Photo courtesy of Steven Holl Architects

The Performing Arts Center

New Jersey, U.S.A.

Turner

Technical Assignment 2: Production Analysis

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Photo courtesy of Turner Construction Co.

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Executive Summary

The Performing Arts Center will be the premier space for music and performing arts in higher education. It has been chosen to be analyzed for the Penn State Architectural Engineering Senior Thesis in addition to being the focal point of the Schreyer Honors Thesis. The AE Senior Thesis investigates the construction of this structure in depth from preconstruction, to completion and turnover. This portion of the report, Technical Assignment Two, focuses on Production Analysis.

Technical Assignment Two concentrates on field production planning and resource use for the façade and enclosure system of The Performing Arts Center. The façade is analyzed by individual systems, how they contribute to the larger system, means and methods for construction, design parameters, resources and equipment that are necessary for construction. In order to ensure community engagement with the performing arts experience, there is a balance between curtain wall and stone cladding. The curtain wall system makes up 51% of the façade, with 10% composed of other glazing and 39% Lecce Limestone paneling. Beyond these major exterior enclosure systems include the cast-in-place concrete wall, sheet waterproofing, rigid insulation, anchors and bracing.

To meet the schedule needs of the owner, the façade construction is sequenced by staggering the work between the four different buildings, the DRUM, Theater and Dance Building, Music Building and Arts Tower. This design allows for efficient flow where tasks are overlapped and trades work from one building to the next. The production schedule illustrates this workflow and the production labor curve necessary to staff the construction of the façade. The overall detailed estimate cost of the façade system is $12,928,277. Logistics, on-site workflow and material staging are organized around this staggered sequencing moving from the western portion to the eastern portion of the site.

Overall, the production is designed well to overlap manpower between buildings and maintain flow through the jobsite. However, when delays arise this system seems fall apart offering areas for new sequencing solutions such breaking down the sequencing from four separate crews to only two crews, leveraging more efficient concrete pouring techniques and alternative equipment usage. With recent changes in stone cladding material and delays on pre-fabricated equipment, the project team is designing new ways to build the Performing Arts Tower. The site is restricted from a logistical standpoint due to the University setting, therefore innovative approaches to production, means and methods and logistics need to be developed to ensure completion by fall 2017.

Production Plan

System Construction Means and Methods:

The façade of The Performing Arts Center is a complex system interwoven with specialized material and difficult geometries. As seen in Table 1, the exterior finish system is mainly comprised of Lecce Limestone paneling, curtain wall and glazing system. The balance between solid stone paneling and curtain wall is essential to ensuring Steven Holl's vision of creating a music and visual arts space that promotes campus connection to the musical experience but maintains solidarity for focused rehearsal.

Table 1: Overall Exterior Facade Material breakdown

Façade Exterior Material Breakdown		
Element Type	**Total SF**	**% of Façade**
Lecce Limestone Panel	25503	39%
Curtain Wall System	33277	51%
Glazing Window/Opening	6271	10%

Lecce Limestone Exterior Stone Cladding

The exterior stone cladding system is composed of Lecce Limestone Panels that vary from 2'0" high by 3'0" wide to 3'0" high by 5'0" wide. The panels are 3" thick and are supported by stainless steel anchors which transfer the dead load to the cast-in-place concrete wall and integrated steel structural system. Plug anchors secure the stone to the steel bracket channels in the concrete wall to resist wind and lateral loads. Supporting brackets were installed to test labor efficiency. The project includes 500 brackets with 4 holes that anchor the bracket to the concrete wall. In 1 day, 10 of them were installed in 8 hours. This meant the steel installer drilled 40 holes, installed 40 anchors and hung 10 brackets. At 500 brackets, performing 10 a day means that it will take 50 days of work to drill holes. To install these brackets, workers will be supported by knee-brace scaffolding that is raised by a crane and sits along the wall at a certain height.

Figure 1: Bracket-anchor system to support Lecce Limestone Panels & waterproofing barrier on DRUM Facade

In between the stone panels and the concrete face lies mineral-wool board insulation and a bituminous sheet waterproofing system. The waterproofing consists of 160 millimeter thick fiberglass mat coated with styrene-butadiene-styrene (SBS) bitumen. See figure 1 below to see the initial system of supporting brackets and weather barrier on the Theatre & Dance "DRUM" on the northwest section of the Performing Arts Center.

Joints between the stone panels are .375" thick using non-stain, non-bleed elastomeric sealant and backer. To ensure a smooth façade appearance, these joints have stone dust mixed in with material to provide a soft lime mortar texture. It is crucial for an open ventilation gap to be constructed where stone panel meets glazing sills and windows so that optimal ventilation is provided. All structural performance of this system is designed against ASCE 7 and Uniform New Jersey Construction Code. In addition to the exterior stone cladding system, Lecce limestone makes up the stone benches, sculptures and architectural bollards that populate the courtyard area. See figure 2 below for construction of the façade system.

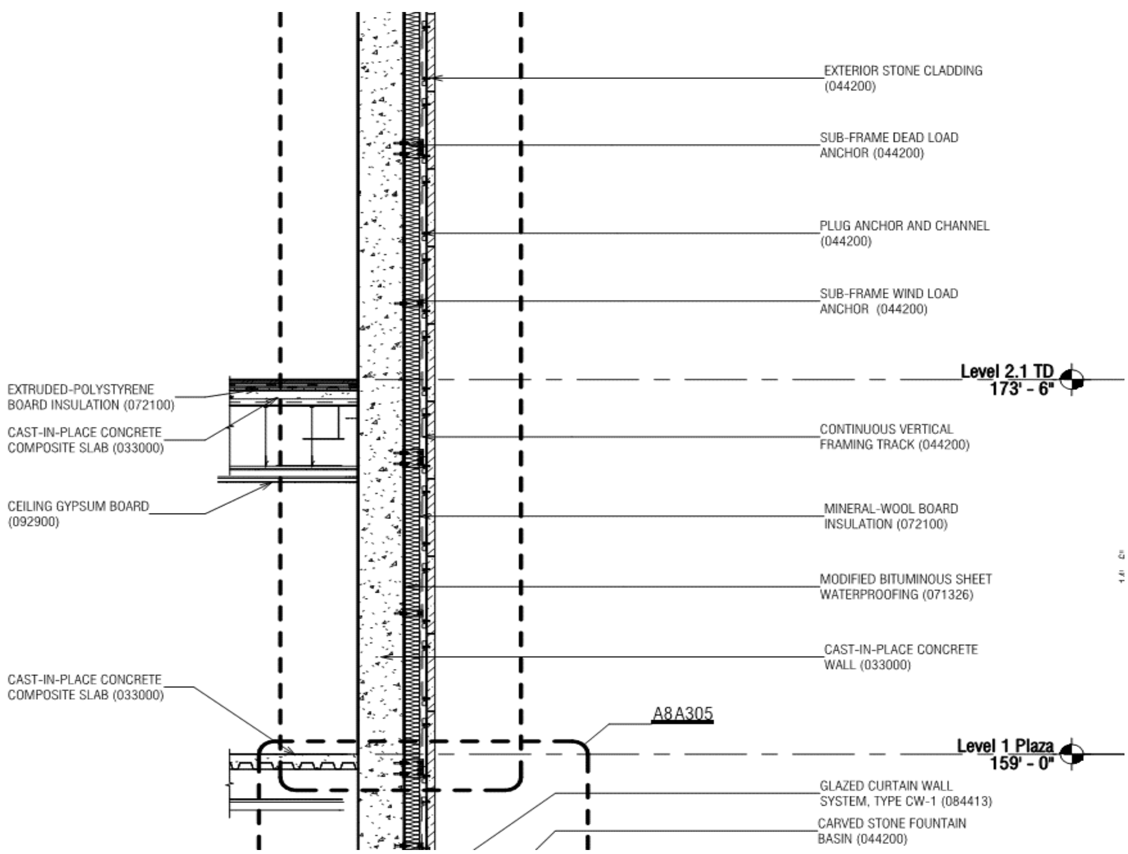


Figure 2: 100% Contract Documents – Volume 6 – Turner Construction – Exterior Wall Sections – A300

Cast-in-Place Concrete Wall Facade

Below the exterior stone cladding, anchoring system, insulation and waterproofing lies the cast-in-place concrete wall system. These walls are composed of 5,000 psi normal-weight concrete that makes up 2,166.81 cubic yard of material. This represents 13% of the total concrete used in the entire building. The overall building system includes straight runs of concrete wall, however the Theatre / Dance DRUM is a radial concrete pour. From a quality assurance standpoint, the highest concern are DRUM concrete pours. The concrete façade walls need to be extremely accurate to the drawing specification so that curtain wall connections and structural truss connections are correctly aligned with the system. These need to be within ¼" for every 10 feet. To ensure the level of quality throughout the project, walls are checked with surveyors. This can be referenced in the Production Schedule as "Layout and field verify façade". Moreover, many of these straight and radial walls are poured to create an architectural concrete finish that is made possible by prefabricated plywood board-forms. The forms are prefabricated in Norton, Massachusetts. This creates high risk because the specialization of this material can lead to schedule delays due to delivery and laydown logistics.

Figure 3: A105 – Board Form Locations throughout concrete façade structure

Concrete is placed on the façade walls 3-4 times a week with 100 – 300 cubic yard poured per day. This equates to 13 trucks a day, necessary to pour façade walls based on a standard 10 cubic yard concrete truck. When pouring concrete, a very unique solution is used as a means of maximizing length of each pour. On a straight run, the entire form will be raised along the length of the wall. The board form is placed inside, along with rebar. Then, the other wall is flown in pieces and stood up next to the wall. To make this work, the wall needs to be slid with the crane and inched over until it fits snug. See figure 4 to see the inside of a form before the second wall is slid into place. In many areas, there will be dowel bar notches in the concrete wall so that re-bar can be screwed in later. In order for this happen, cup-shape metal pieces are attached to the formwork to leave a gap for the re-bar. This is especially effective when it is necessary to add re-bar to an existing wall that will tie into another wall.

