The New Science Building

Texas A&M International University
Laredo, TX

Nicole Griffith
Construction Management Option

Senior Thesis 2005
Department of Architectural Engineering
The Pennsylvania State University

New Science Building

Texas A&M International University
Laredo, TX

Primary Project Team

General Contractor:
Constructors & Assoc., San Antonio, TX
www.constructorsworld.com
Architect:
Kell Munoz Architects, San Antonio, TX
Consulting Structural & Civil Engineer:
Jaster-Quintanilla, San Antonio, TX
Consulting MEP Engineer:
Shah Smith & Associates, Houston, TX
Owner:
Texas A&M University System
www.tamu.edu

General Project Information

Function:
Houses classrooms, research laboratories, offices including the dean's office, and a planetarium.
Size:
80,966 S.F. distributed over 3 floors
Dates of Construction:
June 13, 2003 to December 23, 2004
Cost Information:
$15,591,670 in direct costs
$1,140,242 in general conditions
$301,142 in fee (1.77%).
$17,033,054 contract total
Project Delivery Method:
Design-Bid-Build

Architectural Features

The building footprint consists of three interlocking buildings forming a triangle with a courtyard in the center.
Planetarium: Steel structure consisting of a metallic dome within a glass pyramid on a colored concrete base.
Dean's Tower: Holds the office of the dean next to the planetarium.
Façade: Exterior of brick veneer, with galvanized steel bands running horizontally. Embossed metal panels run along the top of the building, while glass mosaic tile lines the bottom. The tower features embossed metal panels around the exterior.
Roof: The roof of most of the building is flat, with the exception of the tower, which is sloped clay tile.

MEP Systems

Mechanical: Includes a variable air volume system with stainless steel ductwork to withstand a corrosive environment, 2 chillers, and a cooling tower, as well as chilled and hot water supply for additional service to the laboratories.
Plumbing: Features anti-corrosive glass waste pipes and a 1000 gallon acid neutralization basin to withstand the chemicals that will be dumped in the laboratories
Electrical: Includes 12,470 volt & 4160 volt distribution, and both 480/277 & 208/120 service, as well as raceways for telecommunications systems. An electric generating system will serve as backup power.
Fire Protection: Consists of a standard wet pipe system with standpipes throughout the building.
Structure: Cast in place drilled pier foundations with a mud slab and concrete columns and floors.

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http://www.arche.psu.edu/thesis/2005/nlg127

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Executive Summary

This report discusses various analyses and research to determine the possibilities of making the design and construction of systems in the Science Building better. The topics addressed include research for 4D model analysis, planetarium concrete structural and construction feasibility, and a planetarium acoustical analysis.

4D Model Analysis

The use of 4D models in construction is important for better visualization of the schedule. A new, more readable schedule was created for this project and linked a 3D model of the structure of the planetarium to locate any deficiencies within the schedule.

Planetarium Concrete – Structural and Construction Feasibility Analysis

The cast-in-place architectural concrete base of the planetarium was formed with the intended finish to be smooth as-cast. Concrete specifications and different types of formwork were investigated to determine the best course of action or alternate for this portion of the project.

Planetarium Acoustical Analysis

The owner's representative for this project felt uncertain about the acoustical quality that the planetarium would have after its completion. During construction, the planetarium was very noisy due to the lack of finishes. A reverberation time calculation was performed to determine the acoustical quality of the finished space in order to alleviate the owner's concerns. A sound transmission class rating was also obtained for the mechanical room walls to determine whether sound from those rooms would transmit into the planetarium space.

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April 5, 2005

Mr. Stephen P. Byrne, FAIC, CPC
Associate Executive Director
Texas A&M University System
A&M System Building, Suite 1162
200 Technology Way
College Station, TX 77845

Re: Available Alternatives

Dear Mr. Byrne:

The information contained within this summary book pertains to available alternatives for the New Science Building at Texas A&M University in Laredo, Texas. The information is in response to your request in August 2004 for suggestions on improving the construction process by using 4D modeling, analyzing options for correcting the finish to the architectural concrete at the planetarium, and performing an acoustical analysis of the planetarium.

All information and recommendations regarding these issues are contained herein.

All supplemental information can be located in the appendix. This information is also available at www.arche.psu.edu/thesis/2005/nlg127/

