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Technical Assignment Three

Penn State AE Senior Thesis

UMBC
Performing Arts &
Humanities Facility
Baltimore, MD

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Executive Summary

Technical Assignment Three is intended to identify areas of the project that are good topics for research, alternative methods, value engineering and schedule compression for the UMBC Performing Arts & Humanities Facility. This project includes a 90,000 SF addition to the UMBC campus. The largest challenge associated with this project is the complicated relationship between the site excavations, structural excavation, foundations and structural elements. Certain areas on this project are isolated structurally causing delays in the adjacent work. Another aspect making this project challenging is that the structural system consists of three different elements; concrete, masonry, and steel. The planning for this project needs to be carefully analyzed and planned accordingly to accommodate for the different challenges presented.

The top three constructability issues identified on this project are the acoustic isolation and integrity, having three different structural elements on this project, and the conduits in the walls of the theatre. Each issue presents different challenges that must be addressed by the project team. The critical path of the project runs through the proscenium theatre including such tasks as the foundations, rigging, specialties, and the finishes. The most important challenge on the project is getting the structure up in a timely fashion with the least amount of delays. Some of the schedule acceleration scenarios include extended work hours, maintaining a consistent manpower and regulating the amount of workers to continue an aggressive schedule. Value engineering topics that were either accepted, pending, or denied on this project are described and include construction methods and material selection ideas that maintain the expected quality of the project at a lower cost.

Through the detailed analysis of the constructability challenges, schedule acceleration scenarios, and value engineering topics along with the Project Management interview with Patty Carper of The Whiting-Turner Contracting Company, several features were identified as potential problematic areas on the UMBC Performing Arts & Humanities Facility. These features are further discussed in the technical analysis methods that include the reduction of the amount of different structural elements, the use of different architectural finishes to the façade, the acoustical isolation, and the use of prefabrication and/or 4D scheduling. Each of these methods provides insight into possible research topics for the spring thesis proposal.

Constructability Challenges

Acoustic Isolation & Integrity

The UMBC Performing Arts & Humanities Facility is an exciting, challenging project that will benefit the UMBC community as well as the public at large. The fact that the project will serve as the new gateway to the campus makes it even more significant in terms of its design, scope and quality. In order for the project to truly be a success, it is important that the finished venues perform to the levels anticipated in the vision and the design of the space. Therefore, the project challenge is to achieve the proper level of performance of each space by developing procedures in constructability that will result in the necessary acoustic integrity of the various performance spaces. The impact of the acoustic isolation is often underestimated and therefore often underachieved. It is important to understand all of the variables that affect the acoustic integrity of each space and how to best incorporate that knowledge into the constructability of the facility.

The performance venues in the facility have numerous construction challenges inherent in a building of this complexity, but the maintenance of the acoustic integrity of these performance venues is the most critical challenge facing the project team. The acoustic coordination dictates everything that is done in the design and the construction of the space and it has implications that extend to the aesthetics, the functionality, the schedule and the cost. Every penetration through a wall, every piece of structure that crosses acoustic isolation points, every piece of equipment that causes noise or vibration serves to undermine the acoustic integrity of the space and ultimately defines the final performance experience. Each venue will have its own level of acoustic performance that is trying to be achieved and therefore each space must have its own, very clear constructability review and standards developed. Education is the key to the successful construction of this project. The way to ensure that the necessary level of acoustic integrity is achieved is by educating the workers, implementing the constructability plan, and inspecting the installation at each construction milestone. Part of the education process is developing an understanding of the acoustic principals of each space and how violating those acoustic principals cause significant problems to the final product. Whiting-Turner will set precedence early on in the project to ensure the acoustic integrity of the building is preserved from the foundation up. One of the best ways this is achieved is by mandating acoustic training for the trade foreman for all the significant trades, led by the acoustic consultant who is most knowledgeable in the design of the building. A Quality Control Program will be developed and implemented specifically to the Acoustic Isolation of the Performance Venues. This program will include training, quality control during the foundation and structure, quality control during MEP rough-in, and quality control during framing/finishing.

