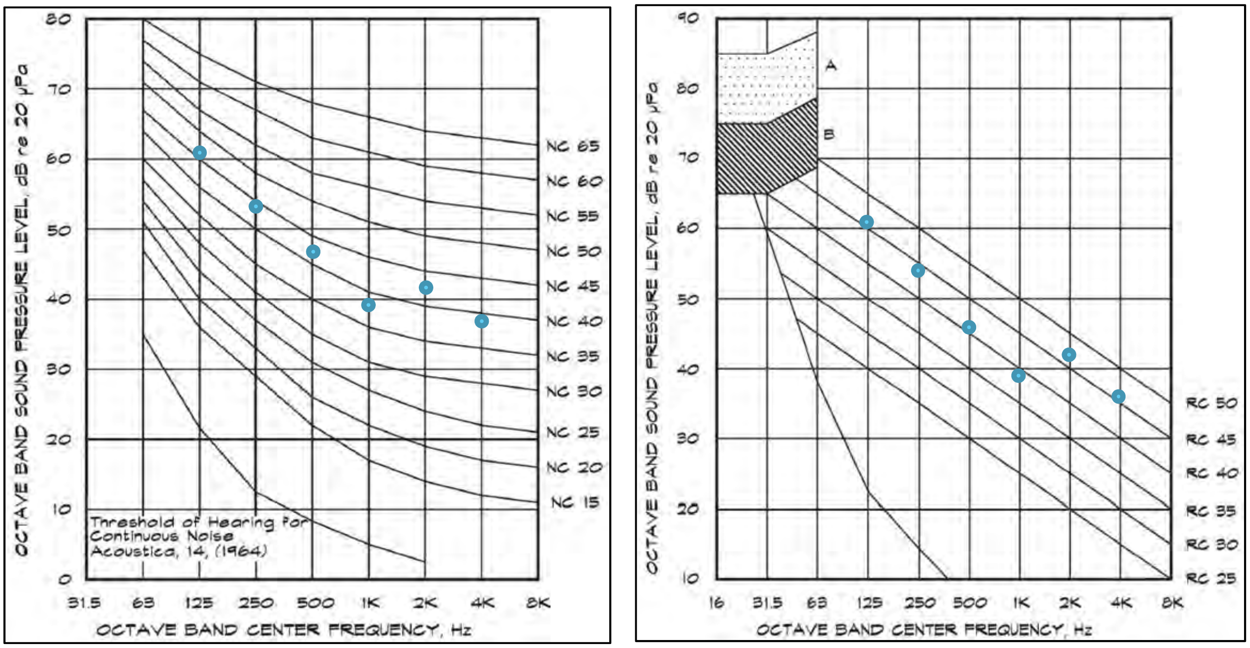

Figure 19: Alternate Design (Atrium) NC and RC Charts – Courtesy of Ramuel Holgado

The fifth and sixth floors of the alternate design feature an identical open office floor plan and an adjoining wall that is composed of salvaged limestone and windows rather than the curtain wall of the atrium. Therefore, for the purposes of this analysis, only the fifth floor was analyzed. The materials, absorption coefficients, and total room absorption for this space may be seen in Table 15.

Table 15: Alternate Design (Office) Total Absorption – Courtesy of Ramuel Holgado

	Absorption Coefficient						Total Absorption						
	Coefficients							Room Absorption					
	125 HZ	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	Area (m^2)	125 HZ	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
South Wall	0.36	0.44	0.31	0.29	0.39	0.25	67.4	24.25	29.64	20.88	19.53	26.27	16.84
South Wall Windows	0.35	0.25	0.18	0.12	0.04	0.04	66.9	23.41	16.72	12.04	8.03	2.68	2.68
East Wall	0.36	0.44	0.31	0.29	0.39	0.25	31.2	11.24	13.73	9.68	9.05	12.17	7.80
East Wall Windows	0.35	0.25	0.18	0.12	0.04	0.04	25.1	8.78	6.27	4.52	3.01	1.00	1.00
West Wall	0.36	0.44	0.31	0.29	0.39	0.25	31.2	11.24	13.73	9.68	9.05	12.17	7.80
West Wall Windows	0.35	0.25	0.18	0.12	0.04	0.04	25.1	8.78	6.27	4.52	3.01	1.00	1.00
North Glazing Type 1	0.35	0.25	0.18	0.12	0.04	0.04	58.8	20.59	14.71	10.59	7.06	2.35	2.35
North Glazing Type 2	0.35	0.25	0.18	0.12	0.04	0.04	73.8	25.84	18.46	13.29	8.86	2.95	2.95
Floor	0.02	0.06	0.14	0.37	0.60	0.65	656.4	13.13	39.39	91.90	242.87	393.85	426.67
Ceiling	0.29	0.10	0.05	0.04	0.07	0.09	656.4	190.36	65.64	32.82	26.26	45.95	59.08
Columns	0.29	0.10	0.05	0.04	0.07	0.09	180.6	52.37	18.06	9.03	7.22	12.64	16.25
People (40 Adults Seated)	0.39	0.57	0.80	0.94	0.92	0.87	76.0	29.64	43.32	60.80	71.44	69.92	66.12
							Total	419.63	285.94	279.73	415.40	582.97	610.56

Unlike the atrium, the adjoining office floor plan is composed of only two elements: the limestone wall and windows. The transmission losses for these components were found along with the intensity transmission coefficients in order to compute the composite transmission loss. The reverberant field level was then calculated after determining the noise reduction and can be examined in Table 16.

Table 16: Alternate Design (Office) Reverberant Field Level – Courtesy of Ramuel Holgado

Reverberant Field Level (L_{irf} in Receiving Room)						
Octave Band (Hz)	125	250	500	1000	2000	4000
Reverberant Field Level (dB)	54	50	42	34	33	21

The values were then plugged into the NC and RC charts, as seen in Figure 20. The open office floor plans of the fifth and sixth floors have an NC Rating of 40 and an RC Rating of 40. The NC and RC recommended range for an open plan area of an office is listed from 35 to 40. Therefore, the ratings for the open office floor plans of the alternate design are within the appropriate levels.

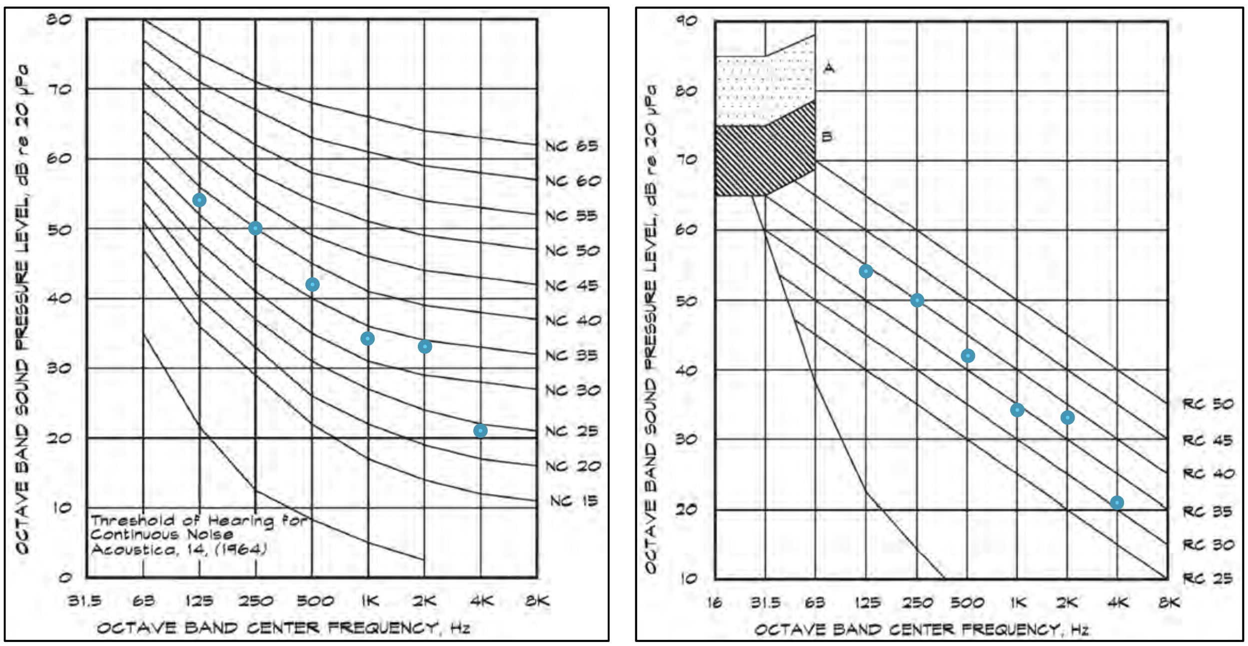

Figure 20: Alternate Design (Office) NC and RC Charts – Courtesy of Ramuel Holgado

CONCLUSION

In conclusion, only the open office floor plans of the alternate design fall within the recommended range. Both the original and alternate atrium designs were slightly above the recommended levels. Potential solutions include adding more absorptive materials into the respective spaces, such as carpet or acoustical board. This will increase the total room absorption relative to the surface area of the adjoining wall, which will increase the noise reduction and lower the reverberant field level as well as the NC and RC ratings.