Figure 4: Pre-fabricated wooden Board form placed inside steel concrete form with rebar being set.

Curtain Wall System & Glazing

The curtain wall system comprises 51% of the entire building façade. It is made up of two different systems, a four-side supported and two-side supported structural silicone glazed steel mullion assembly. Both are made up of high performance low-iron insulating glass units that are glazed to custom steel profile mullions to fit the unique geometry of the various buildings of this project. For the four-side supported, the vertical steel mullions are restrained at the top and are axially slipped at the bottom. The two-sided system's steel transoms and frames are constructed with standard steel shapes and stainless steel spiral wire strand. Both systems are doubly sealed with a continuous primary air and water seal and a secondary water seal, closure and flashing. See the *Field Supervisor Interview* section for constructability issues pertaining to seal quality assurance.

The glazing for clerestories, vision glass, entrances and long stretches of façade glass vary throughout the project to ensure high transparency at points and visual protection at others. This is to create the compelling experience envisioned by Steven Holl and BNIM so that students and faculty can walk through the courtyard and feel at one with the musicians performing in the visible spaces. The design encourages inspiration and education beyond the walls of the performing arts departments. See figure 5 below to visualize the contrast between curtain wall system and vision glass for music building instrument rehearsal. The vision glass is low-e-coated and features sound absorptive lining to ensure acoustical performance STC 56. High forms of transparency in the curtain wall and vision glass elements are contrasted with private, translucent glazing featured on much of the theatre/dance building as well as clerestories and smaller glazing panels. This glass is Low-E coated, insulating laminated glass with an acid etch to create a blurred image visual.

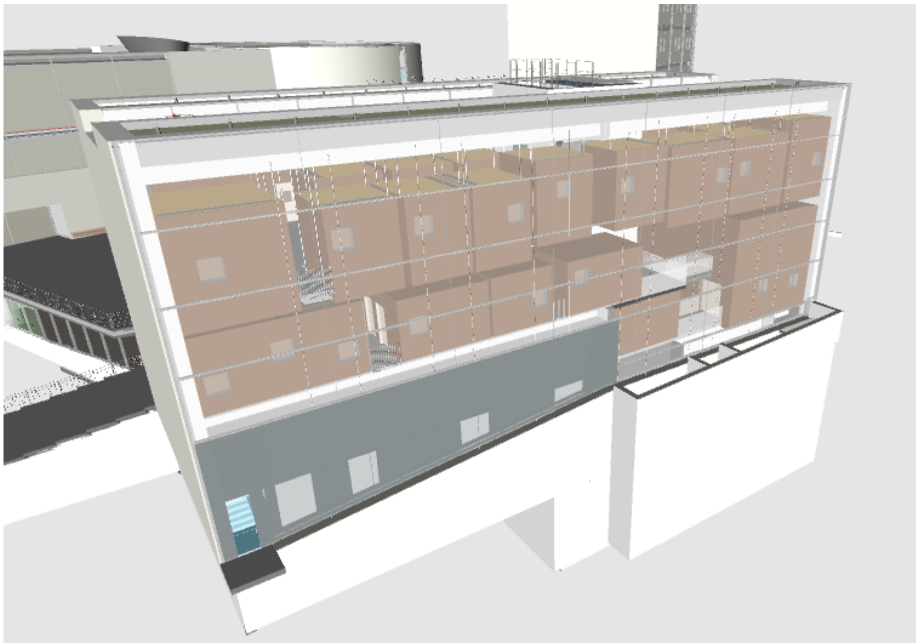


Figure 5: East façade of music building featuring clear visual to hanging cube, practice rooms

Installing the glazing and curtain wall systems is no easy task on the Performing Arts Center. Due to complex and irregular geometric forms, connections need to be engineered and installed with great detail. For instance, on the DRUM's north façade, the first portion of glazed curtain wall system was being installed with extreme attention to detail so that connections followed up the radial curve of the DRUM and so that the steel paneling would integrate successfully with the steel structure. It took at least 4 hours for glazing subcontractors and surveyors to lay out and field verify connection levels and angles so that the strip of curtain wall would fit correctly. Next, they would install the stainless steel brackets that have been cut out of the waterproofing lining. Anchors will be secured to the base structure and attached to the glazing system. A crane will pick up panels and then crews will secure the steel structure of the glazing to the anchors.

Figure 6: Installation of glazed curtain wall system on north DRUM Façade

Production Schedule:

*Reference Appendix A

The production schedule developed illustrates the detailed schedule of façade construction within the overall milestone schedule of the Performing Arts Center. Note that the façade construction spans from June 2015 until January 2017. During planning stages, it was designed that sequencing would be staggered on a building-by-building basis. Therefore, the detailed schedule follows original schedule phasing and plans. Please see *Production Analysis and Field Supervisor Interview* sections to see how this schedule has changed and will continue to change in the future. Façade construction will see the point of the project where total manpower rises to its maximum resource level. Ideally, 200 men will be onsite at peak production level when façade and interior work will be completed simultaneously on alternate buildings. All schedule values are based on an 8 hour workday.

The labor curve below illustrates the change in crew size and overall manpower in man-hours on site during façade system construction. The initial peak illustrates the high resource demand during cast-in-place concrete pouring throughout the various buildings. Large crew sizes perform erect board forms, place steel concrete forms, run electrical systems, install rebar and pour concrete to construct quality cast-in-place concrete facades. The dip in manpower during mid-2016 illustrates an overall shift from glazing and curtain wall installation into stone setting toward the end of 2016. Reference Appendix A to see the full detailed schedule with the production curve.

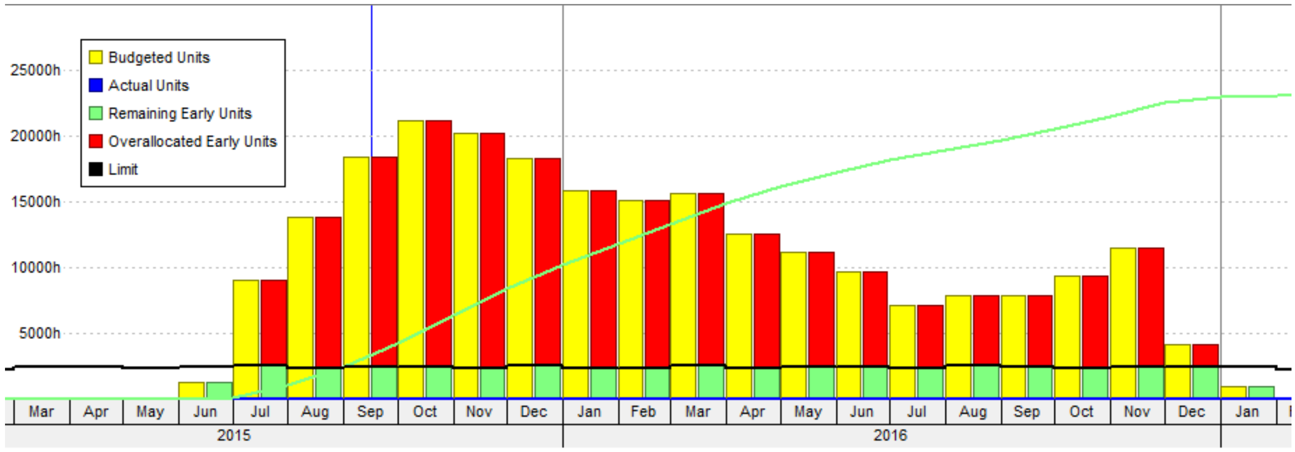


Figure 7: Installation of glazed curtain wall system on north DRUM Façade

Detailed Cost Estimate:

*Reference Appendix B

The total cost for the Performing Arts Center façade came to $12,928,277. This was calculated using Sage Timberline using MeansDB due to its high complexity of systems included within the item takeoff. Items included in the estimate reflected the major components of the façade system. These contain Concrete walls, limestone panel, masonry anchors, waterproofing, insulation, glazing, and curtain wall systems. Takeoffs were completed using the 100% construction drawings provided by Turner Construction Company as well as the BIM 360 Glue concrete and architectural models provided by Turner Construction Company. Please see Appendix B for total estimate, takeoff quantities and illustrations.

Description	Amount	Totals	Hours	Rate	Allocatable	Cost Basis	Cost per Unit	Percent of Total
Labor	5,417,550		76,553.038 hrs					41.90%
Material	7,477,371							57.84%
Subcontract								
Equipment	33,356							0.26%
Other								
	12,928,277	12,928,277						100.00 100.00%
Total		*12928277*						

Figure 8: Timberline estimate totals for façade system

Site Plans & Logistics:

*Reference Appendix C for full-scale phasing graphics

The 3 phase logistics phasing for the façade is designed around three major steps: Cast-in-place concrete façade progress, curtain wall and glazing and setting limestone. In figures 9-11, the site evolves to meet the needs of each phase.