In order to keep track of all necessary acoustic measures during construction, a rigorous quality control system will be put in place and maintained for the duration of the project. The inspections and the reporting will be invaluable. Each report, either positive or negative, will reference drawing details, submittals, specifications and pictures. Pictures have been found to have the most impact with trade contractors and consultants when reviewing the different acoustic aspects of the project. The use of pictures helps to enforce good construction quality during the life of the project. The diligent pursuit of the correct procedures necessary for acoustic integrity will insure the proper level of performance envisioned for each space.

<u>The Three Different Structural Elements</u>

There is a complicated relationship between the site excavations, structural excavation, foundations and structural elements. There are multiple structural systems being used on this project. The different systems incorporated into this building are concrete structures, masonry bearing structures, structural steel, and some areas have a combination of all three as shown in Figure 1. Certain areas are isolated structurally from adjacent areas and since there are varying depths of excavation and areas of structural foundation, this will cause a hold up in the progression of the adjacent foundation work. Similarly, due to the structural concrete isolation of the theatre, the steel structure of the building in the areas outside of the theatre will also be postponed. In Figure 2, the structural steel in the humanities section is shown down in the basement level. One would think the structural steel structure could proceed since it is independent of the concrete theatre, especially since they are designed to be isolated from one another and therefore do not rely on each other for support. Unfortunately, the concrete structure of the theatre (which is the slowest section compared to the installation of steel) has to be installed prior to the steel for constructability reasons. Basically, no one is allowed to work below the concrete installation operation, and therefore that adversely affects the installation of the steel at the humanities portion of the building. A special element that affects the schedule with respect to finishes is the colored, ground, polished concrete in the theatre. It needs to be carefully scheduled to balance the needs for access onto that slab area for the entrance of the construction above, protection for above, and then removal of the protection. The grinding and polishing of the floor in the theatre has to be done at a time when the majority of the work in the theatre is complete. Then the floor needs to be protected again so that the finish work that comes afterwards can be done without harming the finished/polished floor surface. Finally the protection is removed from the theatre floor and the fixed seating is installed. The way Whiting-Turner

Figure 1: View of all 3 Structural Elements in Basement

Figure 2: View of Structural Steel in Humanities Section

overcame this challenge of sequencing the structural elements in an efficient but effective manner was good planning and coordination. The different crews, as stated above, had to stop and start work in adjacent areas to accomplish the project team's goal but had to make sure that not a lot of time was lost and the quality of the structure was still adequate.

Conduit in the Theatre Walls

When it comes to the proscenium theatre, there is a big challenge that the project team had to overcome – fitting a lot of conduit into the theatre walls in the cast in place concrete without weakening the strength of the structure. There is a large quantity of conduits required in the theatre for power, lighting, dimming controls, audio/visual, telecommunication data, theatre controls, etc. There are nearly three hundred conduits for lighting/dimming controls alone. The conduits are only allowed to penetrate the walls of the stage and theatre in a few very confined locations due to acoustical concerns. The conduits are also not allowed to be surface mounted because the concrete is left exposed in the stage area and only a single layer of drywall is laminated to the concrete in the theatre seating area. Therefore, surface mounted conduits would be exposed to the view of the audience which would not be very pleasing to them or the university. This forces all of the conduits to be embedded in the concrete walls as shown in Figure 3. The challenge is how to route hundreds of conduits within the concrete walls to only a few points where they would be allowed to penetrate to the other side of the wall and maintain the spacing and density limitations required of the structural engineer. The solution that the project team came up with was to route the conduits to a few oversized junction boxes located at two locations where the walls were allowed to be penetrated. The oversized junction boxes (3'x12'x6') allowed the conduit spacing to be controlled, allowed the conduits to come from multiple sides, eliminated the concern of conduit bends, and allowed the conduits to then be combined to larger conduits back to the electrical panels, control panels, and AV racks. See Appendix A for a sample of a few of the drawings submitted showing the routing of the conduit in the theatre.