ANALYSIS 2: NEW ADDITION FOUNDATION SYSTEM

- ***To view the Geotechnical Report, please reference Appendix G.***

PROBLEM IDENTIFICATION

The foundation system for the New Addition of the GSA Headquarters Modernization is composed of 25 caissons that are drilled roughly 75 to 80 feet below grade. The caissons were designed to be positioned underneath the loads of the grade beams, which transfer the loads from the building columns. At $1.56M, the caissons are responsible for approximately 30 percent of the $5.2M structural system. Therefore, with a price that is comparably high in regards to the rest of the structure, it might be advantageous to explore alternate foundation systems that offer better value at a lower price. These options may include deep foundation types, such as mini piles, and shallow foundation types, such as spread footings, raft or mat slabs, and combined footings.

BACKGROUND INFORMATION

A preliminary examination of the geotechnical report showed that the natural residual materials collected on the construction site were relatively consistent with the regional geology and soils information. A list of the natural soils encountered include clay, silty sand, clayey sand, poorly-graded sand, poorly-graded sand and gravel, and clayey sand and gravel. Residual soils were encountered at approximately 55 to 60 feet below grade and typically became denser with depth. The water table is located about 20 to 30 feet below basement elevation. As previously mentioned, the caissons were drilled until they hit bedrock, which was roughly 75 feet below grade.

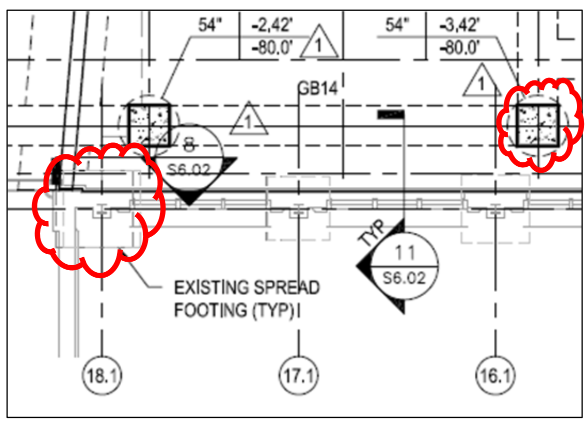

Figure 21: Structural drawing showing the existing spread footings and caissons of the New Addition – Courtesy of the Whiting-Turner/Walsh Joint Venture

RESEARCH GOAL

The goal of this research is to complete an alternate foundation redesign for the New Addition of the G Headquarters that will consider the impact on cost, schedule, and constructability.

POTENTIAL SOLUTION

Structural drawings indicate that the foundation system for the existing building uses spread footings, as seen in Figure 21. Therefore, a feasible potential solution would be to also implement spread footings for the New Addition since it will be situated adjacent to the existing wings and will rise to the same height as the rest of the existing building. An analysis on whether this alternate foundation type can be built faster and at a lower cost than caissons must be completed. Constructability challenges will also need to be considered to determine feasibility. Additionally, a more in-depth examination of the geotechnical report and foundation loads is required to establish whether spread footings are even a viable alternate option.

METHODOLOGY

- Interview the Whiting-Turner/Walsh Group Joint Venture regarding the current caissons foundation system with information relating to why the system was chosen, constructability challenges, and schedule impact
- Explore alternate foundation systems, including both shallow and deep systems
- Examine the geotechnical report
- Analyze the foundation and building loads
- Select and design the most viable alternate foundation system
- Compare cost, schedule impact, and constructability challenges between the current caisson foundation system and the alternate foundation system

RESEARCH RESOURCES AND TOOLS

- Industry Professionals
- The Pennsylvania State University Architectural Engineering Faculty
- The Whiting-Turner/Walsh Joint Venture Project Team
- A. Morton Thomas Engineering (Civil Engineer)
- Brayman Construction Corporation (Caisson Subcontractor)
- Applicable Project Documents
- CE 397A – Geotechnical Engineering for AE Majors

EXPECTED OUTCOME

Since the existing building uses spread footings as its foundation system, the expected outcome is that spread footings for the New Addition will be a practicable alternative. In general, spread footings may be faster and easier to construct and may potentially cost less to implement. However, several factors such as subsurface conditions, soil types, location of the water table, soil bearing capacity, soil pressure, and building loads must be considered to ensure spread footings can be a possible alternate foundation system.

REVIEW OF THE GEOTECHNICAL REPORT

A review of the geotechnical report was completed before a redesign of the foundation system could start. The subsurface exploration procedures consisted of four soil borings that were performed with a truck-mounted auger drill rig. Soil samples were acquired by means of the split-barrel sampling procedure in accordance with the American Society for Testing and Materials Specification D-1586. During this process, the drill crew maintained a field log of the different soils encountered. Each sample was then brought to a laboratory for further visual examination and laboratory testing. The testing program included visual classification of the soil samples, natural moisture content, Atterberg Limits, and grain size analysis.

The natural residual materials encountered on site are relatively consistent with the regional geology and soils information available. Asphalt encountered on site ranged from four to nine inches thick. The asphalt was underlain by about two to seven inches of gravel. Existing man-placed fill material, consisting of silty sand and poorly-graded sand materials with gravel and cinders, were encountered within all of the borings at depths ranging from approximately two to six feet below the existing ground surface.

Underneath the asphalt, gravel, and man-placed fill material, terrace deposit soils and residual soils were encountered. The boring depths ranged from 73.05 feet to 78.8 feet below the existing ground surface. As previously mentioned, the natural soils encountered were typically comprised of clay, silty sand, clayey sand, poorly-graded sand, poorly-graded sand and gravel, and clayey sand and gravel. The residual soils were encountered at depths between 55 to 60 feet below the existing ground surface and generally become denser with depth. The Standard Penetration Test N-values in the natural soils ranged from 10 blows per foot to over 50 blows per one inch of sampler penetration. This indicates that the natural granular materials have a medium dense to extremely dense relative density. Additionally, the cohesive clay encountered on site had an N-value of 6 blows per foot, which indicates a consistency of medium stiff.

In auger drilling operations, groundwater can be determined by visual observation of water flowing into the borings. In this case, groundwater was observed in three instances: while drilling, after boring but before the augers were removed, and after the augers were removed before backfilling. Groundwater was observed in all of the borings administered on site at depths ranging from 28.5 feet to 33.5 feet below the existing ground surface. Furthermore, bedrock was located approximately 75 feet below grade.

BUILDING LOADS AND MATERIAL PROPERTIES

All building loads and material properties were provided by the structural engineer, the Thornton-Tomasetti Group, and are listed below.

1. Concrete Unit Compressive Strength, f'c = 3000 psi

2. Reinforcing Steel Yield Strength, Fy = 40 ksi
3. Structural Steel Yield Strength, Fy = 30 ksi
4. Allowable Soil Bearing Pressure, q_a = 5000 psf

Typical floors have a load capacity of 80 pounds per square foot for live loads with an additional 20 pounds per square foot for partitions. The typical roofs have a snow load capacity of 30 pounds per square feet. Typical interior column loads were estimated at 285 kips, while exterior columns were listed at 225 kips.

ORIGINAL FOUNDATION SYSTEM

The foundation of the existing building consists of 23 different types of reinforced concrete, square spread footing as well as four types of rectangular spread footings. Sizes ranged from 4'-0" to 11'-6" and depths that varied from 1'-4" to 3'-6". The design details of a typical spread footing of the existing building may be seen below.

1. Footing size: 7'-4" x 7'-4" x 2'-6"
2. Number of rebar: 21 - #4 longitudinal, 21 - #4 Transverse

The original foundation system chosen for the New Addition of the GSA Headquarters consists of 25 caissons. Shaft diameters ranged from 30 inches to 102 inches. The caissons were drilled to a depth of approximately 75 to 80 feet below the existing ground surface. The caisson schedule may be viewed in Table 17.