Sincerely,

Nicole Griffith
The Pennsylvania State University

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Existing Conditions

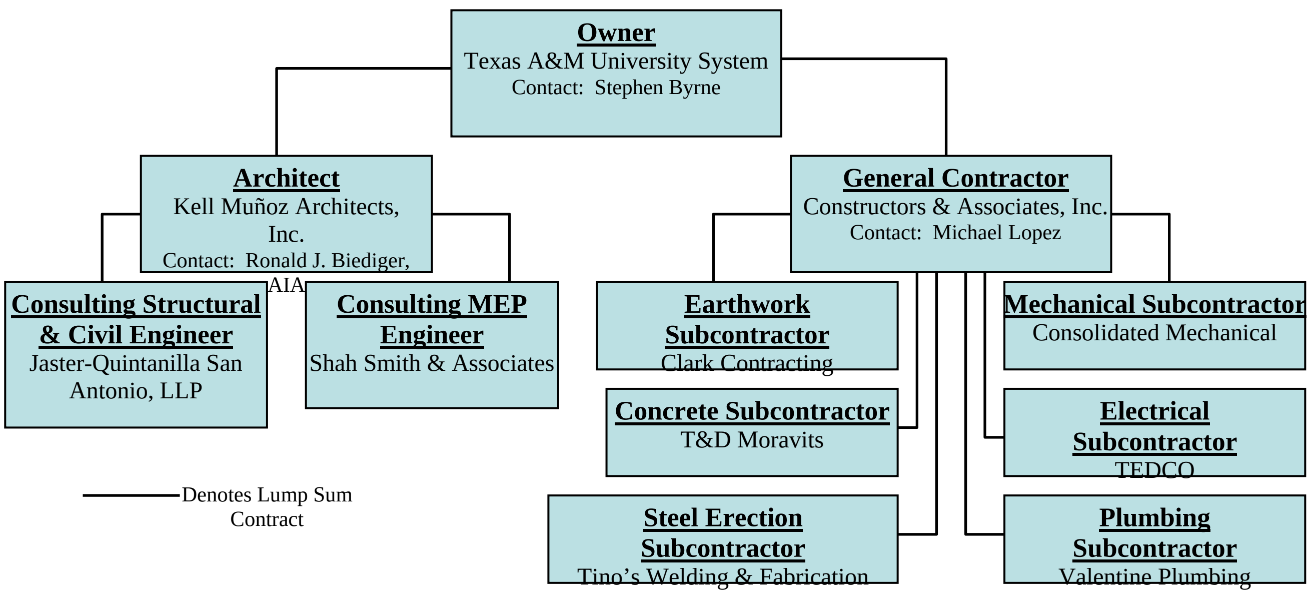
Description of the Project

Project Delivery System

The New Science Building is a public project because it is being built for Texas A&M University System. Most public projects are design-bid-build with a General Contractor and are sent out to competitive bid, and this one was no exception.

The contracts are all lump sum, with Texas A&M holding contracts with the Architect and the General Contractor. The Architect has two Consulting Engineers, and the General Contractor holds all contracts with the Subcontractors.

Contracts



All of the contracts for the project are lump sum contracts. The owner and architect put the project out to bid on March 6, 2003. The bid submittals consisted of 5 parts: (1) The competitive sealed proposal with base bid, alternates, and bid bond or cashier's check, (2) project qualifications, (3) financial qualifications, (4) historically underutilized business subcontracting plan and (5) subcontractor qualifications and cost reduction considerations.

Constructors and Associates won the bid and received a lump sum contract of $18,000,000. 540 days from notice to proceed were allotted by the owner for completion.

If force majeure occurs, or inclement weather delays the project for more than the given weather delay days, the contractor may be allotted additional time for completion. After the bid was won, payment and performance bonds were required. The contractor was also required to have public liability and property damage insurance with an umbrella policy for $1,000,000, as well as employer's liability, comprehensive general liability, comprehensive automobile liability, owner's protective liability, and builder's risk insurance.

Constructors and Associates hired subcontractors based on their bids, qualifications, and historically underrepresented business (HUB) status. Each subcontractor was awarded a lump sum contract. Based on the size of the subcontractor's work, payment and performance bonds may have been required. If the amount of the subcontractor's contract was greater than $25,000, particularly site work, structural, and MEP contractors, the bonds would be required. Each subcontractor was also required to carry his own standard insurance on the project, such as worker's compensation.

The lump sum contracts awarded are typical for public projects. The owner is looking for the best price, because his budget is limited. However, the lowest bidder does not usually put out the best product. Because the general contractor had to bid for the project, the subcontractors also had to bid, so that the general contractor could get the best price. The general contractor also had to take into account the HUB contractors, which also affected the selection process.

Because of Constructors' limited control of subcontractor selection, numerous subcontractors were not able to handle the size of this project, and removed themselves from the project. This required Constructors to re-bid these scopes, which took time and money, and subsequently delayed the project. This type of contract might seem to be optimal for a public owner; however, the consequences of bid-build projects with lump sum contracts can far outweigh the advantages.

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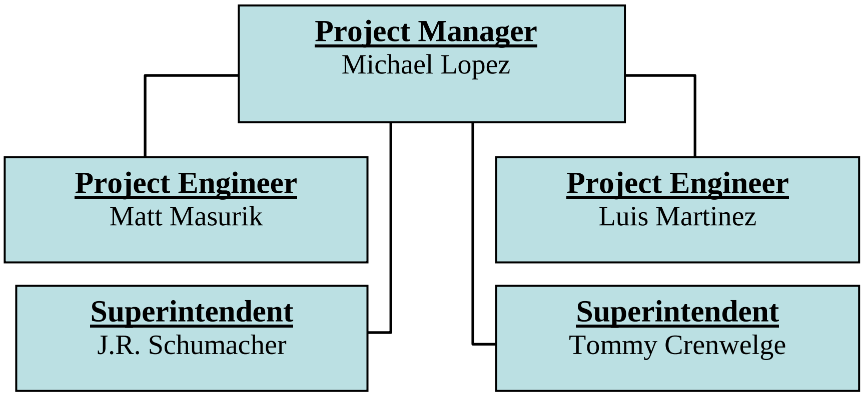
Staffing Plan



The field construction staff consists of the project manager, Michael, two project engineers, Matt and Luis, and two superintendents, J.R. and Tommy. Michael oversees both project engineers and both superintendents.