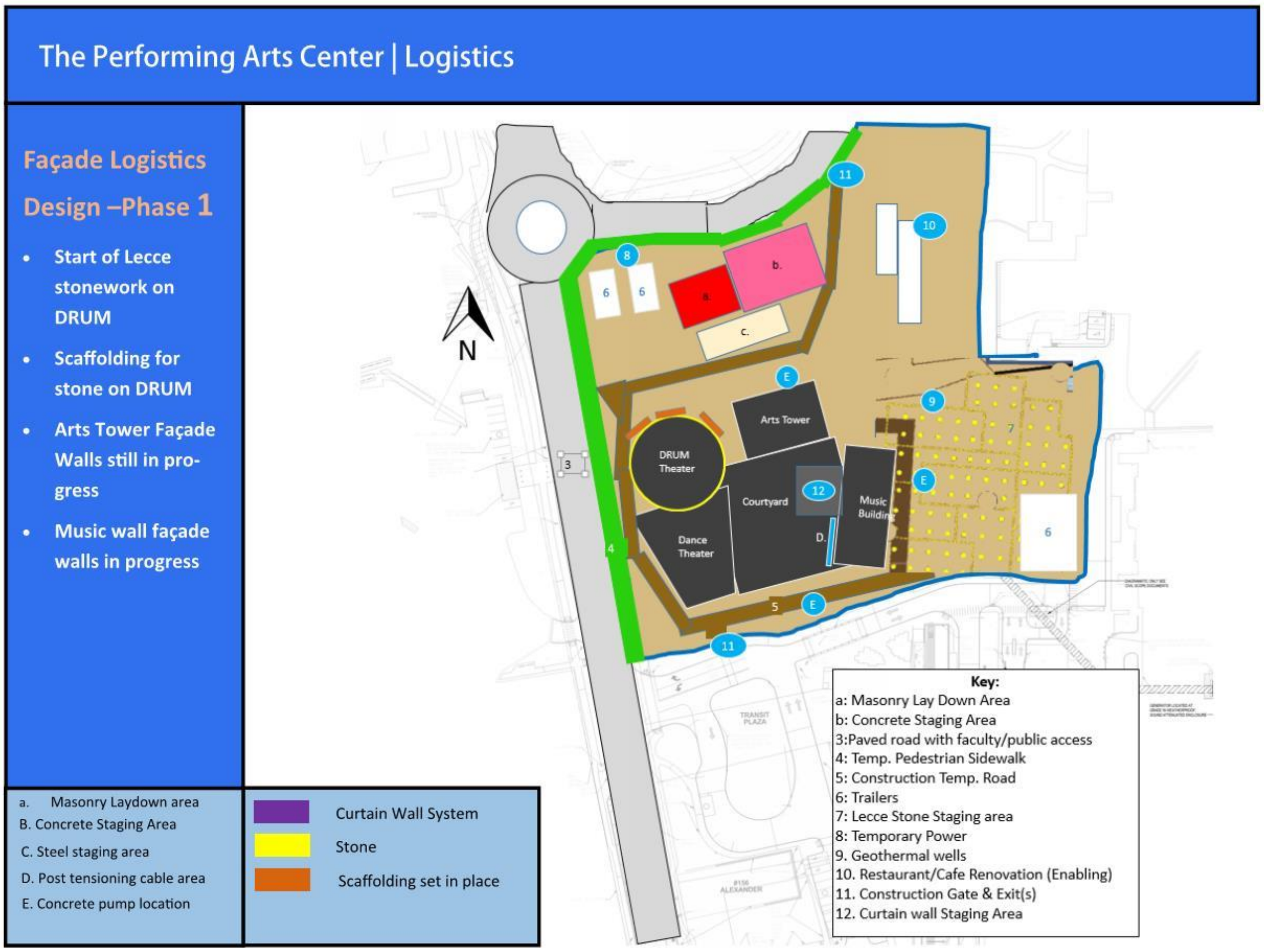


Figure 9: Logistics Plan – Phase 1

The Phase 1 Logistics Plan illustrates the site layouts while the concrete wall façades are being completed. An interesting piece is that the southeast portion of the site is largely empty except for trailers and a concrete pump. Workflow has shifted to the northern portion of the site to accommodate the heavier work taking place on the DRUM. This includes laydown for stone, concrete staging, and steel staging. The scaffolding around the drum is utilized to install limestone panels. In addition, curtain wall shipments arrive. At first the project team staged the curtain wall on top of the wide-open courtyard for quick installation, then they begin to stage toward the east in later logistics plans.

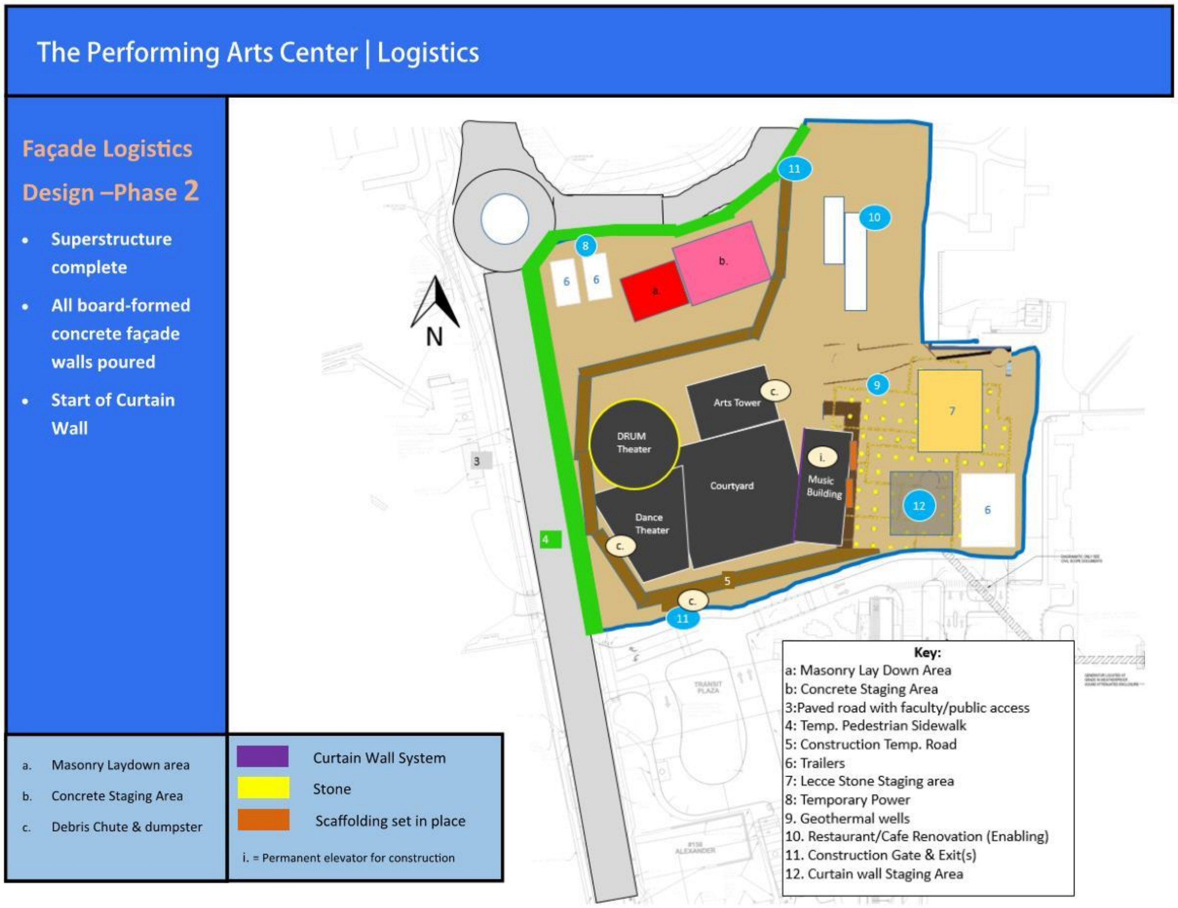


Figure 10: Logistics Plan – Phase 2

Phase 2 of the logistics phasing illustrates the start of curtain wall installation. Note that the staging area has moved from the courtyard to the southeast portion of the site. Also, workflow is moving into the southeast region for stone installation. Due to the large amount of debris and the shifting of activities from concrete to curtain wall, multiple debris chutes and dumpsters have been brought onsite. Workflow is shifting from the DRUM to the eastern portion of the site to apply curtain wall to the music building.