Table 17: Caisson Schedule – Developed by Ramuel Holgado

Caisson Schedule		
Shaft Diameter (in)	Reinforcement	
	Vertical No & Size	Ties Size & Spacing
30	6 - #7	#4 @ 18"
36	8 - #8	#4 @ 18"
42	10 - #8	#4 @ 18"
48	8 - #10	#5 @ 18"
54	10 - #10	#5 @18"
60	12 - #10	#5 @ 18"
66	12 - #11	#5 @18"
72	14 - #11	#5 @ 18"
78	16 - #11	#5 @18"
84	18 - #11	#5 @ 18"
90	22 - #11	#5 @18"
96	24 - #11	#5 @ 18"
102	28 - #11	#5 @18"

A total of 24 different grade beams bear on the caissons. These grade beams range from 24 inches to 48 inches in width and height. Reinforcing varies from #7 bars up to #9 bars. The grade beams are located beneath the columns of the New Addition. Figure 22 shows the foundation plan for the New Addition.

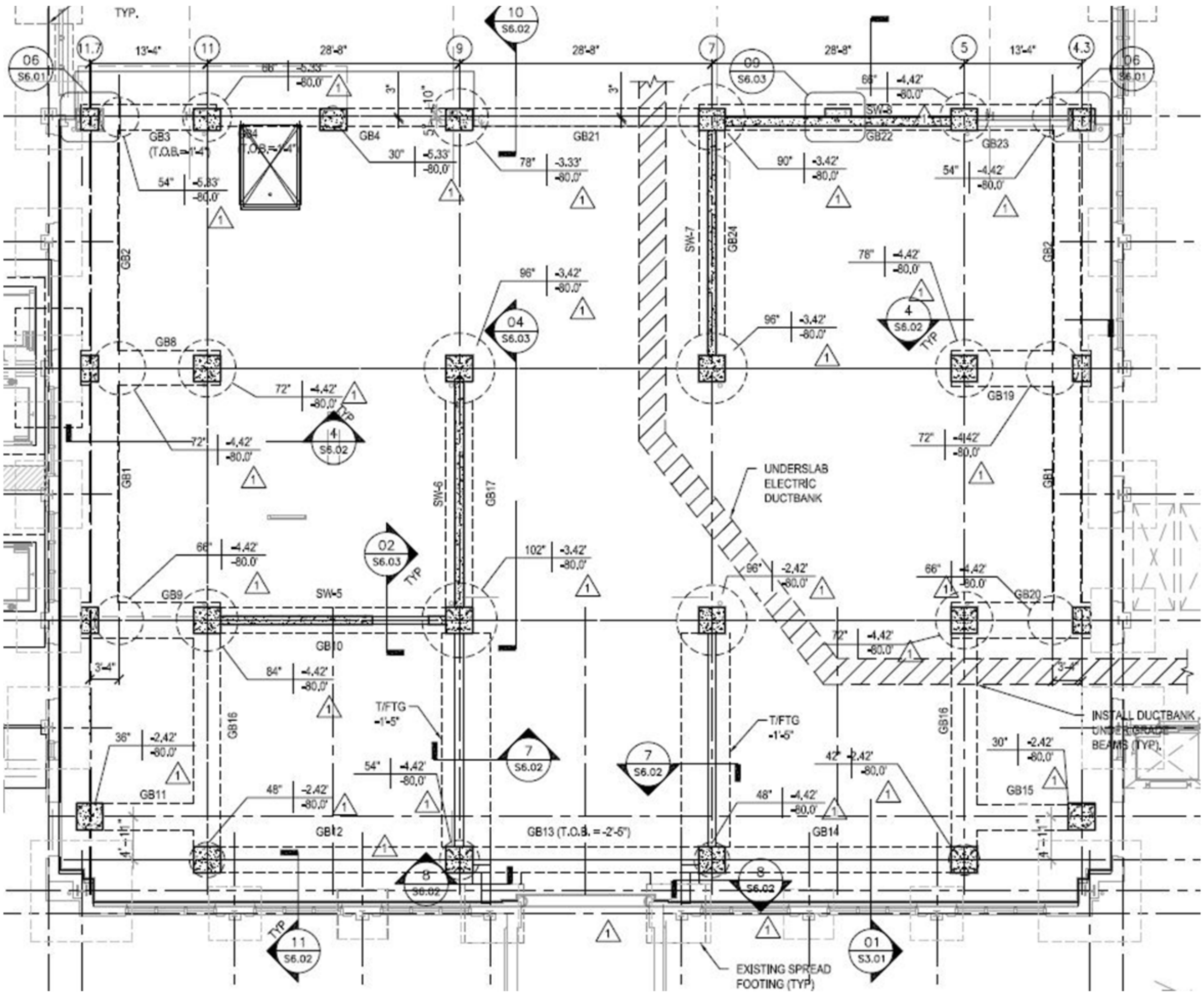

Figure 22: New Addition Foundation Plan – Courtesy of the Whiting-Turner/Walsh Joint Venture

ALTERNATE FOUNDATION SYSTEM

Since the foundation system for the existing building utilizes spread footings, this analysis will examine the feasibility of implementing this type of system for the New Addition in lieu of caissons. The designing and detailing of the spread footings was completed using the aforementioned building loads and material properties as well as with the assistance of the Geotechnical Engineering course, CE397A. These foundation calculations may be found in Appendix H.

A total of 25 spread footings were designed and detailed. This includes 12 interior spread footings located along columns lines F and H along with 13 exterior spread footings located along column lines D and J. The size of the spread footings and the reinforcing required are detailed in Table 18. Totals for cubic yards, square feet of contact area, and amount of reinforcement were summed up for the purposes of completing the schedule and cost estimate.

Table 18: Spread Footing Details – Developed by Ramuel Holgado

Location	Concrete						Reinforcement			
	Size			Cubic Feet	Cubic Yards	Formwork (SFCA)	Bottom Bars	Top Bars	Weight (lbs)	Total Weight (tons)
	W (ft)	L (ft)	H (ft)							
D-4.3	7.0	7.0	1.0	49.00	1.81	28.00	14 - #5	14 - #5	233.63	0.12
D-5	7.0	7.0	1.0	49.00	1.81	28.00	14 - #5	14 - #5	233.63	0.12
D-7	7.0	7.0	1.0	49.00	1.81	28.00	14 - #5	14 - #5	233.63	0.12
D-9	7.0	7.0	1.0	49.00	1.81	28.00	14 - #5	14 - #5	233.63	0.12
D-11	7.0	7.0	1.0	49.00	1.81	28.00	14 - #5	14 - #5	233.63	0.12
D-11.7	7.0	7.0	1.0	49.00	1.81	28.00	14 - #5	14 - #5	233.63	0.12
F-4.3	7.0	7.0	1.0	49.00	1.81	28.00	14 - #5	14 - #5	233.63	0.12
F-5	8.0	8.0	1.3	85.33	3.16	42.67	16 - #5	16 - #5	233.63	0.12
F-7	8.0	8.0	1.3	85.33	3.16	42.67	16 - #5	16 - #5	311.51	0.16
F-9	8.0	8.0	1.3	85.33	3.16	42.67	16 - #5	16 - #5	311.51	0.16
F-11	8.0	8.0	1.3	85.33	3.16	42.67	16 - #5	16 - #5	311.51	0.16
F-11.7	8.0	8.0	1.3	85.33	3.16	42.67	16 - #5	16 - #5	311.51	0.16
H-4.3	8.0	8.0	1.3	85.33	3.16	42.67	16 - #5	16 - #5	311.51	0.16
H-5	8.0	8.0	1.3	85.33	3.16	42.67	16 - #5	16 - #5	311.51	0.16
H-7	8.0	8.0	1.3	85.33	3.16	42.67	16 - #5	16 - #5	311.51	0.16
H-9	8.0	8.0	1.3	85.33	3.16	42.67	16 - #5	16 - #5	311.51	0.16
H-11	8.0	8.0	1.3	85.33	3.16	42.67	16 - #5	16 - #5	311.51	0.16
H-11.7	8.0	8.0	1.3	85.33	3.16	42.67	16 - #5	16 - #5	311.51	0.16
J-4.3	8.0	8.0	1.3	85.33	3.16	42.67	16 - #5	16 - #5	311.51	0.16
J-5	7.0	7.0	1.0	49.00	1.81	28.00	14 - #5	14 - #5	233.63	0.12
J-7	7.0	7.0	1.0	49.00	1.81	28.00	14 - #5	14 - #5	233.63	0.12
J-9	7.0	7.0	1.0	49.00	1.81	28.00	14 - #5	14 - #5	233.63	0.12
J-10	7.0	7.0	1.0	49.00	1.81	28.00	14 - #5	14 - #5	233.63	0.12
J-11	7.0	7.0	1.0	49.00	1.81	28.00	14 - #5	14 - #5	233.63	0.12
J-11.7	7.0	7.0	1.0	49.00	1.81	28.00	14 - #5	14 - #5	233.63	0.12
TOTAL					**61.52**	**876.00**				**3.35**
TOTAL + WASTE FACTOR					**64.59**	**919.80**				**3.52**

It should be noted that square footings at this size may be difficult to construct given the space constraints. With a width and length of seven feet, many of the exterior spread footings will be located in very close proximity to the spread footings of the existing building due to the location of the columns of the New Addition. Extra care and precaution should be taken during the excavation and construction of the spread footings to avoid damage to the existing building.