Matt joined the team to help with the coordination of the MEP contractors. He was involved in the acquisition of these trades, and helped find a new plumber after the original plumber went out of business and left the project. Luis handles most of the regular project engineering work. J.R. and Tommy work jointly on the project because of its size, and J.R. is also overseeing the work on the central plant.

Constructors and Associates' office is located in San Antonio, about three hours from San Antonio, so this team is made up of people who were both capable of completing the job successfully and willing to relocate for the duration of the project.

Building Systems

Steel: The Planetarium has a structural steel dome within a structural steel pyramid on an architectural concrete base. The concrete base supports the steel framing at the bottom, while the connections at the top are bolted and field welded. A mobile crane was used to erect the steel, and was located beside the location of the planetarium during the erection of the steel. Various small cranes have been used throughout the project. Each crane is brought in by the subcontractor using it, because a single crane wasn't continuously needed for the whole project.

Concrete: The entire structure of the north and south buildings, and the central plant are composed of cast in place concrete. The forms were all standard plywood and sheet metal because the building is only three stories, which negates the need for any special types of vertical forms. A pump truck was used to place all concrete.

Mechanical System: The mechanical system features stainless steel ductwork and anti-corrosive glass waste piping. The system uses centrifugal chillers, cooling towers, and air handlers with variable frequency drives for distribution. There is a mechanical room located centrally in the in each of the north and south buildings, and another smaller mechanical room adjacent to the planetarium. The fire suppression system is standard wet pipe with standpipes.

Electrical System: The electrical system includes 12,470 volt & 4160 volt distribution, and both 480/277 & 208/120 service, as well as raceways for telecommunications systems. These services will be provided from the existing Texas A&M Campus system via underground duct banks. An electric generating system will serve as backup power.

Masonry: The façade of the north and south buildings and the Central Plant consist of brick veneer tied to the sheathing with galvanized straps, bars, bolts, and rods.

Design Coordination

The scope of the Mechanical/Electrical/Plumbing required includes the entire building. MEP systems run through all floors and many walls. This is because there are numerous laboratories throughout the building. There are also two mechanical systems, including VAV ductwork and chilled and hot water piping to the laboratories. The waste piping includes both standard black iron, as well as anti-corrosive glass piping which runs from the laboratory sinks to the acid neutralization basin.

According to the specifications, **section 01040 – Coordination**, mechanical and electrical work must be coordinated with the work of other trades so that various components of systems are installed at the proper time, fit available space, and allow proper service access to all systems that require maintenance. Project space and sequence of installation of MEP work should be coordinated as indicated on the drawings. Routings shown on the drawings for pipes, ducts, and conduits should be followed as closely as possible. Coordination drawings must be prepared to define the relationships between sleeves, piping, ductwork, conduit, ceiling grid, lighting, fire sprinkler, HVAC equipment, and other MEP equipment with other building components such as beams, columns, ceilings, and walls.

The areas that would require the most coordination are the areas around the laboratories, due to the supplementary systems that are included. Also, mechanical and electrical rooms and the areas around them would require close coordination due to the large amount of system components located in those areas. The planetarium would also pose coordination issues, because it does not have any walls in which system

components could be run through. All systems have to be located under the first floor, in the crawl space.

MEP coordination began with a coordination meeting including the mechanical, electrical, plumbing, and fire protection contractors. Any major areas of concern were brought to light at that meeting. Then the mechanical contractor started the process to create the coordination drawings, by inserting his scope of work in the drawings provided by the architect. The coordination drawing needed to follow the design plan as much as possible, according to the specifications. Following was the plumbing contractor, next the fire protection contractor, and lastly the electrical contractor. After the coordination drawings were complete, another meeting was held to discuss the results and any subsequent problems that occurred or were discovered during the process.

General Conditions Estimate

A general conditions estimate was performed to calculate the total cost of the project due to general conditions. This estimate includes the cost of the contractor's labor, field offices, temporary utilities, and other project related costs to the contractor. This estimate is similar to that of most other projects; however in addition to the typical costs of general conditions, other costs also apply due to the location of the project versus the location of the contractor's home office.

The contractor needed to temporarily relocate the field management for this project to Laredo from San Antonio. This relocation added costs to the project including temporary housing for 18 months, and traveling and entertainment expenses.

The total cost of the general conditions estimate is $1,087,984, with a monthly cost to the project of $60,455. See Appendix A for the general conditions estimate.

Local Conditions

Laredo, TX is an old town only two miles from the Mexican border. For this reason, much of the population of Laredo is of Mexican descent. Laredo is also quite small, and is about three hours from the closest U.S. city.

Because of the size of this area, the only construction services that are readily available consist of retail builders, and architectural services for small facilities. Therefore, all services for construction of the science building were recruited from outside cities.

The preferred method of construction for most of Texas is quite traditional, with little technological advancement. Most buildings have concrete structures, however, both concrete and steel are utilized.

The site for the science building is located on the Texas A&M International University campus on an open lot beside an existing parking lot. This allows for plenty of construction parking and storage, especially during the summer months when classes were not in session.

The soil in this area, as in most of Texas, is clayey sands, silty sands, and clay. The area is very dry, with ground water observed at about 15 feet below the surface. This level can fluctuate drastically with precipitation because this area can see many inches of rain at one time. A standard sump and drainage system was used to manage the water on the site.