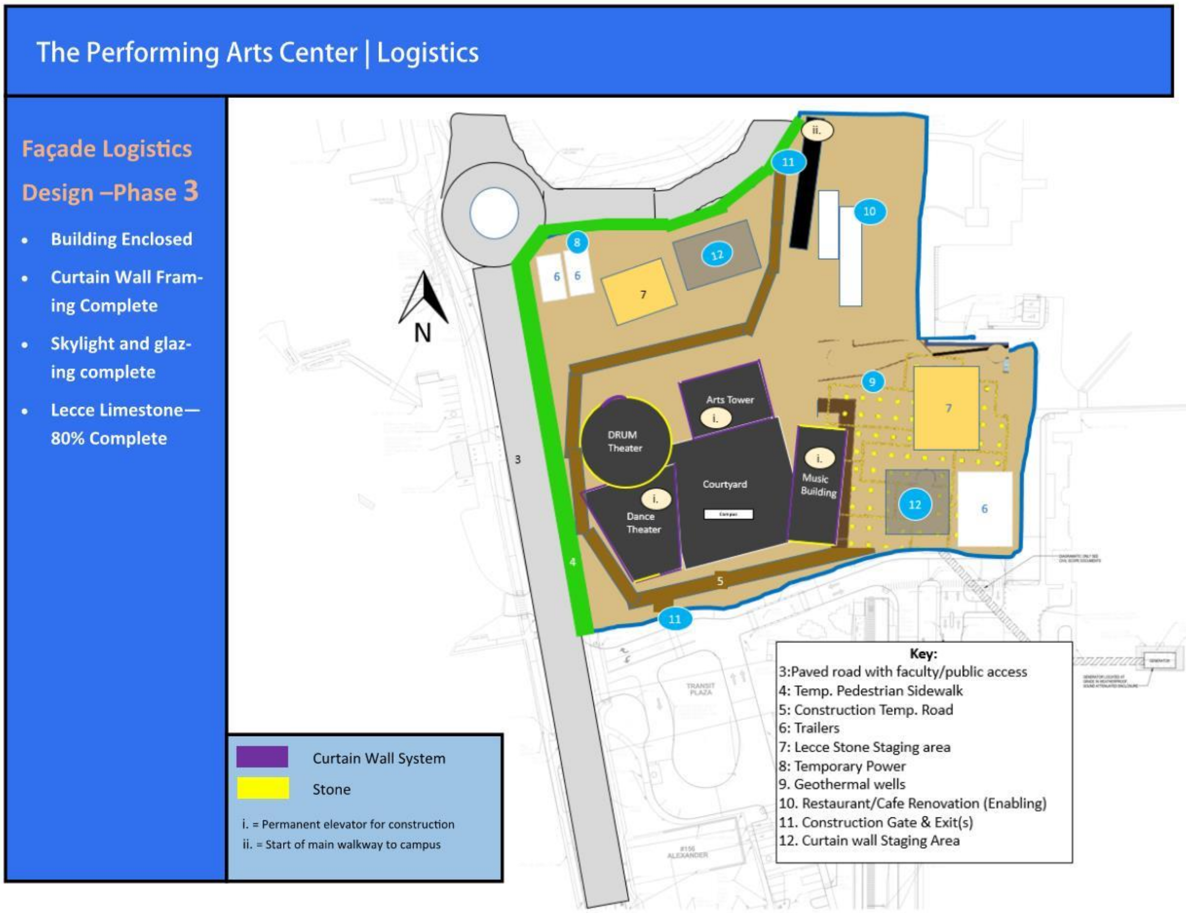


Figure 11: Logistics Plan – Phase 3

In the 3rd phase of façade logistics, the entire building is enclosed. Finishing curtain wall installation and hanging limestone are the focuses of manpower. This is illustrated by the heavy amount of laydown area for Lecce limestone and curtain wall staging in the northwest and southeast portion. From this point on, façade material deliveries will diminish and there will be a transition into interior fit out. Another notable milestone is that the main walkway through the project courtyard is being constructed.

Production Analysis:

Production:

The overall production plan is to stagger the buildings in the order of Theatre / Dance, then the DRUM, then the Music Building, then the LCA Arts Tower. For the façade system, the sequencing of construction will progress from cast-in-place wall pours to waterproofing installation, and then installation of brackets and anchors for glazing. After that, the glazing, curtain wall and glazing system structures will be installed. Finally, stone anchoring system and stone connection will take place.

This production design is extremely efficient, however it is overly idealistic of variable scenarios. It is well suited for a project that does not undergo many design changes or delays since it provides for simultaneous, overlapping work of successive construction activities to occur on different buildings. With the ability to increase crew sizes to a level of 200 men on site, this becomes a fantastic design to ensure efficiency and meet the demanding schedule needs of The University. Furthermore, the design means that different trades are not on top of each other. For instance, concrete will be on the Theatre / Dance building while glazing is starting on the DRUM. It allows trades to flow from one building to the next while the next trade moves in. This flow cycle is illustrated in Appendix A, the Production Schedule.

However, this project experiences significant delays due to the great attention to detail of the owner in terms of material change decisions as well as the difficulty in obtaining certain specialized items on time. Both are natural, important occurrences to such a unique, specialized project. Therefore, the production is not as efficient as originally planned for the entire project duration. This means that the production cannot be overlapped because the flow is stopped by certain elements. These high risk elements consist of board form equipment procurement and limestone paneling supplier changes late in the project.

Board forms are a critical element to successful sequencing for a largely start-start relationship schedule. These board forms are all prefabricated offsite. The management issue is that not all of the board forms can be delivered simultaneously because of laydown area. When some board forms had to be thrown away due to weather damage, a lack of expected material onsite led to delays in pouring walls. It is an optimization of element quantity while managing risk. The delay in pouring concrete pushes the entire façade schedule back, thus pushing back entire construction because of potential water damage without complete enclosure.

Another major delay is that the supply of Lecce Limestone stone panels was rejected in a go/no go decision in early October. Therefore, fabrication and delivery will be delayed. While anchoring and brackets can still be installed, the stone delay will impact close out items. If there is scaffolding around the outside of the building, then landscaping, sidewalks and courtyard paving are all delayed. These are major milestones which prevent opening the Performing Arts Center by fall 2017.

In future projects, potential solutions include designing a weather protected area for weather-sensitive, critical schedule items. This could be a shelter onsite, an existing facility rented from the owner or a warehouse rented locally. In addition, major material go/no go decisions should not occur this late in the project. The decision was based on a freezing test that failed. This test should be completed at the beginning of the schedule, or materials should only be selected that have been proven to meet the specified freeze/thaw test. See *Field Supervisor Interview* for further solutions and how the schedule will be accelerated to make up for lost time.

Cost Analysis:

The cost analysis resembles the cost nature of the Performing Arts Center based on the systems within the façade. The labor and resources devoted to crew size relate to the estimated work in place for the specific systems included in the overall façade system. When compared to the square foot estimate, this estimate is 300% the total cost of the exterior enclosure of that estimate. It was expected that the R.S. Means Square foot estimate would be extremely low due to the unique nature of this project compared to a regular auditorium. If one compared the percentage of the exterior enclosure to the total project cost, this estimate does not follow normal project cost parameters. R.S. Means projects 21.7% of the total cost to be in exterior enclosure. This detailed estimate totals $12,928,277 or 9% of total project cost. This accounts for an error margin of 57%. Explanation for this can be attributed to the extremely expensive interior millwork and finishes in this project. This and other high up-front costs including geothermal wells and 100% green roof allow for such a high total project cost which influences the normal % breakdown of systems. In previous hypotheses it was estimated that the façade would be an area of extremely high price, however, after studying the procurement and material costs of the Lecce Limestone material, these projections were determined to be high. After confirmation with project management, other parameters mentioned above impact a higher total cost.

Logistical Analysis:

Logistics and heavy site restrictions present efficiency issues when trying to perform more work in a shorter amount of time. For instance, local ordinances prevent multiple shifts in a day by limiting work from 5 AM – 7 PM. This is to allow students to study at night. Furthermore, the site shuts down during University reunions and exam periods. Finally, no construction can occur on Sunday. These parameters restrict logistics before any planning can occur.

From a planning standpoint, the workflow of material staging and laydown functions very well with the project production flow. While the manpower and type of work shifts from the western portion to the eastern portion (DRUM & Theatre/ Dance to Music and Arts Tower), the material staging and deliveries follow similarly. However it is inefficient to not stage any material in the southeastern portion of the site. Since there are issues with space for board forms onsite, this space can be leveraged to hold the material. Moreover, this space could be utilized to construct a temporary shelter facility to protect high risk lead items such as pre-fabricated board form.

In order to accelerate the schedule to make up for delays mentioned in *Production,* manpower needs to be reorganized so that it is not staggered between trades. Since each building will be waiting for limestone façade, larger crew sizes and more equipment will be required onsite to enable all buildings to be clad at the same time. Therefore, more cranes will be onsite and a higher quantity of limestone will be staged. The limestone should be staged in the courtyard area so that it is in a central location and picks can be performed by two separate crews with cranes. At this point the limestone will be critical to gaining schedule time. The picks can be directed to two separate areas and thus accelerate the schedule. Furthermore, during limestone installation, knee-brace scaffolding should be leveraged so that the flooring below is open. By having more cranes onsite, moving this scaffolding will be easier and having the floor open below allows for courtyard paving, landscaping, sidewalk paving, etc.

Field Supervisor Interview:

The field supervisor interview took place on October 13th, 2015 at 1:30 PM in the Turner On-Site trailer at the University in New Jersey. The interview was conducted with Don Deakyne, General Superintendent of the Performing Arts Center and Sean Tonnesen, enclosure and exterior superintendent.

Schedule Acceleration Scenarios:

Finishing the façade is a major driver to the overall schedule because the building needs complete enclosure to begin interior construction. Moreover, interior construction is proposed to take a year to complete. Therefore, the façade needs to be completed by April or May 2016 so that the interiors can be finished May 2017. To enclose a building, the curtain wall needs to be completely finished. Consequently, the schedule is riding on Gartner, the curtain wall subcontractor, to finish the work in six months (October 2015 until April 2016). At this point in time, the curtain wall is a month behind. Turner is strategizing to accelerate the concrete façade and waterproofing areas so that Gartner can follow and install curtain wall after concrete is finished. Turner plans to increase efficiency by increasing the amount of cranes onsite, and increase the amount of material allocation staging onsite. In order to have more curtain wall on hand, Turner has rented local warehouses and the curtain wall provider is storing in their local warehouses. It is ideal to have Supor use their warehouse because it takes some of the risk off of Turner.

A high risk element that can make or break a schedule is concrete pouring. In this case, the highest risk element is the prefabricated board forms used to create architectural concrete finishes. To accelerate the schedule, delays need to be eliminated by protecting board forms from the weather and optimizing just in time deliveries of the proper board forms. In this case Just-In-Time delivery means 2 days ahead of time for staging and logistics.

A means and methods solution that Turner uses to improve the construction process is an innovative strategy with concrete form placement. One solution for a straight, regular wall is to line one form up the entire side of where the wall is to be formed, and then fly the other wall in pieces. These can be slid in with a crane that nudge the wall into the perfect location. This technique is used so board forms can be installed on both sides. However, concrete placement of a wall is limited to 60' at a time. If concrete is poured on a wall over 60' there is chance for shrinking and cracking.