COST IMPACT

A breakdown of the spread footing cost estimate may be viewed in Table 19. Quantities for the cubic yards of concrete, square feet of contact area for formwork, and amount of reinforcing were taken off and entered into RS Means CostWorks. The total cost for the spread footings, including the forms, reinforcing, and excavation, came to $203,857.78 including overhead and profit.

Table 19: Detailed Foundation System Estimate – Developed by Ramuel Holgado

Detailed Foundation System Estimate									
Item	Unit	Daily Output	Bare Total	Total Incl O&P	Quantity	Project Total		Project Total Incl O&P	
Division 03 - Concrete									
C.I.P. concrete forms, aluminum, average cost, buy, includes accessories, exludes ties	SFCA	315.00	29.23	34.50	919.80	$	26,885.75	$	31,731.44
Cast-In-Place Concrete, Columns, square (4000 psi), 12" x 12", Over 3% reinforcing	CY	9.03	2036.20	2641.11	64.59	$	131,527.21	$	170,601.03
TOTAL						$	158,412.96	$	202,332.48
Division 31 - Earthwork									
Excavation common earth with no sheeting or	BCY	200.00	5.17	7.00	217.90	$	1,126.54	$	1,525.30
TOTAL						$	1,126.54	$	1,525.30
DETAILED STRUCTURAL SYSTEM ESTIMATE TOTAL						$	159,539.50	$	203,857.78

Table 20 compares the cost of the original foundation system, which included caissons and grade beams, against the cost of the alternate system. The original system was built by two separate subcontractors. The caissons were assembled by Brayman Construction Corporation with an original contract value of $1.56M. The grade beams were constructed by Perrin Enterprises, LLC with an original contract of $195,000. Therefore, the total cost for the original foundation system summed up to $1,755,000. As mentioned previously, the cost for the alternate foundation system totaled to $203,857.78. Hence, the total savings for the alternate foundation system comes to $1,551,142.22.

Table 20: Foundation System Cost Comparison – Developed by Ramuel Holgado

Foundation System Cost Comparison				
System	Caissons	Grade Beams	Spread Footings	TOTAL
Original	$ 1,560,000.00	$ 195,000.00	$ -	$ 1,755,000.00
Alternate	$ -	$ -	$ 203,857.78	$ 203,857.78
SAVINGS				$ 1,551,142.22

SCHEDULE IMPACT

Table 21 shows a brief overview of the activities for the alternate system as well as their durations. Durations were determined by comparing the quantities to the daily outputs provided by RS Means CostWorks. Overall, the spread footings will take a total of 12 working days to complete.

Table 21: Alternate System Schedule Overview – Developed by Ramuel Holgado

Activity	Units	Daily Output	Quantity	TOTAL DAYS
Excavation	BCY	200.00	217.90	2
Concrete Forms	SFCA	315.00	919.80	3
Cast-In-Place Spread Footing with Reinforcing	CY	10.25	64.59	7
TOTAL				12

Table 22 displays a schedule comparison between the original system and the alternate system. The durations for the caissons and grade beams were obtained after examining the project schedule. The caissons will take 27 days to complete while the grade beams will take 20 days for a total of 47 working days. As a result, a total of 35 working days may be saved when constructing the alternate system over the original system.

Table 22: Foundation System Schedule Comparison – Developed by Ramuel Holgado

Foundation System Schedule Comparison				
System	Caissons	Grade Beams	Spread Footings	TOTAL
Original	27	20	0	47
Alternate	0	0	12	12
DIFFERENCE				35

CONSTRUCTABILITY

From a constructability standpoint, it was difficult for the Whiting-Turner/Walsh Joint Venture to work efficiently because the Thornton-Tomasetti Group did not use consistent sizes for the caissons. A total of 12 different types of caissons were used. The most a single type of caisson was used was four times and there were five different types of caissons that were used only once. This also ensured that more storage and laydown area was needed for the bits delivered to the site.

The alternate system utilizes only two different sizes of spread footings. This will allow the general contractor and subcontractors to work quicker and more efficiently, as the schedule comparison illustrates, while also freeing up more storage space. However, as noted earlier, it may be difficult to excavate and construct the new spread footings due to their close proximity to the existing spread footings.

RECOMMENDATION AND CONCLUSION

Redesigning the foundation system to utilize spread footings rather than caissons and grade beams may yield many favorable results. First of all, spread footings can save a substantial amount of money. At $203,857.78, it costs approximately 12 percent of the original foundation system, which totals to $1,755,000. Secondly, the spread footings can save about 35 working days when compared to the caissons and grade beams. Finally, the alternate system may be easier to work more efficiently as there are only two different sizes compared to the 12 different sizes of caissons.

All in all, I would not recommend the implementation of spread footings over caissons and grade beams. Although they may offer many benefits over the original system, the tight space constraints of the East Courtyard may be the overarching factor. Spread footings designed to be seven to eight feet long and wide may be located too close to the existing spread footings, which could make the excavation and construction of the new spread footings very difficult. Therefore, all of the time and money saved by redesigning the foundation system does not outweigh the potential risk of damaging the existing building foundation. As a result, caissons, as originally recommended by the structural engineer, may seem like the most feasible foundation system due to the limitations of the site and project.

STRUCTURAL BREADTH: FOUNDATION REDESIGN

- ***To view the complete Foundation Takeoffs and Calculations, please reference Appendix H.***

The structural breadth coincides directly with Analysis 2. This breadth examines the foundation system of the New Addition and includes a foundation redesign from caissons and grade beams to spread footings. Calculations were guided by the Geotechnical Engineering course, CE 397A.

Two sizes of spread footings were designed for the New Addition. This includes the interior spread footings that transferred an estimated compressive load of 285 kips from the interior columns along column lines F and H as well as the exterior spread footings that transferred an approximated compressive load of 225 kips from the exterior columns along column lines D and J. Since the exact number for the compressive dead and live loads were not provided by the structural engineer, these values were estimated to be nearly equal and about half the total compressive load. Calculations were completed with an allowable soil bearing capacity of 5000 pounds per square feet, a concrete unit compressive strength of 3000 pounds per square inch, and a local frost depth of 30 inches. A square concrete pier measuring 36 inches long by 36 inches wide was also used in the calculations. All calculations for this breadth may be observed in Appendix H.

Dimensions for the interior and exterior spread footings may be seen below. For a more complete overview of the alternate spread footing design, which includes spread footing locations, square feet of contact area for formwork, and total weight of reinforcement, please refer to Table 18.

1. Interior Spread Footings: 8’ x 8’ x 1.33’ with (16) #5 each way
2. Exterior Spread Footings: 7’ x 7’ x 1’ with (14) #5 each way

As indicated in Analysis 2, the alternate spread footing foundation design for the New Addition of the GSA Headquarters Modernization is not recommended due to their close proximity to the existing spread footings and the tight space constraints of the East Courtyard.

ANALYSIS 3: THREE-DIMENSIONAL (3D) LASER SCANNING IMPLEMENTATION

- ***To view the Leica ScanStation C10 Brochure and Datasheet, please reference Appendix I.***

PROBLEM IDENTIFICATION

Since the GSA Headquarters was originally built in 1917 and later updated in 1935, many of the as-built drawings contained outdated and inaccurate information. Seeing that that the project is a modernization, this created numerous coordination issues, especially regarding the complex MEP systems to be installed. In addition, the GSA Headquarters Modernization did not incorporate BIM into any phase of the project, including the conceptual, design, and construction phases. Therefore, the MEP systems were designed and coordinated without the use of any 3D coordination software.

Considering the Owner has established the integration of $37M in allowances throughout the schedule of the project, further research can determine where this money has been allocated and whether it would be appropriate to spend a portion of it on the implementation of 3D laser scanning. This portion would include money spent on personnel, training, software, and equipment, among other factors.