Client Information

Texas A&M University System is an owner that is similar to Penn State. They want a new science building in order to expand the size of the International University, and to diversify the curriculum and research capabilities of the campus. The building will house science faculty and students with classrooms, offices, research laboratories, and a planetarium. The office of the dean will also be located in the tower of this building.

Texas A&M is a public university and is therefore especially concerned with the cost of constructing the science building. They want a high quality, durable building that will last a long time and is easily maintained. The university wants to keep construction accidents to a minimum. The construction site is completely fenced in, and all gates are kept locked at all times. The schedule was made so that many of the construction activities occur during the summer months.

The entire building, with the exception of the interior of the planetarium, is scheduled to be completed December 2004, in time for the spring semester. The equipment for the planetarium is being supplied and installed by the university, and is expected to be completed in March 2005.

Most important to the university is to complete the project for the spring semester. They also want to incur as few change orders as possible, to prevent any further costs. The science building is designed to reflect the other buildings on campus. Success in this area is imperative, because the general contractor wants to be able to work with Texas A&M University System again in the future.

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Estimate Summary

The New Science Building is scheduled to have a building construction cost of $14,911,209 and a construction cost per square foot of $186.39. This cost only includes direct costs, and does not include site work. The total project cost is $17,033,054, which includes all construction costs, fees, and general conditions. The total cost per square foot is $212.91.

The major building systems costs include the Electrical, Mechanical, Plumbing, and Laboratory Equipment (including fume sump), and are as follows:

	Cost	Cost/SF
Electrical	$1,252,000	$15.65
Mechanical	$3,000,000	$37.50
Plumbing	$950,000	$11.88
Lab Equip.	$1,043,000	$13.04

A D4 cost estimate was performed for comparison to the actual cost. D4 estimated a total building cost of $20,593,548 ($15,364,065 without general conditions and site work) and $257.42 per square foot for a similar 3 story, 80,000 square foot educational building located in Laredo, TX, with a masonry veneer, metal stud/drywall walls, built-up roof, and terrazzo flooring.

The D4 estimate is about $452,856 more than the actual cost, when compared without general conditions and site work. This estimate is close to the actual estimate because it considered the building envelope, foundation, and number of floors. Comparing the actual cost to the D4 estimate reveals that the cost of the science building is similar to that of other educational buildings in the Laredo, TX area. See Appendix A for the Estimate Summary.

Summary Schedule

The construction schedule is set up with the North Building, South Building, Planetarium, and Central Plant scheduled separately. However, these separate sections are not necessarily phased. The North and South Buildings begin all phases at essentially the same time, with a small lead (about 2 days) for the North Building.

The Planetarium is scheduled to begin its structure at the same time as the north and south buildings, but because of the complexity and uniqueness of the design, the structure has a much longer duration. The interior also has a much longer duration than the other buildings.

The Central Plant has a schedule that is independent of the science building; however the structure is scheduled at about the same time as the science building.

The foundation is scheduled as part of the super-structure because it only consists of drilled piers with a mud slab, and is only allotted about 3 weeks to complete. The entire structure of the north and south buildings and the Central Plant is concrete, while the structure is steel with a concrete base for the planetarium. This allows the schedule to keep all of the buildings in the same phases more easily because there are two subcontractors able to work on the structure at the same time.

All of the buildings are scheduled to be completed in December 2004 by the General Contractor. The interior of the Planetarium will be completed by the Owner in March 2005, because of the special equipment required. See Appendix A for the Summary Schedule.

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4D Model Analysis

Introduction

4D models can be useful either as alternatives to CPM networks and bar charts, or as supplements to these schedules. People can more easily understand the project schedule and identify potential problems. Inconsistencies in level of detail of activities, impossible sequences, and incompleteness of the schedule can all be more easily identified when a 4D model is used.

While 4D model interfaces are not yet where they need to be, they still carry invaluable assets that otherwise cannot be utilized. 4D models are still being generated by creating the 3D model and schedule in separate programs, and then combining them in a third program. A 4D model interface needs to include bar charts, component lists, and annotation tools so that models can quickly and efficiently be created and modified to display multiple levels of detail and alternative scenarios.

A 4D model of the structure of the Science Building was created in order to learn the benefits of using such technology by examining the model to understand the valuable information that can be understood with a model, rather than with only the schedule.

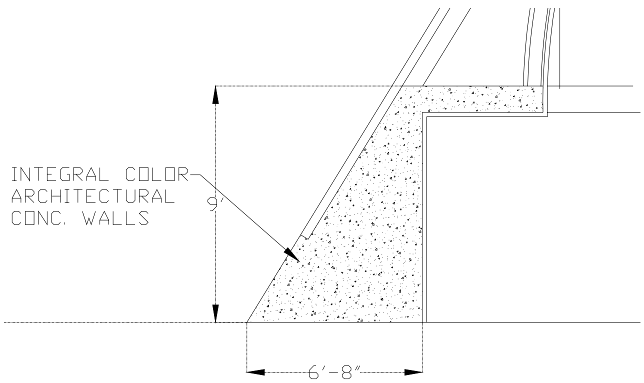
The schedule for the science building is quite confusing. The schedule obtained from the General Contractor on the project is split into building sections (north building, south building, and planetarium), and within each building section, the schedule is further broken down into construction phase (structure, exterior, interior, etc.). This schedule structure was hard to read and interpret, and was especially difficult in trying to relate activities between building sections.