Another high risk element is the Lecce Limestone stone cladding that is now going to be heavily delayed due to changing the supplier. The solution will be to assign two crews for each item of work, rather than staggering between the buildings. For instance, the crew installing limestone panels on the DRUM will move to the Arts tower and the crew on dance/theater will transition to the Music building. This breaks the schedule down from 4 steps into only 2 steps. Logistical implications from this include more lulls in labor efficiency, more scaffolding onsite, more Turner staffing and higher overall manpower onsite.

For Turner to accelerate the schedule on a general level, the key is in resource loading. This means adding more equipment, material and manpower to a shift. In this case, Saturdays are the only form of overtime as night shifts and

Sundays are restricted by local ordinance. However, another solution is to change the design of a building element so that construction can occur at a faster pace. This is very uncommon to use this strategy in Turner's experience.

Constructability and Logistical Challenges

One of the major constructability issues related to the façade has been the intersection of systems at the southwestern corner of the Dance/Theater building. The issues have been due to drawing coordination issues between the architect and structural engineer. Major schedule delays have resulted. The site team overcame these challenges by coordinating communication at an accelerated level beyond how the engineer and architect were communicating to solve the problem. In the future, the contractor should be involved with the architect and engineer when decisions are made for this aspect of the design. That way the contract will be able to pinpoint issues related to constructability and thus prevent schedule delays.

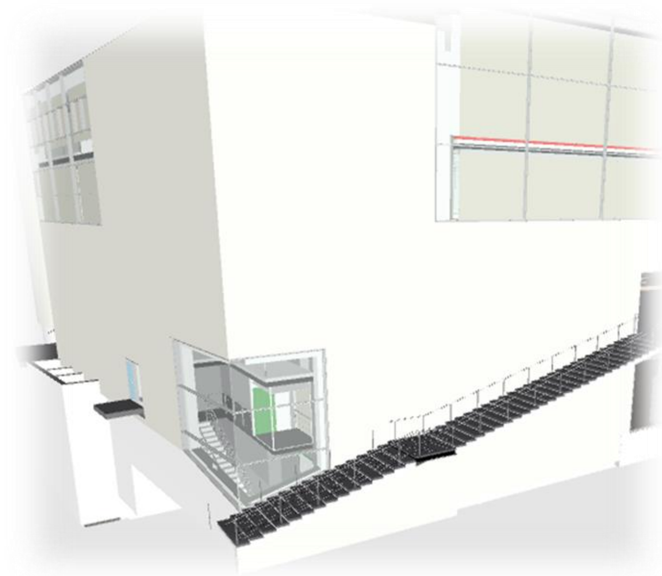


Figure 12: Major constructability issues have been at the Southwestern corner

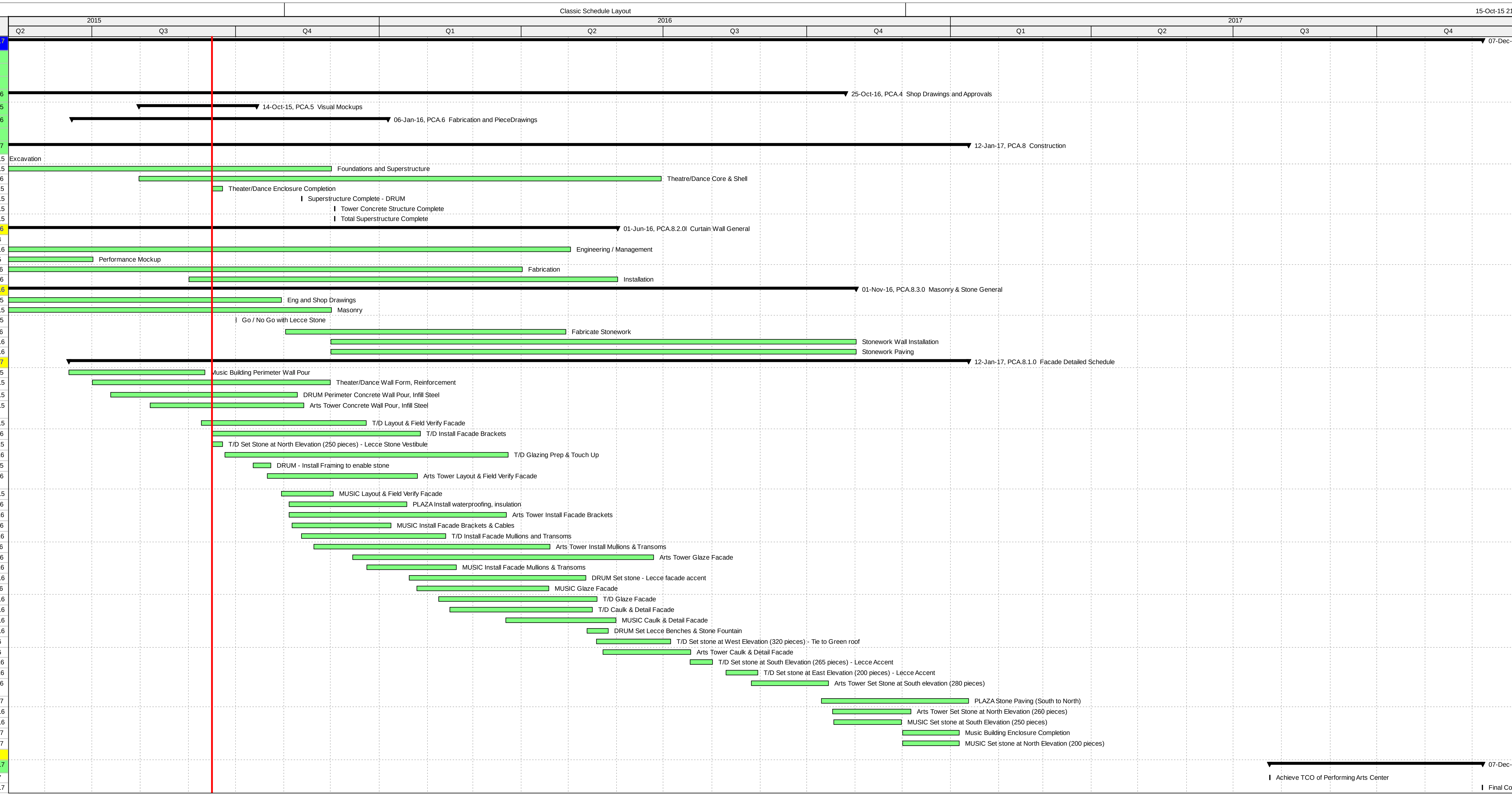
With a sophisticated geometrical design, there are always opportunities for leaks. The façade's most important role is to prevent leaking to the interior. To ensure that leaks are prevented, the key is monitoring every detail. One needs to remember that the product is only as good as the installer. If an installer has a bad day, this could negatively impact the effectiveness of the product. However, to ensure proper design early on, constructability reviews take place where the contractor will meet with the architect and major stakeholders. When there is going to be a problem, an exterior façade expert will sit down with the sub and pinpoint re-design or onsite changes that need to take place. Holding meetings early on where all relevant subcontractors attend is critical. Therefore, everyone can attest that their system is covered where façade systems intersect. Then, subs can warranty their system. However, with big firms it is important that foremen attend these meetings, rather than executives who will not actually be onsite.

To prevent leaking for this project and ensure cohesiveness of the façade, performance mockups were tested in Germany. The critical systems were tested for water leaks at a basic level. However, these tests did not incorporate interface detailing with flashing details and caulk that are necessary for detailed water leak testing. On many projects, dynamic testing occurs where water is pushed through the façade using an air-plane jet. Other techniques include a smoke bomb test where the room is pumped with smoke to see where smoke exits through seams and cracks.

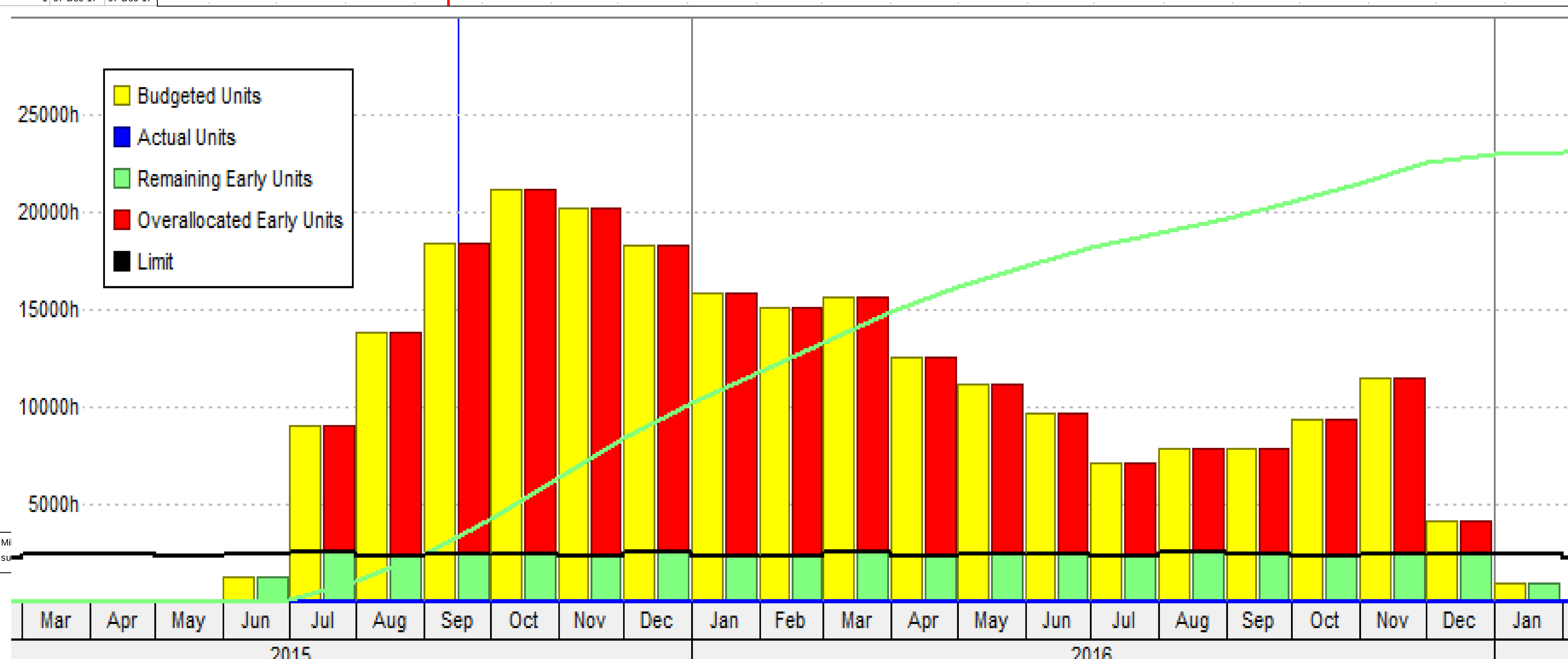
In some examples, caulk is overly utilized. This negatively impacts the façade functionality because water has no way to leave the void. Another solution to prevent leaking might be reevaluating the procedure of construction. If the designer specifies that construction occur in A, B, C sequencing, it may be more effective to build in the rearranged sequence of B, C, A.