BACKGROUND INFORMATION

Figure 23: Leica ScanStation C10 – Courtesy of Leica

On renovation projects in the construction industry, the use of 3D laser scanning is a highly efficient way of capturing and analyzing the existing conditions of a building. Leica is a company that creates exceptionally accurate 3D scanners and software that can be utilized for building construction and BIM. The Leica ScanStation C10, as seen in Figure 23, is a versatile and cost-effective scanner that integrates a high-accuracy and long-range scanner, tilt sensor, data storage, and auto-adjusting video camera and laser plummet. It is also encased in a compact and portable design that can be easily carried around on the construction site. As noted by Dr. Craig Dubler, a virtual facilities engineer at the Office of Physical Plant and professor of the Department of Architectural Engineering at the Pennsylvania State University, the Leica ScanStation C10 is currently the best and most popular scanner in the industry.

RESEARCH GOAL

The primary research goal is to analyze the effects of implementing 3D laser scanning onto the GSA Headquarters Modernization. This includes examining the effectiveness of evaluating existing building conditions and comparing them to the as-built drawings. The cost impact will be measured by comparing implementation costs to potential savings from change orders. Project schedule impact will be examined as well.

POTENTIAL SOLUTION

The implementation of 3D laser scanning on a project may provide numerous potential solutions. As mentioned previously, the Leica ScanStation C10, which is an extremely capable laser scanner, can produce as-built drawings and 3D models of any space in an existing building. This created real world visualization may improve coordination among the subcontractors, which can lead to an increase in production on the project. Additionally, the use of 3D models can help with clash detection both virtually and in the field. All of these factors may potentially accelerate the schedule and reduce the overall cost of construction while producing a higher quality building.

METHODOLOGY

- Research the advantages and disadvantages of 3D laser scanning
- Analyze how 3D laser scanning enhances 3D modeling and coordination
- Determine which major players on the project may benefit from 3D laser scanning
- Interview the Syska Hennessy Group and John J. Kirlin, LLC in regards to the design and coordination of the project's MEP systems
- Contact the Whiting-Turner/Walsh Group Joint Venture to research the allocation of the Owner-approved $37M in allowances
- Develop an implementation strategy
- Measure the impact that the implementation of 3D laser scanning can have on the current schedule
- Estimate the return on investment by completing a cost analysis on the implementation of 3D laser scanning

RESEARCH RESOURCES AND TOOLS

- Industry Professionals
- The Pennsylvania State University Architectural Engineering Faculty
- The Whiting-Turner/Walsh Joint Venture Project Team
- Syska Hennessy Group Architect/Engineering Team (MEP Designers)
- John. J. Kirlin, LLC (Mechanical Subcontractor)

- Applicable Project Documents
- BIM Project Execution Planning Guide developed by The Computer Integrated Construction Research Program
- AE 473 – Building Construction Management and Control

EXPECTED OUTCOME

Based on preliminary research, the expected outcome is that 3D laser scanning Implementation will be highly advantageous on the GSA Headquarters Modernization by improving coordination, accelerating the project schedule, and reducing construction challenges. In addition, it is expected that there will be a quick return on investment due to the relatively small initial investment compared to the anticipated total project savings.

RESEARCH

BENEFITS OF 3D LASER SCANNING

In the construction industry, the implementation of 3D laser scanning may present a wide variety of benefits. A brief list of these benefits may be observed below.

- Improves efficiency in planning, design, construction, and project maintenance phases
- Creates accurate and cost-effect 3D models and two-dimensional (2D) drawings
- Detects clashes between existing conditions and planned designs ahead of construction
- Produces as-built drawings by capturing existing conditions
- Improves coordination between the Owner, architects, engineers, and contractors
- Develops retrofit designs
- Provides accurate dimensions to assure pre-fabricated items may be installed correctly without error prior to delivery
- Potentially minimizes errors and the magnitude of change orders, thereby possibly reducing overall project schedule and cost
- Improves overall quality control

PRODUCT INFORMATION

As previously indicated, Dr. Craig Dubler stated that Leica Geosystems is leading the trend in 3D laser scanning processes. Furthermore, he believes that the Leica ScanStation C10 is most likely the best and most popular scanner in the industry at the moment. Coupled with Leica Geosystems HDS Cyclone (Leica Cyclone) 3D point cloud processing software, the ScanStation C10 can be used as a powerful tool in the construction industry.

The Leica ScanStation C10 is a scanner that offers great versatility and higher productivity for as-built drawings at a lower cost of ownership. Leica Geosystems' official website states that "the versatile Leica ScanStation C10 includes a high-accuracy/long-range scanner, tilt sensor, battery, controller, data storage, auto-adjusting video camera and laser plummet all in one compact, portable instrument" (Leica ScanStation C10). Its Smart X-Mirror™ design allows users to conduct full-dome interior scanning in a short time period by using a spinning mirror. Some of the major benefits of the Leica ScanStation C10 include its unprecedented versatility, major productivity advances, valuable cost savings, and a user-friendly total station-like interface. It also contains integrated real-time streaming video with zoom, onboard controller that allows review of scans, and a high-resolution digital image display that can create photo-realistic color mapping of point clouds (Leica ScanStation C10).

The Leica Cyclone 3D point cloud processing software, as emphasized on Leica Geosystems' official website, provides "point cloud users with the widest set of work process options for 3D laser scanning projects in engineering, surveying, construction and relating applications" (Leica Cyclone). This software, used in conjunction with the Leica ScanStation C10, allows users to create as-built models more efficiently and cost-effectively. Leica Cyclone is actually composed of numerous software modules that contribute to the project in various different ways. Some of the capabilities that these software modules can do include aligning point clouds captured from various scanning positions, using point clouds to directly create objects that can be exported into AutoCAD, and allowing individual members of workgroups to concurrently access data and models. These software modules are listed below.

- Cyclone-SCAN
- Cyclone-REGISTER
- Cyclone-MODEL
- Cyclone-SURVEY
- Cyclone-IMPORTER
- Cyclone-VIEW Pro
- Cyclone-SERVER
- Leica TruView and Cyclone-PUBLISHER

Leica TruView and Cyclone PUBLISHER are especially beneficial when it comes to streamlining coordination. According to Leica Geosystems' official website, "Leica Cyclone PUBLISHER publishes point cloud data for web-based sharing and viewing allowing access from anywhere in the world" (Leica TruView & Cyclone PUBLISHER). Leica TruView allows users to accurately measure dimensions and extract real 3D coordinates from the models created from the point clouds. All these reasons and more illustrate why this software is a powerful tool that can improve coordination between the Owner, architects, engineers, and contractors.

CHANGE ORDERS

The GSA Headquarters Modernization contained many constructability challenges and unexpected issues that eventually led to change orders. A majority of these change orders occurred during, but were not limited to, the demolition phase. The following contains a summary of some of the change orders that may have been impacted with the implementation of 3D laser scanning.

NEW ADDITION CURTAIN WALL

The curtain wall on the New Addition may have benefited from the services of 3D laser scanning in a variety of ways. The west face of the curtain wall has an expansion joint that is scheduled for four inches, but there is approximately only two inches available. The project team believes that a dimensional shop drawing bust caused this error. Currently, the structural engineer is verifying if this reduction in the expansion joint is acceptable.

The project team also had to notch out some of the belt courses that protruded into the curtain wall. This unexpected site condition delayed the schedule about 15 days. Furthermore, they needed to verify that the truss columns were plumb and that the spacing was correct in order to ensure that the curtain wall would align and clip correctly.

Implementing 3D laser scanning technology prior to the erection of the truss columns and curtain wall may have prevented the dimension bust that resulted in this error. It may have also prevented the design error that caused the project team to notch out belt courses that clashed into the curtain wall. After the erection of the truss columns, this technology may have been used to check the plumbness and spacing with general ease.

WING 2 TRENCH INFILL

Typical details on the plans of the sixth floor of Wing 2 show that there is a recess in the floor of average depth 3/8 inch to be infilled with leveling compound where the corridor walls have been removed. The recess was field measured to an average of about four inches in depth. This depth cannot be filled with a leveling compound. Instead, the recess was filled with concrete at an additional cost, which totaled to $28,257.

The use of 3D laser scanning techniques may be able to eliminate dimensional inconsistencies between drawings and field measurements. It could potentially be used in this situation to find the exact volume of concrete needed, rather than estimate the average depth of the recess.

SIXTH FLOOR WING 2 REBUILD COLUMNS

A total of 25 columns on the sixth floor of Wing 2 needed rebuilding to accommodate the furniture dimensions of the tenant fit-out drawings. Each column included the demolition of the existing 2.5” shaft wall and the installation of a 4” shaft wall. The total for all the work involved in this change order summed up to $24,905.

The application of 3D laser scanning during the design phase may have led the architects and designers to accommodate the furniture to the dimensions of the columns, rather than the other way around. This would have prevented the deconstruction and reconstruction of the columns.