Figure 3: View of the Conduit in the Theatre Walls

Schedule Acceleration Scenarios

The critical path of a project normally runs through the main activities of a project that need to be accomplished to stay on schedule. Unique to the UMBC Performing Arts & Humanities Facility is that the main path of activity is just through the proscenium theatre. The humanities portion of the building that contains classrooms and offices is not as important but still has to remain on schedule without delays so that it can tie into the theatre properly. This is essential for the success of the project so that it is completed efficiently in a timely manner.

Currently, as stated above, the critical path of the project runs through the proscenium theatre. Every item in the theatre is critical from the start of the foundations through the finishes, the rigging, the specialties, tension grids, etc. The most important task on the project is getting the structure up in a timely fashion. The biggest risk to the project completion date is if there are any delays with the construction of the proscenium theatre structure. A major impact that would cause delays is the weather, which is outside of the control of the project team. More so than rain, the wind is the primary concern according to the weather effects because of the tower crane on site. The tower crane is used to swing the forms into place for the concrete structure on the theatre. In Figure 4, the tower crane is used to place the forms on the Proscenium Theatre foundation and structure. The workers must also be tied off and safe while installing these forms, tying rebar and placing rough-ins in the theatre walls. In order to affect the schedule in a positive way, or at least minimize the negative effects, the workers will work every Saturday on the job just on the critical path activities. Also, the concrete contractor is routinely working longer days (6am-6pm) as light allows so that they maximize the time spent on the concrete structure to make up time lost due to weather. The MEP trades have to provide the manpower to support such a schedule which is not an easy task. There needs to be well thought out coordination necessary to minimize the cost impacts while continuing a very aggressive schedule. Also, maintaining a consistent manpower rather than drastic peaks and valleys is a good consideration, especially for the electrician, while the other trades are doing significant rough-ins in the theatre walls.

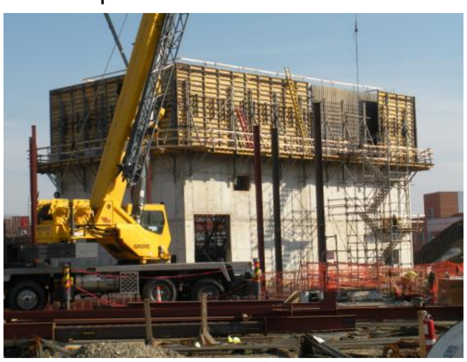


Figure 4: Tower Crane Placing Forms on PT

As for the other two areas of the facility, the back of house support space and the humanities structure can be constructed within the timeframe allowed for the theatre – so the critical path does not run through those areas. At the same time, significant delays to those areas can affect the overall schedule and potentially change the critical path so those parts of the facility must not be ignored just because they’re not part of the critical path. By ignoring those activities or causing delays would create a multiple area critical path and would put more stress on the overall project. Also, those areas need to be timed properly so that the multiple levels surrounding the theatre are tied in with respect to flashings, roofing, and water tightness as the skin goes on the building.

Value Engineering Topics

It was determined that the Owner's Program and the Owner's Budget were not properly coordinated in the preconstruction phases. Therefore an intensive program review was implemented to better define the needs verses the wants of the university. The architect started by incorporating all of the "needs" first and then prioritizing the "wants" and adding them in as appropriate.

The finishes on the project are fairly modest so there was not a lot that could be value engineered in those certain divisions (9, 10, 12). Ideas were considered but not implemented. Similarly, ideas for savings by choosing an alternate brick and an alternate metal panel skin were reviewed but rejected. The university wanted the special brick and stainless steel panel siding that was originally presented, so the skin of the building was more or less off limits. Although, Whiting-Turner did value engineer areas based on site lines of what could and could not realistically be seen. For example, in certain areas, they substituted the stainless steel to brick and other areas from brick to corrugated metal panels with an alternate bid to change from corrugated metal to composite metal panels. The largest programmatic change was in the theatre where they eliminated the orchestra pit lift. This had equipment savings in addition to significant structural changes. While this was not initially preferred by the owner, the review of the needs of the school showed that this element would not be used that often. Ultimately the theatre department chose to eliminate the pit lift in exchange for tension wire grids and also upgraded the recording and rehearsal spaces.