Creating the 3D Model using AutoDesk Revit

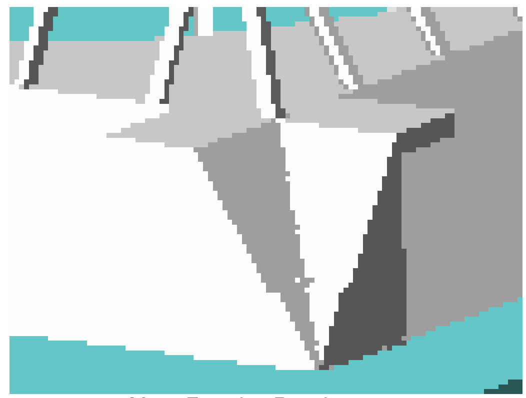
Autodesk Revit 7.0 was used as the 3D modeling program for this project. Revit 7.0 does not work well with a 4D model interface, but allows phasing within Revit to visualize the building process. However, phasing is not the equivalent of 4D modeling because there is no time reference. Essentially, the phasing function in Revit works to layout on different sheets the appearance of the order of the construction process without reference to time. Therefore, after creating the model in Revit, it had to be exported into AutoCAD 2005, where the model could then be transferred into Common Point 4D, the 4D model interface.

Revit is an exceptional program for modeling. It is a parametric modeling tool that allows the user to draw a building using actual building elements, instead of creating shapes that represent building elements like most other CAD programs. This type of program is great in most cases, except where unique design elements are present. For instance, with the planetarium, the concrete base, structural steel dome, and structural steel pyramid all had to be created using the massing function. Curved or angled structural elements could not be created

using the standard structure commands. While massing worked quite well for creating the planetarium elements, the process was very time consuming, and editing those elements after they were created was difficult and often impossible. For example, when creating the concrete base, where the corners are supposed to be horizontal, the program would only create them vertically and not allow editing.



Intended Representation in Model


Mass Function Results

Creating the 4D Model with Common Point 4D

In order to be able to export the model into Common Point 4D to combine it with the schedule, the model had to first be exported from Revit into AutoCAD 2004 format. Within AutoCAD, the building elements that corresponded to the schedule items needed to be put into different layers so that when exported into Common Point the model could be exported by layers, and the elements would remain separate. This task also proved to be difficult and time consuming. When a model is exported from Revit into AutoCAD, the building elements are no longer single entities, but rather combinations of faces. Instead a having a single box in Revit, for instance, there are six rectangles representing a box in AutoCAD.

Also, when the model was exported into AutoCAD, the level of detail, like surface texture, that was available within Revit was lost, as well as some building elements all together. Certain elements shifted and became invisible because they were covered by another element, such as the first floor being covering by the topography. Layer properties, such as color, were also difficult, if not impossible, to change. These errors and omissions did not contribute to the results of this analysis, because the level of detail of the elements was not important.

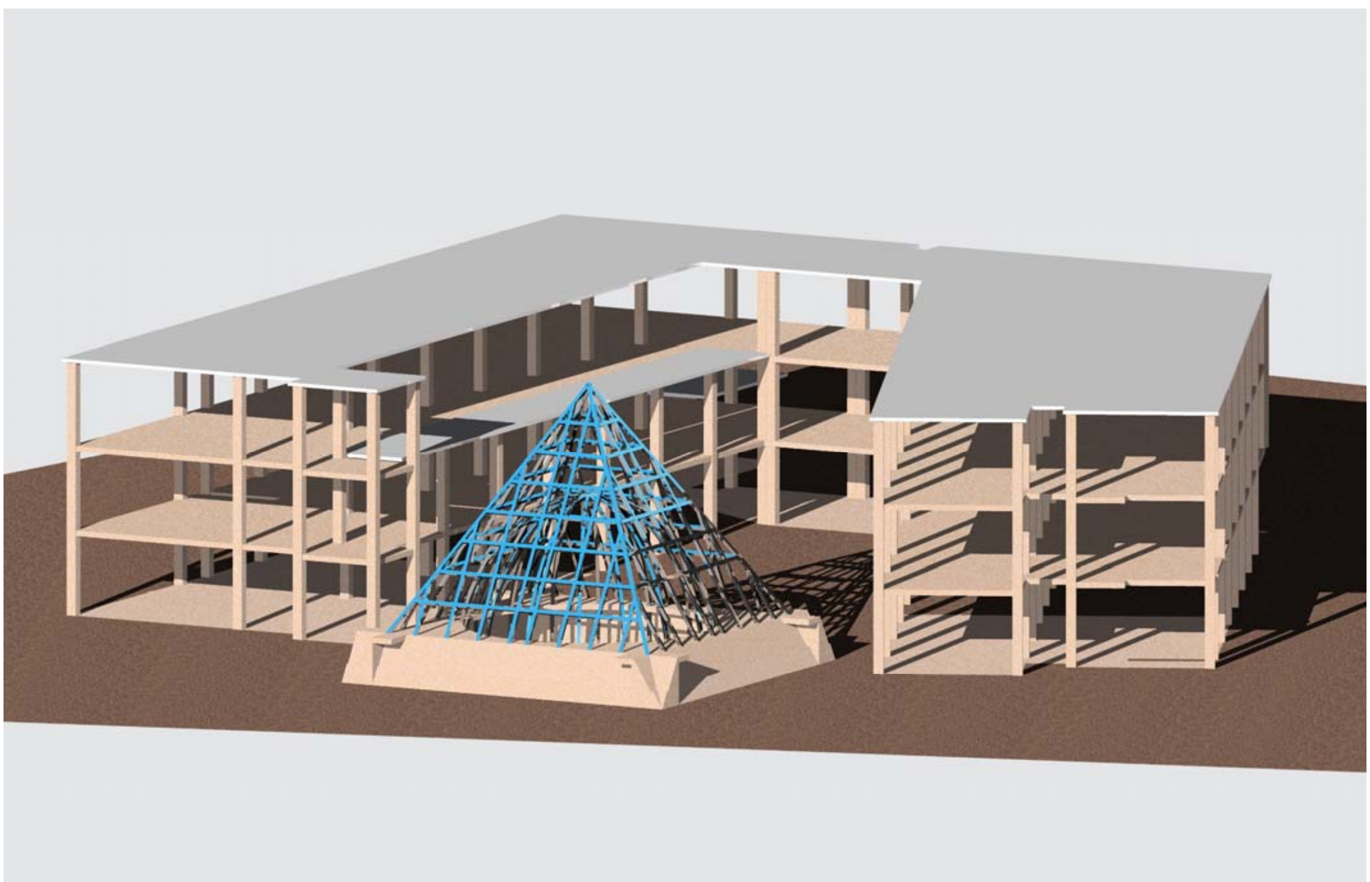
Once all of the elements had been placed in their proper layers, the model was exported from AutoCAD into Common Point 4D. Within Common Point 4D, the schedule was recreated.