ADDITIONAL CEILING HEIGHT CHANGE ON THIRD AND FOURTH FLOORS OF WING 2

The ceiling heights on the third and fourth floors of Wing 2 were changed from 8’-8” to 9’-0”. Therefore, the previously installed bulkheads on these floors were adjusted accordingly. Furthermore, this meant that the columns at these locations needed to be reframed. The total cost for this change order came to $22,787.

Utilizing 3D laser scanning technology during the design phase may have prevented the ceiling height change on the third and fourth floors. Given the proper dimensions, architects and designers may have been able to determine the appropriate ceiling height the first time around.

ADDITIONAL CONCRETE DEMOLITION AT THE EAST COURTYARD

During the demolition phase of the East Courtyard, additional concrete that needed to be demolished was found in various places in the East Courtyard. The additional concrete found under the ramp into the East Courtyard ranged in depth between four to six inches under the pavement. The additional concrete in the slab that had to be removed from the existing main mechanical room totaled to over 35 cubic yards. As a result, the demolition and disposal summed up to $36,960.

The generation of as-built drawings with the use of 3D laser scanning applications may have helped this issue. This technology may have been used to find the exact amount of concrete to be demolished in the East Courtyard.

WINDOW SILL REPAIRS

A window sill survey of the existing east and west facing windows of the sixth floor was conducted. All frames and sills were stripped of paint and were found to have a combination of cracks, gouges, fiber separation, and decay. The sills facing east were somewhat more decayed.

The subcontractor conducting the survey confirmed that 100 percent of the sills surveyed needed a combination of liquid and paste epoxy repairs and therefore believed that all 3,650 window frames and sills involved in the project required restoration. The total cost of the window frame and sill restoration added up to $377,200.

The implementation of 3D laser scanning may have prevented the restoration of all windows on the project. With the creation of a highly accurate 3D model using point clouds, each window may have potentially been examined individually for defects in an efficient manner. This could have possibly reduced the total number of window frames and sills that needed to be restored.

IMPLEMENTATION

After review of the project and many of its constructability challenges that were present during both the preconstruction and construction phases, it is evident that the capabilities of a 3D laser scanner, such as the Leica ScanStation C10, may offer several benefits that could prevent various issues that result into change orders. These benefits include the creation of as-built drawings, improved coordination and design, and quality control verification on site.

CREATION OF AS-BUILT DRAWINGS

With the use of the Leica ScanStation C10 and the Leica Cyclone software, it would be possible to create as-built drawings of the project. First, the Leica ScanStation C10 can be used to scan the existing conditions of the building by capturing 3D point clouds. Leica Cyclone can then process these point clouds into objects with CAD geometry so that they can be imported into building software such as AutoCAD. From here, accurate as-built drawings of various plans, elevations, sections, and details of the building can be produced. These drawings may become extremely beneficial to each discipline on the project by improving coordination and design.

IMPROVED COORDINATION AND DESIGN

The Leica ScanStation C10 may be used to capture the existing conditions of the GSA Headquarters with the use of 3D point clouds. Using the Leica Cyclone 3D point processing software, a highly accurate 3D model of the entire building can be created and imported into building software such as AutoCAD.

Using the software modules Cyclone-SERVER, Leica TruView, and Cyclone-PUBLISHER, coordination between the Owner, architects, engineers, and contractors can be more efficient and streamlined. Cyclone-SERVER allows individual members of project teams to simultaneously access 3D point cloud data sets and models. Leica TruView and Cyclone-PUBLISHER allows users to access this data via web-based sharing. This will let the Owner check the progress of the project from a remote location. As a result, the coordination between the different disciplines of the project will be vastly improved.

From a design perspective, a 3D model may present several advantages to the members of the project team. Architects can use the 3D model of the existing conditions to design the building according to the actual dimensions. This may have prevented a few of the issues listed previously including the dimensional bust of the curtain wall and the rebuilding of the columns on the sixth floor of Wing 2. From an engineering perspective, the 3D model of the existing conditions can be used to compare to the planned building designs by using Autodesk Navisworks. This will allow all disciplines to examine the model for clash detection and interference checking before construction commences.

Once the project is complete, the 3D model can be handed over to the Owner to serve as a record model. This model would hold valuable information for the GSA pertinent to the architectural elements and various building systems. Additionally, if the Owner decides to renovate the building again in the future, this model will offer many benefits to the designers and engineers.

QUALITY CONTROL VERIFICATION ON SITE

During the construction phase of the project, 3D laser scanning may have several applications in regards to quality control. As the project progresses, the Leica ScanStation C10 can conduct full-dome scans in needed areas. Leica Cyclone can then process the 3D point clouds before eventually creating a full 3D model. This 3D model can then be used to verify quality control on site. A few examples include slab levelness, plumbness of the truss columns, and installation locations. This ensures that the topmost level of quality control will be retained throughout all stages of the project.

SCHEDULE IMPACT

The schedule impact of implementing 3D laser scanning technology is very minimal. In addition to taking scans during the construction phase, the entire building will be scanned in the preconstruction phase. According to Dr. Craig, Dubler, the Leica ScanStation C10 can scan a typical floor of 25,000 square feet in roughly four hours, which is half a typical work day. The GSA Headquarters has nine total floors at approximately 48,000 square feet each. Therefore, scanning will take about nine full days, which amounts to one floor per day. Furthermore, the Leica Cyclone software takes around one to two weeks to process the information, depending on the size of the project. With roughly 360,000 square feet of floor space in Phase 1 of the project, it is predicted that it would take the full two weeks, or 10 working days, to process all the information. As a result, the scanning and processing of the entire building during the preconstruction phase will take 19 working days.

COST IMPACT

3D LASER SCANNING IMPLEMENTATION COST

The cost for implementing 3D laser scanning technology depends on whether the Owner chooses to purchase and maintain their own equipment or if they choose to rent the process. Since the GSA is a rather large organization with multiple projects, including renovations and modernizations, it is expected that they would choose the former method of implementing this technology.

According to Dr. Craig Dubler, this process includes three major expenses: initial cost of buying the equipment, maintenance, and labor. The initial cost of the equipment comes out to $150,000. Maintenance costs about $2,000 per month. Including one month during the preconstruction phase and 25 months during the construction phase, it is estimated that the cost of maintenance will be $52,000. The rate for labor is $100 per hour for the scanning and model development processes. The schedule states that scanning in the preconstruction phase will take nine full work days to complete. Therefore, this cost will total $7,200. Model development in the preconstruction phase will take another 10 full working days. This will total to $8,000. It is extremely difficult to estimate exactly how much time will be spent scanning and processing models during the construction phase because this may ultimately be up to the Owner. Therefore, it is estimated that the minimum total cost of implementing the 3D laser scanning process on the project is $217,200.

CHANGE ORDER COSTS

The exact cost of change orders that may have been prevented had 3D laser scanning processes been implemented on the project may be nearly impossible to determine. In addition, the aforementioned change orders that could have been impacted by 3D laser scanning did not only considered cost as an impact; some only focused on schedule and quality control. Furthermore, the change orders examined in this analysis were collected from when the construction phase was only about half completed. This means that there could have been many more change orders that could have been impacted in the latter half of the construction phase, whether it would relate to cost, schedule, or quality control. It should be noted that the project integrates $37M in allowances throughout the schedule of the project. This included Owner change orders that the project team had to integrate with the schedule.

RECOMMENDATION AND CONCLUSION

The implementation of 3D laser scanning processes on the GSA Headquarters Modernization may offer many benefits. Its ability to create as-built drawings and a 3D model of the existing conditions can be very advantageous to members of the project team. This can help the architects and engineers with designing the building prior to the start of construction. Coordination between all disciplines is streamlined with the use of 3D point cloud processing software modules such as Cyclone-SERVER, Leica TruView, and Cyclone-PUBLISHER. Quality control issues, such as slab levelness and enclosure plumbness, can be verified on site during the construction phase. It can also have a significant impact on the project schedule by reducing delays and complications that result in change orders. In terms of value, its projected minimum implementation cost of $217,200 is relatively low to the $37M of Owner-approved allowances that is to be used throughout the project schedule. This is not considering the unknown potential savings that it can create on the project. Finally, due to the size of the GSA, it was anticipated that they would choose to purchase and maintain their own 3D laser scanning equipment. This means that they would be able to use the equipment on other projects after the GSA Headquarters Modernization has been completed. As a result, due to all of the aforementioned benefits that 3D laser scanning can offer, its use on the project is recommended.