Also a thorough review of the Central Utility Plant (CUP) work that was being proposed resulted in a cost savings and a design that ultimately increased the capacity of the central utility plant services while saving money by eliminating an addition. The owner wanted to add an addition to the existing central utility plant to make room for more utilities to increase the loads. Whiting-Turner came up with the idea of upgrading the utilities in the existing plant to carry more capacity and eliminating the proposed addition. It was a win-win situation for the university and the project costs. This was done with considerable time in review by all the parties including the designers, engineers, construction managers and the facilities. Shown below in Table 1 is the value engineering cost summary for items accepted, pending, or rejected to this project.

UMBC Performing Arts & Humanities Facility VE Summary		
	Phase I	CUP
Reconciled SD Estimate Amount	$58,477,054	$10,370,578
UMBC PAHF Budget Amount	$50,200,000	$10,000,000
(Over)/Under Budget Amount	$8,277,054	$370,578
Total VE - Accepted to Date	$2,352,377	
(Over)/Under Budget Amount	$5,924,677	
Total VE to Date	$7,087,574	
Total VE - Accepted to Date	$2,352,377	
Total VE - P1 (good potential) to Date	$510,149	
Total VE - P2 (medium potential) to Date	$3,867,248	
Total VE - P3 (low potential) to Date	$476,839	
Total VE - R (rejected) to Date	$120,239	

Table 1: UMBC PAHF Value Engineering Summary

Problem Identification

Through the in-depth analysis of the constructability challenges, schedule acceleration scenarios, and value engineering topics along with the Project Manager interview, several features were identified as potential problematic areas on the UMBC Performing Arts & Humanities Facility. The following issues may possibly be pursued in upcoming research topics.

Use Different Architectural Facade

The UMBC Performing Arts & Humanities Facility has a few architectural finishes on the exterior of the building. The proscenium theatre walls are made from a corrugated metal panel and the humanities portion of the building is mostly comprised of brick and curtain wall. The problem is that the brick design contains multiple colors which make the project more expensive and more difficult to layer the pattern to the satisfaction of the university. Also the metal panels on the theatre are corrugated to give a more architecturally pleasing look to the campus but from far away the corrugated pieces are not visible to the eye and are very bright to any driver passing by. It may be possible to look into a different façade to save on cost but also still maintain the university's wants.

Acoustical Isolation

Being that there is a theatre attached to this facility, the acoustic integrity needs to be achieved while building this performing arts building. So the problem is to make sure that each space achieves the proper level of performance resulting in the necessary acoustic integrity of the various spaces. Every penetration through a wall or a noise or vibration, any piece of structure that crosses acoustic isolation points needs to be carefully monitored to ensure the ultimate performance experience.

AHU's on the Roof

There is multiple air handling units on the roof of this building providing the proper equipment for the mechanical systems. The problem here is the amount of weight each of these AHU's weigh because they impact the load capacity for the roof. There may be a few solutions to this problem. There can be a choice of having just a few large air handling units, having multiple smaller air handling units or just move the AHU's off the roof all together causing there to be less of a load capacity needed to hold this piece of equipment on the roof top.

Reduction of Quantity of Structural Elements

One of the major challenges was the use of a variety of structural elements because different areas needed to be delayed while adjacent areas performed work. This was a major problem when trying to sequence the work completed during the buildup of the structure of this building. If it is plausible, perhaps only one type of structure can be used instead of three different elements. This would cause less stress on the sequencing of the schedule and may also benefit the project by not becoming behind schedule.