The Performing Arts Center | Classic Schedule Layout | 15-Oct-15 21:53

Activity ID	Activity Name	Remaining Duration	Start	Finish
PCA	The Performing Arts Center	1081	01-Oct-13	07-Dec-17
PCA.1	Design Phase	0		
PCA.2	Land & Permit Development	0		
PCA.3	Procurement	0		
PCA.4	Shop Drawings and Approvals	717	27-Jan-14	25-Oct-16
PCA.5	Visual Mockups	54	31-Jul-15	14-Oct-15
PCA.6	Fabrication and PieceDrawings	145	18-Jun-15	06-Jan-16
PCA.7	Material Fabrication	0		
PCA.8	Construction	846	01-Oct-13	12-Jan-17
A2030	Excavation	349	02-Jan-14	05-May-15
A2020	Foundations and Superstructure	477	03-Feb-14	01-Dec-15
A1760	Theatre/Dance Core & Shell	239	31-Jul-15	29-Jun-16
A1700	Theater/Dance Enclosure Completion	5	16-Sep-15	22-Sep-15
A2040	Superstructure Complete - DRUM	1	12-Nov-15*	12-Nov-15
A1870	Tower Concrete Structure Complete	1	03-Dec-15	03-Dec-15
A1880	Total Superstructure Complete	1	03-Dec-15	03-Dec-15
PCA.8.2.0I	Curtain Wall General	695	01-Oct-13	01-Jun-16
A1890	Design Assist	204	01-Oct-13	15-Jul-14
A1910	Engineering / Management	566	03-Mar-14	02-May-16
A1900	Performance Mockup	283	02-Jun-14	01-Jul-15
A1920	Fabrication	370	03-Nov-14	01-Apr-16
A1930	Installation	197	01-Sep-15	01-Jun-16
PCA.8.3.0	Masonry & Stone General	632	02-Jun-14	01-Nov-16
A1940	Eng and Shop Drawings	370	02-Jun-14	30-Oct-15
A1950	Masonry	262	01-Dec-14	01-Dec-15
A2010	Go / No Go with Lecce Stone	1	01-Oct-15*	01-Oct-15
A1960	Fabricate Stonework	130	02-Nov-15*	29-Apr-16
A1970	Stonework Wall Installation	241	01-Dec-15*	01-Nov-16
A1980	Stonework Paving	241	01-Dec-15*	01-Nov-16
PCA.8.1.0	Facade Detailed Schedule	413	16-Jun-15	12-Jan-17
A1790	Music Building Perimeter Wall Pour	64	16-Jun-15	11-Sep-15
A1750	Theater/Dance Wall Form, Reinforcement	109	01-Jul-15	30-Nov-15
A1710	DRUM Perimeter Concrete Wall Pour, Infill Ste	86	13-Jul-15	09-Nov-15
A2280	Arts Tower Concrete Wall Pour, Infill Steel	71	07-Aug-15	13-Nov-15
A2050	T/D Layout & Field Verify Facade	76	09-Sep-15	23-Dec-15
A2070	T/D Install Facade Brackets	96	16-Sep-15	27-Jan-16
A2150	T/D Set Stone at North Elevation (250 pieces)	5	16-Sep-15	22-Sep-15
A2090	T/D Glazing Prep & Touch Up	130	24-Sep-15*	23-Mar-16
A2060	DRUM - Install Framing to enable stone	10	12-Oct-15*	23-Oct-15
A2310	Arts Tower Layout & Field Verify Facade	69	21-Oct-15*	25-Jan-16
A2190	MUSIC Layout & Field Verify Facade	24	30-Oct-15*	02-Dec-15
A2260	PLAZA Install waterproofing, insulation	54	04-Nov-15*	18-Jan-16
A2290	Arts Tower Install Facade Brackets	100	04-Nov-15*	22-Mar-16
A2200	MUSIC Install Facade Brackets & Cables	46	06-Nov-15*	08-Jan-16
A2080	T/D Install Facade Mullions and Transoms	67	12-Nov-15*	12-Feb-16
A2300	Arts Tower Install Mullions & Transoms	108	20-Nov-15*	19-Apr-16
A2320	Arts Tower Glaze Facade	139	15-Dec-15*	24-Jun-16
A2210	MUSIC Install Facade Mullions & Transoms	42	24-Dec-15*	19-Feb-16
A2160	DRUM Set stone - Lecce facade accent	82	20-Jan-16*	12-May-16
A2220	MUSIC Glaze Facade	61	25-Jan-16*	18-Apr-16
A2100	T/D Glaze Facade	74	08-Feb-16*	19-May-16
A2110	T/D Caulk & Detail Facade	66	15-Feb-16*	16-May-16
A2230	MUSIC Caulk & Detail Facade	51	22-Mar-16*	31-May-16
A2170	DRUM Set Lecce Benches & Stone Fountain	10	13-May-16*	26-May-16
A2120	T/D Set stone at West Elevation (320 pieces) -	34	19-May-16*	05-Jul-16
A2330	Arts Tower Caulk & Detail Facade	41	23-May-16*	18-Jul-16
A2130	T/D Set stone at South Elevation (265 pieces)	11	18-Jul-16*	01-Aug-16
A2140	T/D Set stone at East Elevation (200 pieces) -	15	10-Aug-16*	30-Aug-16
A2340	Arts Tower Set Stone at South elevation (280 pieces)	36	26-Aug-16*	14-Oct-16
A2270	PLAZA Stone Paving (South to North)	69	10-Oct-16*	12-Jan-17
A2350	Arts Tower Set Stone at North Elevation (260 p	37	17-Oct-16*	06-Dec-16
A2240	MUSIC Set stone at South Elevation (250 piec	32	18-Oct-16*	30-Nov-16
A1800	Music Building Enclosure Completion	27	01-Dec-16*	06-Jan-17
A2250	MUSIC Set stone at North Elevation (200 piec	27	01-Dec-16*	06-Jan-17
PCA.8.4.0	Waterproofing	0		
PCA.9	Project Closeout	99	24-Jul-17	07-Dec-17
A1550	Achieve TCO of Performing Arts Center	1	24-Jul-17*	24-Jul-17
A1850	Final Completion	1	07-Dec-17	07-Dec-17