ANALYSIS 4: OPERATION AND MAINTENANCE OF ENERGY

- ***To view the Data Collection Tool, please reference Appendix J.***

PROBLEM IDENTIFICATION

As newer technologies are implemented into projects, buildings become more complex and thus become more difficult to operate. As a result, operation and maintenance has become a primary issue long after a building has been completed. Due to the advanced mechanical, electrical, and plumbing systems, along with the several high-performance green building features of the GSA Headquarters Modernization, the operation and maintenance of energy becomes a critical issue to research. One of the main challenges facing the industry regarding this issue is the lack of technology for incorporating ties between a model and the controls of a building (Messner).

BACKGROUND INFORMATION

The GSA Headquarters Modernization already utilizes several features that improve energy efficiency such as photovoltaic installations and occupancy sensors. However, these features are only a small portion of the solution to creating a green building. According to Lucid Design Group's official website, as much as half of the electricity consumption of a building is determined by the building occupants and the daily choices they make (Lucid Building Dashboard). One of the main problems is that most buildings do not have a means of giving feedback to its occupants on how much energy they are consuming. A potential solution to this may be to implement a web-based energy reporting system known as Building Dashboard, by Lucid Design Group. This energy management software essentially implements a social network allowing users to view, compare, and share their building energy and water use information on the internet. Further research may be obtained by examining buildings that have incorporated a web-based energy reporting tool during the operational phase to measure its effectiveness. The target audience will be the GSA as they will benefit most from enhanced energy operation and maintenance methods.

RESEARCH GOAL

The goal of the research to be performed will be to measure the effects that a web-based energy reporting tool may have in improving the operation and maintenance of energy in the GSA Headquarters during the operational phase.

POTENTIAL SOLUTION

Utilizing Building Dashboard on the GSA Headquarters after it has been completed is a potential solution to improve energy operation and maintenance. This will enable occupants to monitor their building energy and water consumption and allow them to compare their results to their coworkers. This could ultimately lead to an improved building life-cycle cost due to an increase of energy efficiency. As Lucid Design Group believes, "it's not just about smarter technology anymore. It's about smarter occupants" (Lucid Building Dashboard).

METHODOLOGY

- Research the benefits of utilizing a web-based energy reporting tool during the operational phase
- Investigate how Building Dashboard functions
- Interview industry experts on energy management software with the Data Collection Tool, which is referenced in Appendix J
- Develop an implementation strategy
- Measure the payback period and improved building life-cycle cost of implementing a web-based energy reporting tool

RESEARCH RESOURCES AND TOOLS

- Industry Professionals
- The Pennsylvania State University Architectural Engineering Faculty
- The Whiting-Turner/Walsh Joint Venture Project Team
- Syska Hennessy Group Architect/Engineering Team (MEP Designers)
- Gensler (Architect)
- AE 473 – Building Construction Management and Control

EXPECTED OUTCOME

The implementation of Lucid Building Dashboard during the operational phase of a building may lead to several benefits on the GSA Headquarters. The expected outcome is an increase in energy efficiency resulting in greater annual savings for the Owner and an improved building life-cycle cost. Furthermore, the initial cost of implementing this web-based energy reporting tool is expected to be minimal when compared to the potential savings that may occur.

RESEARCH

BENEFITS OF BUILDING DASHBOARD

Installing Building Dashboard onto the GSA Headquarters during the operational phase may bestow several benefits. A summary of these benefits may be examined in the list below.

- Allows occupants to receive feedback on their energy and water consumption information
- Enables occupants to share and compare their energy and water consumption information amongst their friends and coworkers via Building Dashboard Network™
- Compares energy and water consumption information between entire buildings and organizations
- Interactive graphs allow non-technical users to easily track and interpret trends in usage
- Visibility of occupant consumption information may lead to overall improved building energy and water efficiency
- Calculates the financial savings and environmental benefits of the renewable energy and water systems
- Can earn Measurement and Verification and Innovation in Design credits toward the USGBC's LEED certification

PRODUCT INFORMATION

According to Lucid Design Group's official website, "Building Dashboard has been designed to be the most technically capable and visually spectacular data monitoring and display system available for commercial and institutional facilities" (Lucid Building Dashboard). It has the ability to connect to nearly all building automation systems and energy management systems. Examples include, but are not limited to, Automated Logic, Cisco, Honeywell, Johnson Controls, Siemens, and Trane. Furthermore, it can connect to all utility meters and submeters with pulse or Modbus registers.

Building Dashboard has the capability for fully automated data collection, processing, and storage. It has the ability to monitor all resources consumed and produced within a building such as electricity, water, natural gas, heating, cooling, solar electricity, wind electricity, solar thermal energy, geothermal energy, rainwater collection and recycling, and wastewater recycling. Individual locations of a building, such as floors and wings, can also be monitored. All information may be viewed real-time using Building Dashboard Network.

In addition to being able to view information real-time, Lucid Design Group's Data Downloader tool enables building operators, facilities managers, and sustainability officers to download archived data that is ready to be imported into Microsoft Excel. This data can then be used for carbon accounting, additional monitoring and verification, and troubleshooting, among other activities.

Implementing Building Dashboard onto a project will also earn the project Measurement and Verification and Innovation in Design credits toward the USGBC's LEED certification. This can count toward either LEED for New Construction or LEED for Existing Buildings.

Building Dashboard Network is fundamentally a social network for building occupants that lets users view, compare, and share their building energy and water use information with other users via the internet. All resource use data and information obtained from Building Dashboard is viewable on Building Dashboard Network. It integrates a user-friendly and customizable interface for effortless browsing. Interactive graphs make it simple for non-technical users to analyze data and identify trends and relationships between resource use data. Interpretive gauges enable real-time data viewing with easy-to-read and engaging graphics. These let users see the consumption of kilowatt-hours, gallons, and carbon dioxide emissions as well as the financial cost of consuming resources.

Within Building Dashboard Network are Apps. Apps are tools that help users understand and learn how to better manage building energy and water use. The Comparison App enables users to compare their usage across their building or organization. Data can be compared during custom time periods between individual floors and wings, apartments, and end uses, among others. Real-time resource use reduction competitions can then be held by comparing collected data. These competitions can be held from a variety of levels, ranging from individual floors or areas within a building to entire organizations. The Renewable App enables users to see the performance of renewable resource technologies of their building with the use of data-enabled illustrations, as seen in Figure 24. For example, occupants will be able to visualize the efficiency, savings, and payback for solar photovoltaic, geothermal, and rainwater collection systems.

Figure 24: Data-Enabled Illustrations of the Renewables App – Courtesy of Lucid Design Group

Widgets are another integral part of the Building Dashboard Network experience. Widgets essentially serve as a smaller version of Apps as they provide a summary of building performance in engaging graphics. One of the important features of Widgets is that it allows users to set custom goals in regards to energy and water use and allows them to monitor daily progress. This helps occupants track their success toward meeting a set budget. Depending on the resource, progress is measured in kilowatt-hours, gallons, carbon dioxide emissions, or dollars. Another vital component of Widgets is its ability to display end use breakdowns. This lets occupants see exactly where all of their energy and water is being used. In addition, further breakdowns enable users to see energy and water use per room, floor, or wing. Figure 25 shows an example of end use breakdowns.

Figure 25: End Use Breakdowns – Courtesy of Lucid Design Group

IMPLEMENTATION

With the ability to connect to nearly all building automation systems and energy management systems, the implementation of Building Dashboard onto the GSA Headquarters would be relatively simple. Some of its biggest benefits is enabling building occupants to track and monitor their resource consumption as well as allowing them to compare their results with their coworkers.

TRACK AND MONITOR RESOURCE CONSUMPTION

Building Dashboard would be used on the GSA Headquarters to let GSA employees see their building energy and water consumption. With the use of Building Dashboard Network in conjunction with Apps and Widgets, employees can determine exactly how much energy and water they are using as well as where they are consuming them. Interactive graphs and interpretive gauges make it easy to identify usage trends and understand data, even for non-technical users. This would hopefully raise awareness among GSA employees and make them more conscious about their resource consumption. As a result, the ability to allow occupants to receive feedback on their resource consumption could potentially increase overall building energy and water efficiency.

BUILDING DASHBOARD ORBS

Building Dashboard integrates a feature known as Orbs. These tell occupants exactly how their building is performing in real-time by interpreting levels of consumption into a spectrum of colors. The color spectrum ranges in colors from red to yellow to green. Red means that building consumption is high, green means that consumption levels are lower than usual, while yellow means that consumption is at about typical levels. Figure 26 shows a Building Dashboard Orb.