Lighting Loads in PT

In the Proscenium Theatre, as discussed above in the constructability challenges, there is a lot of conduit going into the walls to provide lighting controls, power, audio/visual, etc. which poses a problem to the structural strength. Not only is that an issue, but since there is all that power in this theatre with all the different lights, that also means that there is a good amount of load coming from that equipment. This is a problem because that is making the mechanical system run harder to compete with all the lighting loads. A possible solution would be to change out the type of lights to make fewer loads which in turn does not make the mechanical system work as hard.

Prefabrication and 4D Scheduling

Prefabrication and 4D scheduling is a good way to accelerate a project's schedule and decrease the potential risks during construction. The UMBC project does not perform barely any prefabrication other than tying the rebar together on the ground before the crane hoists it into the forms before the cast in place concrete is poured. Although BIM was used to show the building layout and systems, a 4D scheduling model was not incorporated either. If both of these useful tools were implemented on this project, there may have been a better opportunity to accelerate the schedule and have less congestion with the sequencing of the structural elements.

Tying into Existing Tunnel

There is a tunnel being built underground for all the utilities running to the Performing Arts Facility. The problem arises when trying to tie the new tunnel with the existing tunnel. The existing tunnel seems not to have any form of waterproofing and the strength of the tunnel is weakening because of the water seepage. This makes it difficult to connect the two tunnels if one is no longer stable enough to perform the duties of the structure that it was built for.

Technical Analysis Methods

Technical Analysis Method #1: Reduction of Quantity of Structural Elements

As described in the previous section, there are three main components of the structure of this building, steel, concrete and CMU's. Being that there is such a variety of structural elements made the coordination and sequencing very difficult because of the adjacent trades having to stop work while other structures are being placed, causing delays. By looking at the budget, using all three components for the structure made it more costly compared to if only one element was used. Also if the structure was made out of only one element such as concrete, then there is a possibility that the coordination of the entire structure cannot be as complicated and also it may save the owner money.

This analysis will include careful considerations of looking at the material cost of all three materials compared to just one and also consulting the structural engineer to make sure that having all concrete is acceptable for the loads of the building. Also, by eliminating the other two materials, this may potentially accelerate the schedule by not having to stop the adjacent work surrounding the work being done. A close look at the schedule and coordination is key when analyzing the structure of this particular building.

Technical Analysis Method #2: Use Different Architectural Facade

The façade at the UMBC Performing Arts & Humanities Facility is comprised of corrugated aluminum metal panels on the theatre and an architectural design of brick veneer with a curtain wall on the humanities section of the building. Both of these types of finishes have been chosen by the university to be atheistically pleasing and add style into the campus theme. After looking at the project budget, it can be seen that the façade provides an area of analysis that has the potential to reduce both the project schedule and the project costs.

This analysis will include an exploration of techniques available to accelerate the schedule and to reduce the total cost of the façade. One possible solution would be to use plain gray metal panels which cost $80/SF cheaper than the corrugated aluminum metal panels. Also, instead of using the multiple colors of bricks shown in Figure 5, a more solid color of brick found in the area could be used to fit the overall theme of the campus better. Both of the materials wanted by the university are found outside of the region so that jeopardizes them another LEED point as well. Accelerating the exterior finishes and reducing the cost of material would ensure that the project is done on time and under budget.

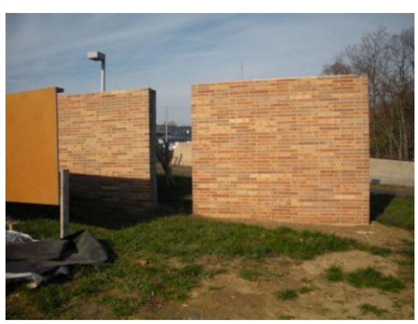


Figure 5: Mock-up of Brick Veneer Finish

Technical Analysis Method #3: Changes in Acoustical Isolation

The project challenge is to achieve the proper level of performance of each space by developing procedures in constructability that will result in a necessary acoustic integrity of the various performance spaces. As discussed in Method #1, there may be the possibility of changing the structure to all concrete is plausible. If that's the case, then having thicker concrete walls everywhere may increase the integrity of the acoustic isolation. Also possibly looking at different acoustical panels in the theatre may decrease the cost and/or help the acoustic isolation.