Actual Level of Effort | Remaining Work | Actual Work | Critical Remaining Work



Appendix B | Detailed Estimate

Group	Phase	Description	Takeoff Quantity	Labor Cost/Unit	Labor Price	Labor Amount	Material Price	Material Amount	Equip Price	Equip Amoun	Total Cost/Unit	Total Amount
3000.000		**CONCRETE**										
	3110.150	Forms: Walls										
		DRUM Wall Forms - Steel Type	27,360.00 sf	1.50 /sf	20.00 /hr	41,040	0.96 /sf	27,054	-	-	2.49 /sf	68,094
		Wall Forms - Steel Type	51,005.64 sf	1.50 /sf	20.00 /hr	76,508	0.96 /sf	50,434	-	-	2.49 /sf	126,943
		DRUM Board Form Liner - Stucco	13,680.00 sf	1.00 /sf	20.00 /hr	13,680	3.60 /sf	50,725	-	-	4.71 /sf	64,405
		Rest of Board Form Liner - Stucco	25,502.82 sf	1.00 /sf	20.00 /hr	25,503	3.60 /sf	94,564	-	-	4.71 /sf	120,067
4000.000		**MASONRY**										
	4410.110	Stone Limestone										
		Panel Limestone Sand Finish 2"	38,940.00 sf	5.38 /sf	20.00 /hr	209,497	15.00 /sf	613,305	-	-	21.13 /sf	822,802
		Panel Limestone Smooth Fin 4"	2,290.00 sf	6.25 /sf	20.00 /hr	14,313	26.00 /sf	62,527	-	-	33.55 /sf	76,839
03-30-00.0		**Cast-In-Place Concrete**										
	03-30-53.40	Concrete In Place										
		Strt concrt,place,free-stndng wall (3000 psi),15"thck x 18'high,incl	2,166.00 cy	192.00 /cy	192.00 /cy	415,872	157.00 /cy	340,062	15.40 /cy	33,356	364.40 /cy	789,290
04-05-19.0		**Masonry Anchorage And Reinforcing**										
	04-05-19.16	Masonry Anchors										
		Masonry anchors, veneer wall ties, corrugated, galvanized, 24 ga	2,000.00 c	35.00 /c	35.00 /c	70,000	9.85 /c	19,700	-	-	44.85 /c	89,700
07-13-00.0		**Sheet Waterproofing**										
	07-13-53.10	Elastomeric Sheet Waterproofing And Access.										
		Elastomeric sheet waterproofing, bitumen modified polyurethane,	39,002.00 sf	0.96 /sf	0.96 /sf	37,442	0.93 /sf	36,272	-	-	1.89 /sf	73,714
07-21-13.0		**Board Insulation**										
	07-21-13.10	Rigid Insulation										
		Extruded polystyrene insulation, rigid, for walls, 25 PSI compressi	39,002.82 sf	0.51 /sf	0.51 /sf	19,891	1.04 /sf	40,563	-	-	1.55 /sf	60,454
08-42-00.0		**Entrances**										
	08-42-26.10	Swinging Glass Doors										
		Doors, glass, swing, tempered, 1/2" thick, 6' x 7' opening, incl. har	10.00 opng	515.00 /opng	515.00 /opng	5,150	4,400.00 /opng	44,000	-	-	4,915.00 /opng	49,150
08-44-00.0		**Curtain Wall And Glazed Assemblies**										
	08-44-13.10	Glazed Curtain Walls										
		Curtain wall, aluminum, stock, including glazing, maximum	33,277.00 sf	9.80 /sf	9.80 /sf	326,115	181.00 /sf	6,023,137	-	-	190.80 /sf	6,349,252
08-81-35.0		**Translucent Glass**										
	08-81-35.10	Obscure Glass										
		Obscure glass, 7/32" thick, textured	5,426.00 sf	6.00 /sf	6.00 /sf	32,556	12.70 /sf	68,910	-	-	18.70 /sf	101,466
08-81-55.0		**Window Glass**										
	08-81-55.10	Sheet Glass										
		Window glass, tempered, 3/16" thick	665.00 sf	1.50 /sf	1.50 /sf	998	9.20 /sf	6,118	-	-	10.70 /sf	7,116

Estimate Company **Estimate Totals** ***10/16/2015*** ***Page 1A***

Performing Arts Center Fa ***3:20 AM***

Description	Amount	Totals	Hours	Rate	Cost Basis	Cost per Unit	Percent of Total
Labor	1,288,565		19,027.056 hrs				14.64%
Material	7,477,371						84.98%
Subcontract							
Equipment	33,356						0.38%
Other							
	8,799,292	8,799,292					100.00
Total		***8,799,292***					

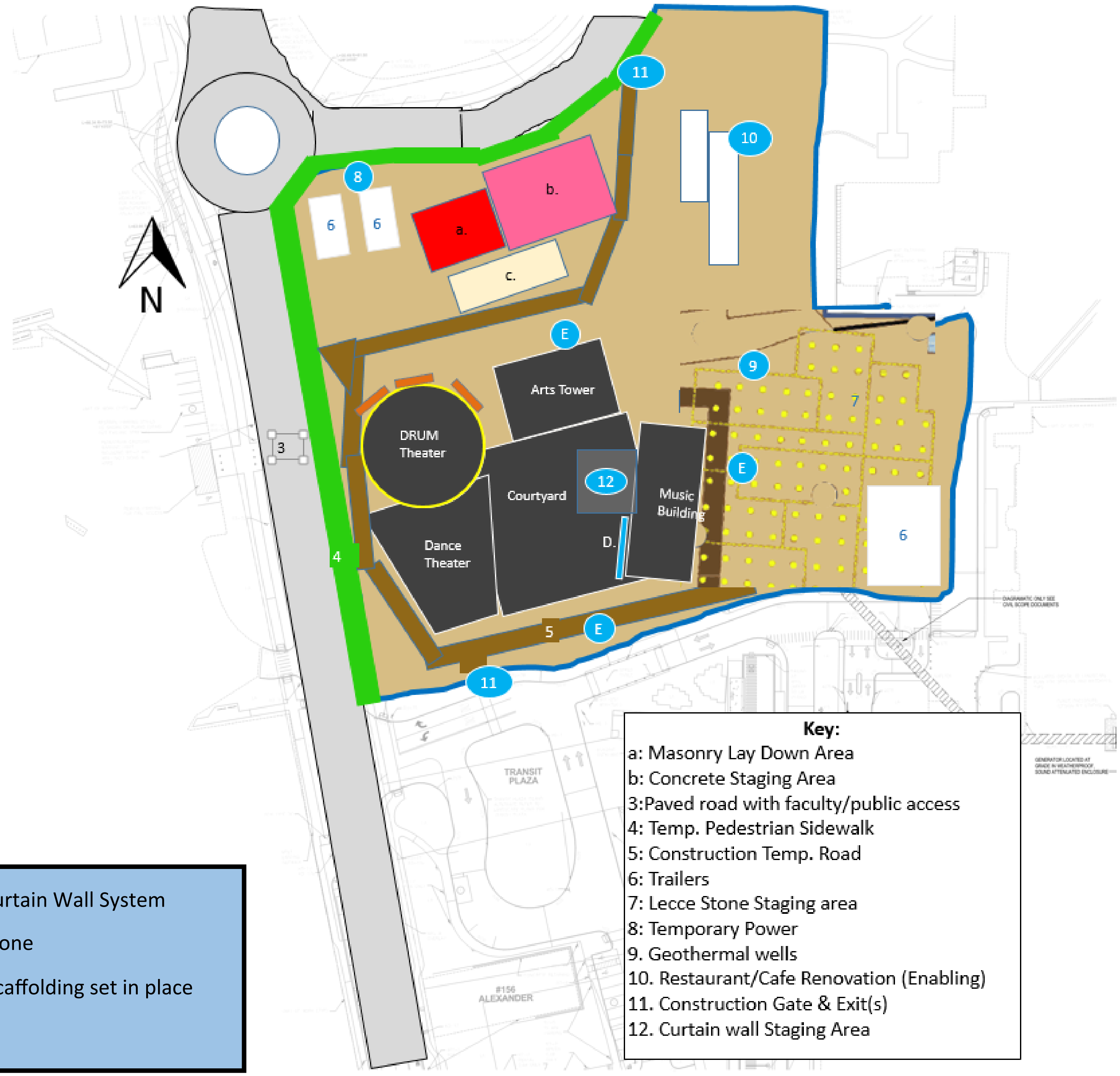
Detailed Cost Estimate Takeoffs			
Element	**Building**	**Area**	**Quantity (Unit)**
Lecce Limestone Veneer	Dance/Theatre	West Elevation	320
	Dance/Theatre	South Elevation	265
	Dance/Theatre	East Elevation	200
	Dance/Theatre	North Elevation	250
	Dance/Theatre	Clerestory	20
	Music	South Elevation	250
	Music	North Elevation	200
	LCA Tower	South Elevation	280
	LCA Tower	North Elevation	260
	DRUM		170
	DRUM		210
	DRUM		170
	All		**2595**
Element	**Quantity**	Dimension	**Unit**
Lecce Limestone Bench	60'	9" deep x 1' wide	LF
	60'	8" deep x 1' wide	LF
	228'	9" deep x 1' wide	LF
	228'	8" deep x 1' wide	LF
Lecce Limestone Bollard	7 each	45" x 62" x 47"	
Concrete Board Formed Wall			
Element	**Quantity**	**Dimension**	**Unit**
Dance Theatre South Wall	Wall Area	3546	SF
Dance Theatre East Wall	Wall area	2351.83	SF
Dance Theatre West Wall	Wall Area	5073	SF
DRUM	**Height**	**60'**	**LF**
	Circumfrence	**228**	**LF**
Breezeway	Wall Area	790	SF
	Wall Area	674	SF
LCA Arts Tower	North Tower Wall	3153.32	SF
LCA Arts Tower	South Tower Wall	3515.67	SF
Music Building	South Wall	3877	SF
Music Building	North Wall	2522	SF
	Total SF (not DRUM)	**25502.82**	
Concrete Wall Item			
Wall Thickness	1.5'		
Total SF	39002.82		
Total CF	**58504**		
Total CY	2166.814815		

Curtain Wall System Takeoff			
Element	**Quantity**	**Dimension**	**Unit**
Music East Curtain Wall	Wall Area	5624.89	SF
Music West Curtain Wall	Wall Area	5885	SF
Arts Tower West Wall	Wall Area	2425.59	SF
Arts Tower East Wall	Wall Area	3234.95	SF
Breezewall South Wall	Wall Area	3113.56	SF
Arts Tower and Breeze North	Wall Area	3090.05	SF
Breezeway north Wall	Wall Area	551.7	SF
DRUM South Wall	Wall Area	2555	SF
T/D West Curtain Wall	Wall Area	1231.26	SF
T/D SW Curtain Wall	Wall Area	451.69	SF
T/D South Curtain Wall	Wall Area	1474.18	SF
T/D East Curtain Wall	Wall Area	2391	SF
T/D North Curtain Wall	Wall Area	57.9	SF
Forum Entrace	Wall Area	1191	SF
	Total	**33277.77**	SF
Translucent Glass Takeoff			
Music Building West Wall	Wall Area	1006.59	SF
Music Building West Wall	Wall Area	1121.47	SF
Clerestories (EG-2.2)		142.87	SF
		272.79	SF
		153	SF
		163	SF
		290.8	SF
		236	SF
		2040	SF
	Total	**5426.52**	SF
Vision Glass Takeoff			
Element	**Quantity**	**Dimension**	**Unit**
DRUM EG-1C (west)	Wall Area	665	SF