Figure 26: Building Dashboard Orb – Courtesy of Lucid Design Group

Building Dashboard Orbs can be implemented on the project to allow GSA employers observe their consumption levels. Orbs can be installed to display the current consumption levels of the entire building or single floors. Similar to Building Dashboard Network, this will hopefully raise occupant awareness in regards to energy and water consumption.

REAL-TIME COMPETITIONS

One of the most important features of Building Dashboard is the ability to host real-time energy and water use reduction competitions. Lucid Design Group's official website states that "studies have demonstrated that competitions can facilitate reduction as high as 56 percent" (Lucid Building Dashboard). Further findings have shown that these competitions are great tools for creating long-term strategies for managing resource consumption.

Competitions may be held between individual floors, buildings, user-defined groups, and entire organizations at local, regional, and national levels. For the GSA Headquarters, a competition may be held between each of the nine floors. Furthermore, since the GSA is a large group with several buildings across the nation, competitions may be held between entire buildings within the organization. The main goal is to educate building occupants and inspire conservation so that building consumption levels will be reduced.

ENERGY AND WATER CONSUMPTIONS

Implementation of Building Dashboard onto the GSA Headquarters may potentially have a large impact on energy and water consumption. As stated previously, studies done by Lucid Design Group show that competitions can facilitate reductions as high as 56 percent (Lucid Building Dashboard). Table 23 shows a summary of recent competition results that Lucid Design Group kept record of.

Table 23: Recent Competition Results – Courtesy of Lucid Design Group

Organization	Duration	Savings	Top Reductions
Franklin & Marshall College	16 days	8,089 kWh	Top reducing residence hall: 17.3% (7 buildings participating)
St. Lawrence University	18 days	3,357 kWh	Top reducing residence hall: 20.2% (22 buildings participating)
University of Victoria	19 days	40,219 kWh	Top reducing residence hall: 56.4% (9 buildings participating)
Google NYC Office	28 days	3,146 kWh	Top reducing floor: 30.4% (13 floors participating)
Agnes Scott College	7 days	8,899 kWh	Top reducing residence hall: 34.8% (5 buildings participating)
Phillips Academy at Andover v. Deerfield Academy	27 days	15,160 kWh	Top reducing residence hall: 45.4% (42 buildings participating)
Bowdoin College	30 days	16,893 kWh	Top reducing residence hall: 29.1% (21 buildings participating)
Elon University	49 days	231,454 kWh	Top reducing residence hall 36.9% (41 buildings participating)
Bowdoin College	11 days	4,376 kWh	Top reducing residence hall: 17.2% (11 buildings participating)
St. John's University	14 days	22,320 kWh	Top reducing residence hall 15.8% (6 buildings participating)
Hamilton College	15 days	44,345 kWh	Top reducing residence hall: 40.9% (11 buildings participating)
Oberlin College	14 days	10,675 kWh	Top reducing residence hall 42.5% (17 buildings participating)
Boston College	28 days	15,212 kWh	Top reducing residence hall: 9.1%

Although a majority of the competition results from Table 23 were from residence halls on college campuses, Google's New York City office could be a good indicator of how the GSA Headquarters would fair in consumption savings. With 18 stories and 13 participating floors, Google's New York City office's top performing floor reduced energy usage by over 30 percent. Although current energy consumption usage for the GSA Headquarters is unattainable at this moment, a 30 percent reduction could result in immense savings.

COST IMPACT

Lucid Design Group was contacted in regards to providing a quote for the implementation of Building Dashboard onto the GSA Headquarters. However, a quote was never received. Therefore, implementation costs of Building Dashboard onto Phase 1 of the GSA Headquarters Modernization during the operation phase are currently unknown.

RECOMMENDATION AND CONCLUSION

Building Dashboard by Lucid Design Group may offer numerous benefits to the GSA Headquarters during the operational phase if implemented properly. First and foremost, it provides feedback to building occupants on their energy and water consumption information. Information is presented in interactive graphs and interpretive gauges that make it easy to identify trends and comprehend data, even for users with non-technical training. This would educate GSA employees on their energy and water usage and hopefully inspire conservation. As a result, resource consumption has the potential to be vastly reduced.

One of Building Dashboard's greatest weaknesses is that its effectiveness relies solely on occupant behavior. Rob Andrejewski of the Campus Sustainability Division of the Office of Physical Plant at the Pennsylvania State University believes that Building Dashboard is only as good as the engagement programs that are integrated with it. From prior experience, he states that occupants tend to enjoy using it at first; however, the system tends to fade with time as occupants have no imperative reason to use it.

Therefore, although Building Dashboard may present many advantages if implemented on the GSA Headquarters during the operation phase, it is not recommended at this time. More research needs to be conducted and more data must be collected from current buildings that are implementing the technology to identify trends, both short- and long-term. Effective implementation strategies that keep users engaged need to be explored and examined. Furthermore, since Lucid Design Group was unable to provide a quote, it is difficult to recommend Building Dashboard at the moment without a more thorough cost analysis.

FINAL RECOMMENDATIONS AND CONCLUSIONS

Over the past academic school year, the GSA Headquarters Modernization was examined for potential areas of improvement regarding cost, schedule, constructability, and design. After extensive review of the project, four issues were chosen to be analyzed. These issues include redesigning the New Addition façade, implementing spread footings as an alternate foundation system for the New Addition, utilizing 3D laser scanning technology during the preconstruction and construction phases, and using a web-based energy reporting system during the operational phase for the maintenance of energy. It should be noted that these analyses were studied strictly for educational purposes and should not be viewed as criticisms of the project.

ANALYSIS 1: NEW ADDITION FAÇADE REDESIGN

The first analysis suggested redesigning the façade by downsizing the atrium. This had the potential to solve numerous issues. Delivery of the built-up truss columns is expected to be easier. A lesser amount of belt courses that clashed into the curtain wall will have to be notched. Furthermore, downsizing the atrium will have saved the owner nearly $3M and three days of acceleration. However, redesigning the façade by downsizing the atrium is not recommended. The projected savings do not outweigh the architectural aesthetics set by the GSA, architects, and designers. In addition, downsizing the atrium will result in eliminating the walkways along the fifth and sixth floor of the New Addition that look down on the atrium and towards the National Mall. This is a feature that the Owner and architects may not be willing to part with.

ANALYSIS 2: NEW ADDITION FOUNDATION SYSTEM

The second analysis examines the possibility of implementing spread footings as the alternate foundation of the New Addition in lieu of caissons. Spread footings are currently used as the foundation system of the existing building. Constructing this alternate foundation system will accelerate the project a total of 35 days and save the Owner an estimated $1,551,142.22. All things considered, spread footings are not recommended for the New Addition. The tight space constraints of the East Courtyard could possibly make it too difficult. The proposed spread footings would be positioned too close to the existing spread footings, making excavation and construction hard to accomplish. Therefore, the originally designed foundation system consisting of caissons seems like the most viable option despite a high cost and long duration.

ANALYSIS 3: THREE-DIMENSIONAL (3D) LASER SCANNING IMPLEMENTATION

The third analysis considers utilizing the Leica ScanStation C10 and the Leica Cyclone 3D point cloud processing software onto the project during the preconstruction and construction phases. This technology would have the capability to generate as-built drawings and a 3D model of the building's existing conditions. Therefore, coordination between all members of the project team will be improved. Architects, designers, and engineers will have a more accurate representation of the building and the existing conditions prior to the design phase. Additionally, quality control issues such as slab levelness and plumbness of the truss columns can be verified on site. These are just a few benefits that the 3D laser scanning process can introduce. Implementation of the technology on the project will cost a minimum of $217,200, depending on how many scans are completed. Initial scans of the entire building along with the processing of a 3D model will take 19 days to complete. It is also expected that the GSA will buy the technology rather than rent it, so that they may use it on future projects. As a result, the implementation of 3D laser scanning on the GSA Headquarters Modernization is recommended.

ANALYSIS 4: OPERATION AND MAINTENANCE OF ENERGY

The fourth analysis investigates the idea of implementing a web-based energy reporting system onto the GSA Headquarters during the operational phase. This system, known as Building Dashboard by Lucid Design Group has the potential to introduce huge savings in regards to building energy and water consumption. One of its main features is its ability to provide feedback to building occupants on their resource consumption. Its simplicity and user-friendly interface allows even those with non-technical training to understand and interpret data. Based on studies conducted by Lucid Design Group, Building Dashboard can facilitate reductions as high as 56 percent (Lucid Building Dashboard). Everything considered, the utilization of this product is not recommended on the GSA Headquarters during the operational phase. The savings and results rely too heavily on occupant behavior. In addition, further studies on long-term usage trends need to be conducted and a more thorough cost analysis must be completed before Building Dashboard can be recommended.

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