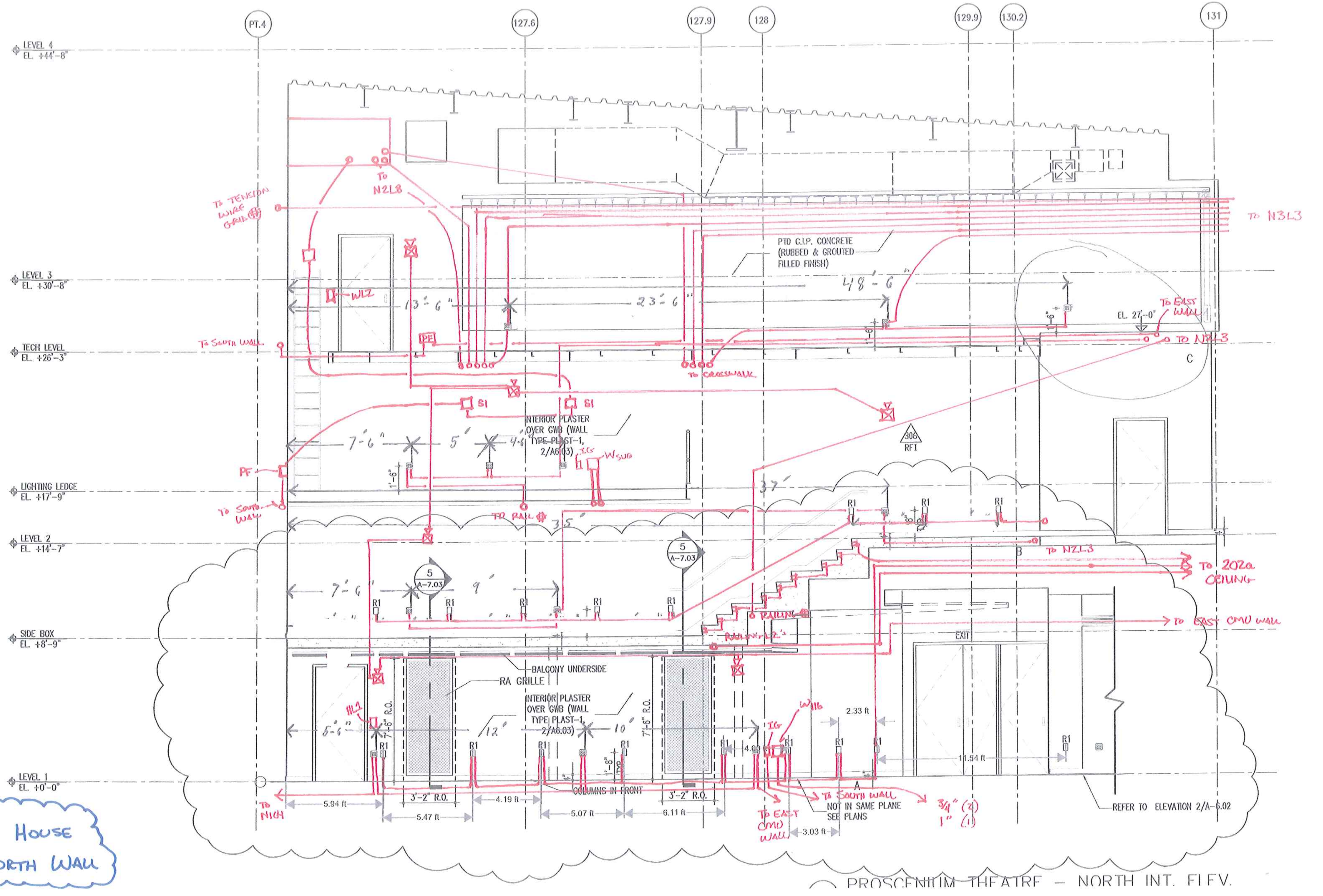
To perform this analysis, every little aspect has to be taken into consideration such as the penetrations, noise, vibrations, etc. Each performance space would be individually looked at and each has their own constructability procedure to see if the concrete structure mentioned above would be the best isolation or not for that particular space. Also speaking with the acoustic consultant on the best acoustic panels suited for this job is essential to see if the cost can be decreased with using other panels or if the isolation would be increased which would achieve the best final performance experience.