This was done because in order for Common Point to correlate items from a schedule imported from Microsoft Project or Primavera, the names of the model layers must correlate to the names of the schedule items. This was not the case. See Appendix B for a Primavera version of the structural schedule recreated in Common Point 4D.

After the schedule was completed, the model layers and schedule items were combined to form the 4D model. This is the simplest part of the entire process. The 4D model can then be viewed directly from Common Point 4D, or an AVI file can be created to be played in a media player such as Windows Media Player.

Results

Below are the resulting images of each program used.



AutoDesk Revit 7.0 Rendering

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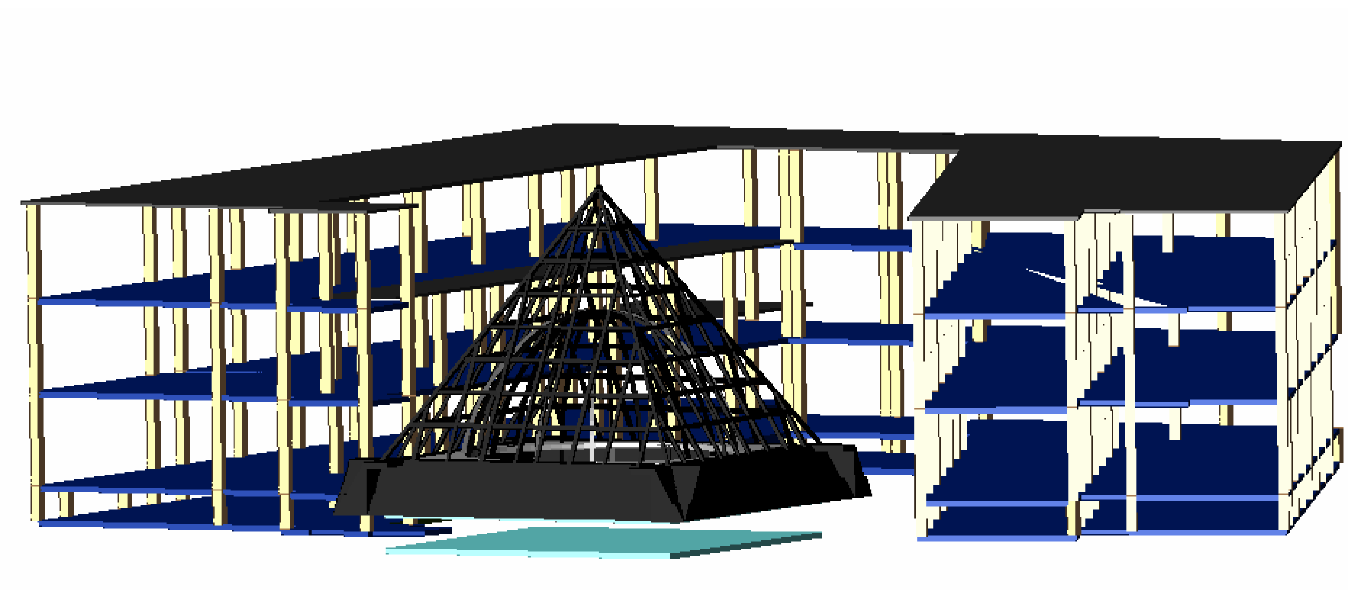
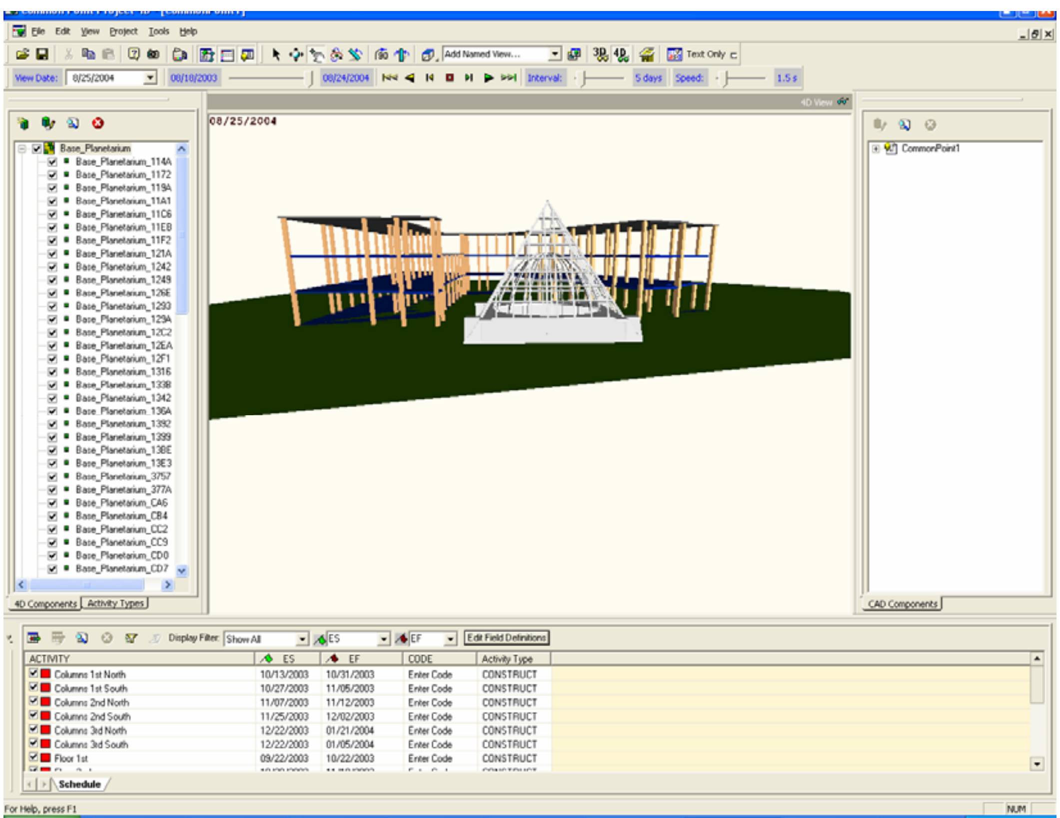