Appendix C | Logistics Planning

Façade Logistics Design –Phase 1

- Start of Lecce stonework on DRUM
- Scaffolding for stone on DRUM
- Arts Tower Façade Walls still in progress
- Music wall façade walls in progress



a. Masonry Laydown area
B. Concrete Staging Area
C. Steel staging area
D. Post tensioning cable area
E. Concrete pump location

Purple	Curtain Wall System
Yellow	Stone
Orange	Scaffolding set in place

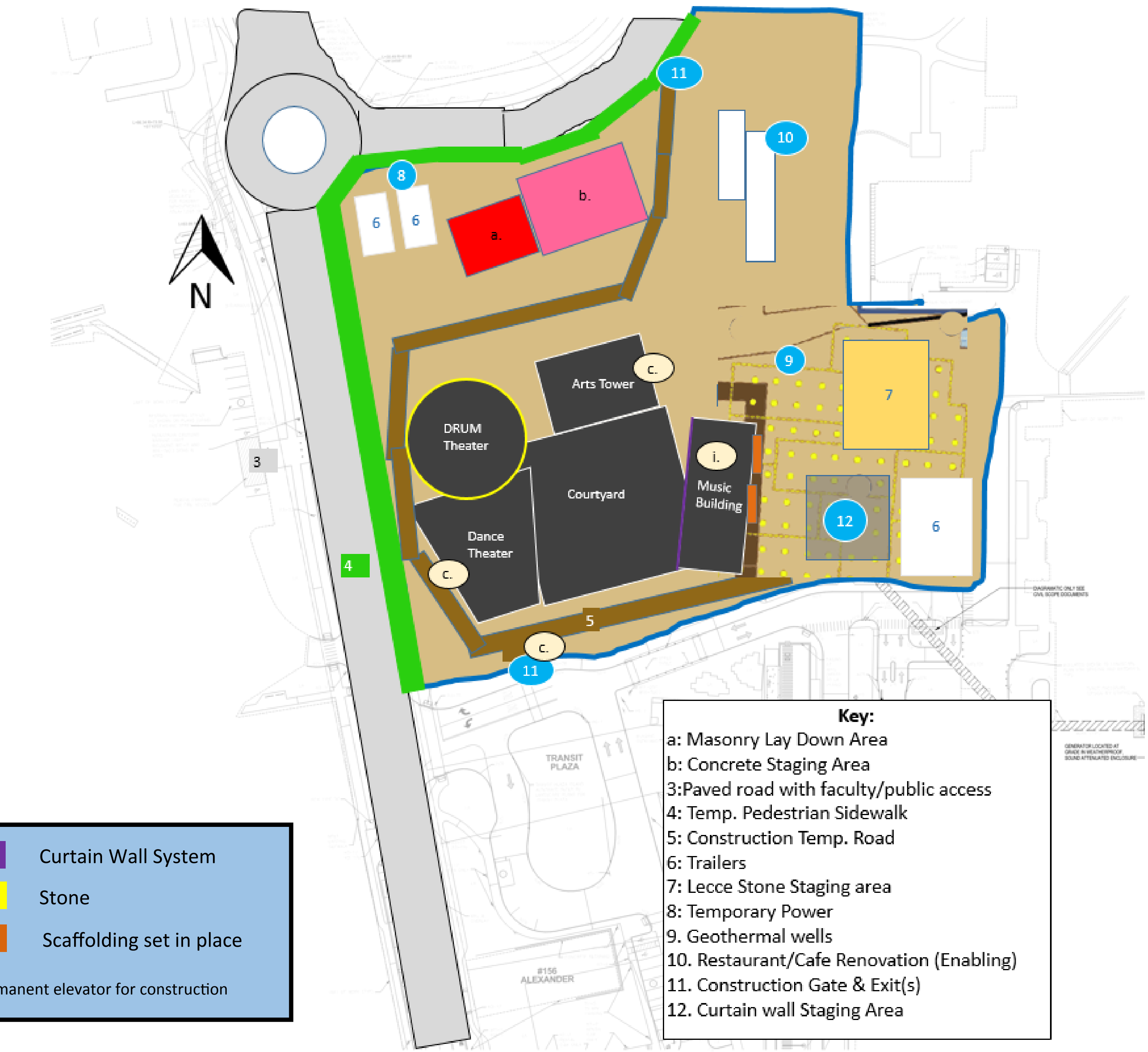
Appendix C | Detailed Estimate

The Performing Arts Center | Logistics

Façade Logistics

Design –Phase 2

- Superstructure complete
- All board-formed concrete façade walls poured
- Start of Curtain Wall



Key:
a: Masonry Lay Down Area
b: Concrete Staging Area
3:Paved road with faculty/public access
4: Temp. Pedestrian Sidewalk
5: Construction Temp. Road
6: Trailers
7: Lecce Stone Staging area
8: Temporary Power
9. Geothermal wells
10. Restaurant/Cafe Renovation (Enabling)
11. Construction Gate & Exit(s)
12. Curtain wall Staging Area

a. Masonry Laydown area
b. Concrete Staging Area
c. Debris Chute & dumpster

Curtain Wall System
Stone
Scaffolding set in place

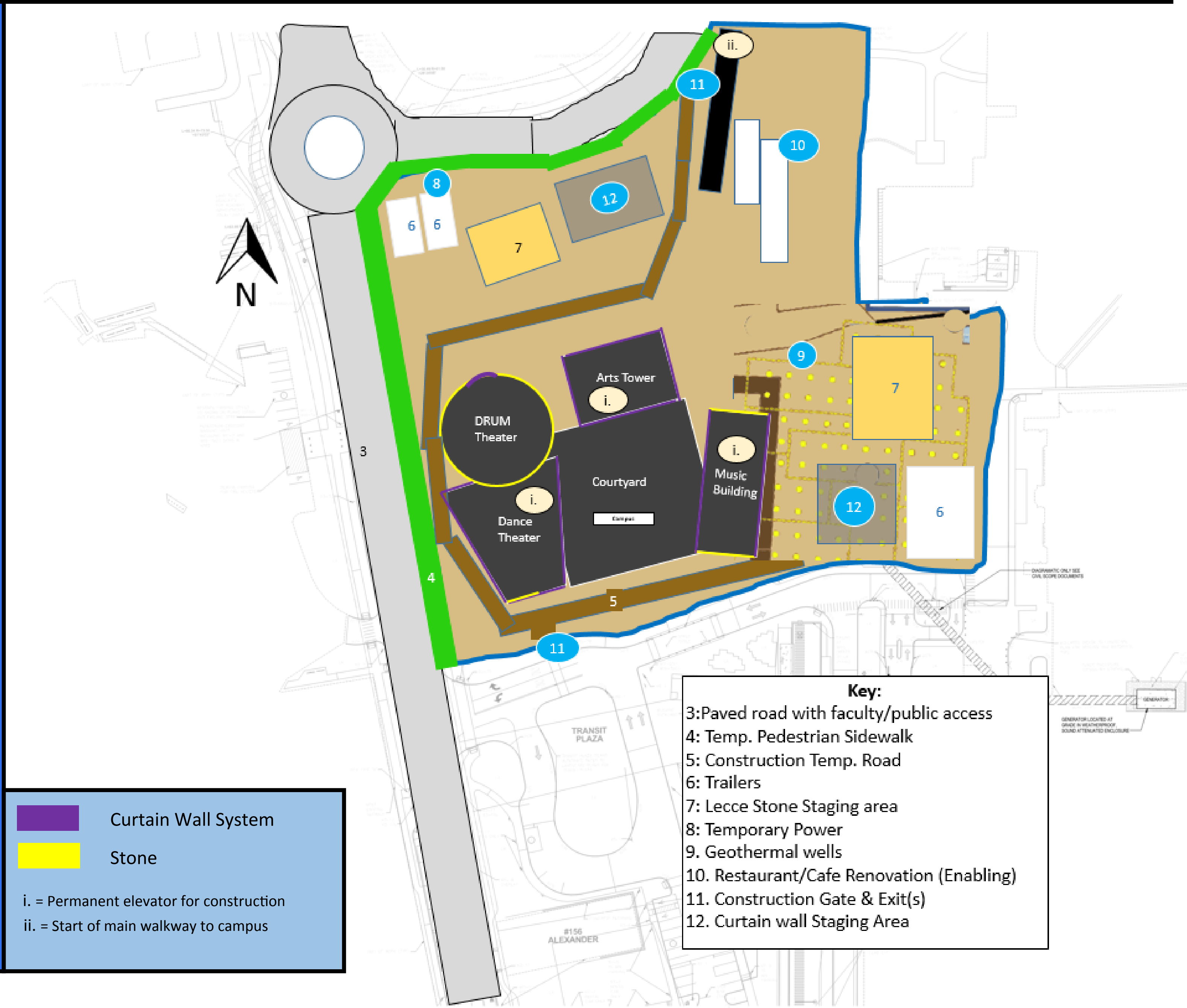
i. = Permanent elevator for construction

The Performing Arts Center | Logistics

Façade Logistics

Design –Phase 3

- Building Enclosed
- Curtain Wall Framing Complete
- Skylight and glazing complete
- Lecce Limestone—80% Complete



Curtain Wall System

Stone

i. = Permanent elevator for construction

ii. = Start of main walkway to campus

Key:

3:Paved road with faculty/public access
4: Temp. Pedestrian Sidewalk
5: Construction Temp. Road
6: Trailers
7: Lecce Stone Staging area
8: Temporary Power
9. Geothermal wells
10. Restaurant/Cafe Renovation (Enabling)
11. Construction Gate & Exit(s)
12. Curtain wall Staging Area