Technical Analysis Method #4: Use of Prefabrication and/or 4D Scheduling

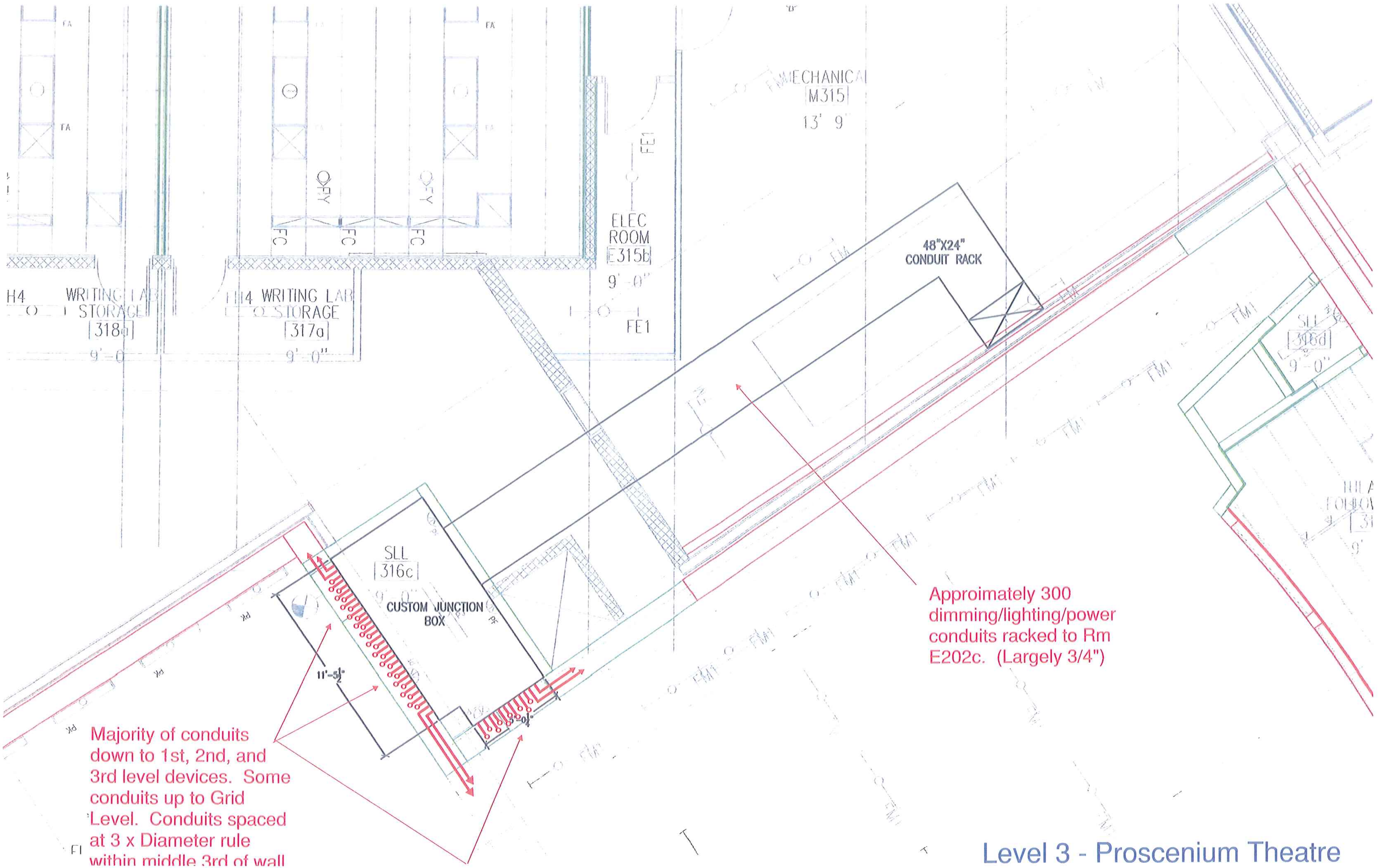
Prefabrication and 4D scheduling is a critical industry issue that was discussed earlier on in the year at an annual PACE conference. These tools are good ways to accelerate a project's schedule and help organize the sequencing of the project a little better. Since this project does not have much prefabrication being performed and also does not utilize a 4D scheduling model, a look at a structural system being prefabricated and a 4D model made from a schedule may help decrease cost and help the time lost during construction.