AutoCAD 2004 3D Model



Common Point Project 4D User Inferface

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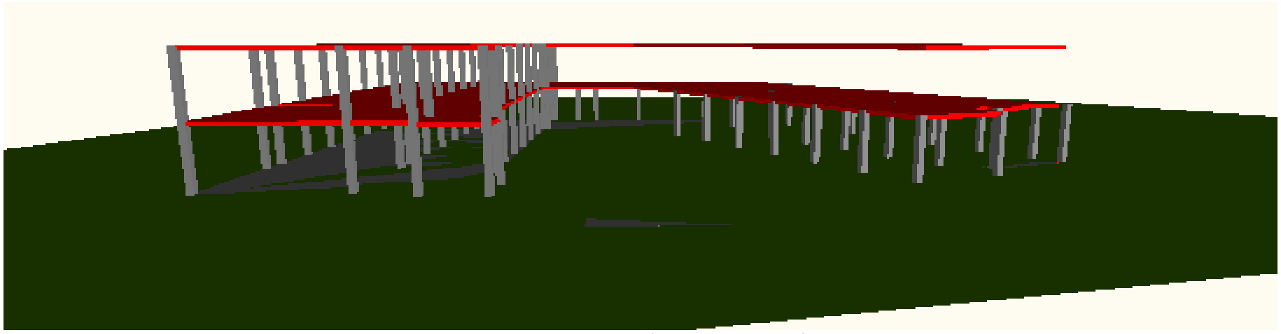
Errors

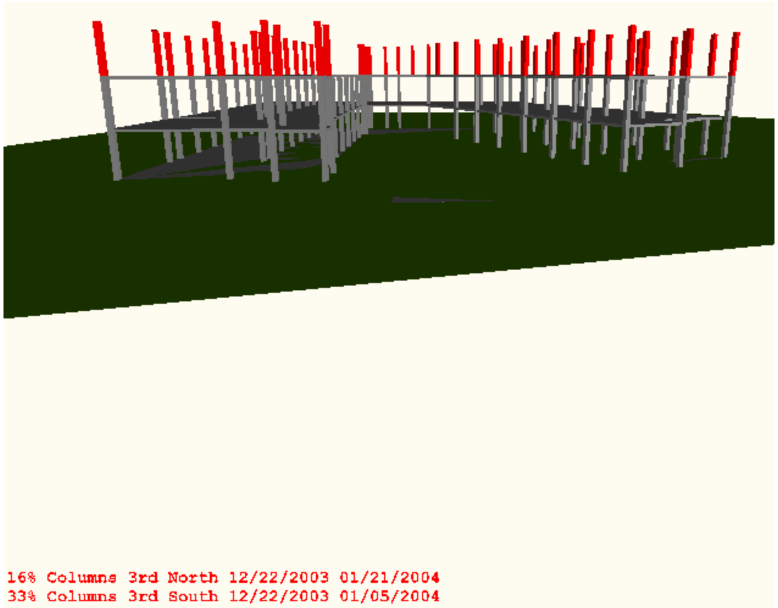
While viewing the completed 4D model, it became apparent that many sequencing and/or level of detail errors had occurred. To be sure that the were no errors conducted during programming, the original schedule created by the General Contractor was compared to the schedule created in Common Point. Upon concluding that there were no errors in transferring schedule data, it was determined that these errors occurred during the creation of the original schedule and that a 4D model may have in fact been useful during the planning of this project.