The process of the prefabrication would need to be studied and analyzed for the prefabrication and installation on site as well as the process for onsite construction. Once the processes have been studied a list of pros and cons would need to be developed. Prefabricating the walls would be a good structural stand point and the work would be completed much faster but negatively it would not be good for the acoustical stand point because of all the conduit rough-in in the walls; it also would not provide enough mass for the acoustical isolation. The cost would need to be analyzed and compared to the original costs. One thing to keep in mind with prefabricating the walls would be shipping the pieces to the site. Additional planning will also be required to ensure that the prefabrication is successful. By analyzing a 4D model for this complicated structure, that would benefit the project team by being able to possibly come up with a better coordination sequence when putting up the different structures of the building and also look at a more detailed logistics plan.

APPENDIX A – Drawings for Rerouting Conduit



PT.4
127.6
127.9
128
129.9
130.2
131
LEVEL 4
EL. +44'-8"
LEVEL 3
EL. +30'-8"
TECH LEVEL
EL. +26'-3"
LIGHTING LEDGE
EL. +17'-9"
LEVEL 2
EL. +14'-7"
SIDE BOX
EL. +8'-9"
LEVEL 1
EL. +0'-0"
To TENSION WIRE GRID
To N2L8
To N3L3
PTD C.I.P. CONCRETE (RUBBED & GROUTED FILLED FINISH)
WL2
13'-6"
23'-6"
48'-6"
To EAST WALL
EL. 27'-0"
To South Wall
PF
To N2L3
To CROSSWALK
C
S1
INTERIOR PLASTER OVER GWB (WALL TYPE PLAST-1, 2/A6.03)
306
RFI
7'-6"
5'
4'-6"
1'-6"
IG
Wsub
37'
To South Wall
To RAIL
35'
R1
B
To N2L3
To 202a CEILING
5
A-7.03
7'-6"
9'
RAILING
To EAST CMU WALL
EXIT
BALCONY UNDERSIDE
RA GRILLE
INTERIOR PLASTER OVER GWB (WALL TYPE PLAST-1, 2/A6.03)
WL1
W116
IG
2.33 ft
6'-6"
12'
10'
7'-6" R.O.
4.08
11.54 ft
COLUMNS IN FRONT
A
To South Wall
NOT IN SAME PLANE SEE PLANS
3/4" (2)
1" (1)
REFER TO ELEVATION 2/A-6.02
To NICH
5.94 ft
3'-2" R.O.
4.19 ft
5.47 ft
5.07 ft
6.11 ft
To EAST CMU WALL
3.03 ft
PT HOUSE NORTH WALL
PROSCENIUM THEATRE - NORTH INT. ELEV.



Level 3 - Proscenium Theatre