Each floor of the building is scheduled as a single unit. However, the columns for each floor are divided by North and South building sections. Therefore, the 4D model displays the construction of the 3rd floor before the 2nd floor columns of the South building are complete. This is a level of detail error.



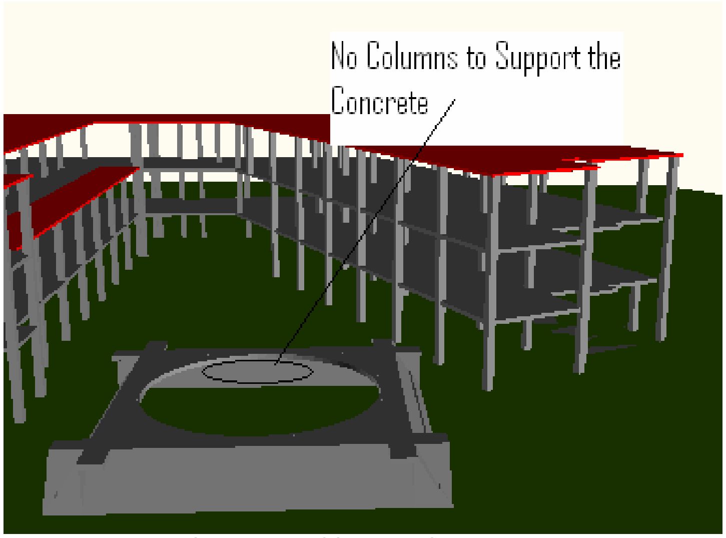
4D Model Displays Level of Detail Error in Schedule

As stated earlier, the columns for each floor are divided by North and South building sections. The North building columns are formed and poured prior to the South building columns, with exception to the third floor. This inconsistency in sequence could be a problem regarding project resources.



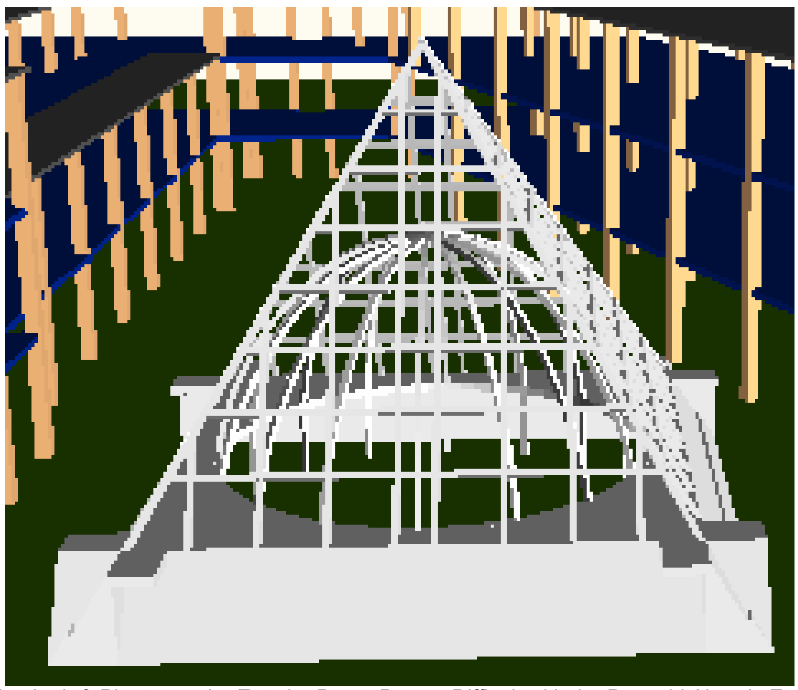
All 3rd Floor Columns Start on 12/22/2003 which is Inconsistent with the Sequence of Columns on Other Floors

The columns that support the upper horizontal portion of the concrete base for the planetarium are scheduled to be erected following the placement of the concrete, creating a sequencing problem that could lead to structural issues.



Improper Sequencing of Structure Could Lead to Failure

The structural dome for the pyramid is covered with lath and plaster that will receive a reflective color-changing metallic paint. The structural steel pyramid was erected around the dome prior to the dome receiving the lath and plaster. This could make installation of the lath, plaster, and paint to the dome very difficult, resulting in schedule delays.



Placing Lath & Plaster on the Exterior Dome Proves Difficult with the Pyramid Already Erected

Conclusion

Even though 4D modeling has a long way to go in user friendliness and compatibility with related programs, strides are being taken by software manufacturers to correct these problems. 4D modeling is a tool that is being used more and more in the construction industry, and eventually will become a construction staple, similar to scheduling and estimating programs such as Primavera, Microsoft Project, Lotus, and Timberline.

4D models can be an invaluable asset for the construction of large projects, especially for those with unique construction. Inaccuracies in the schedule may not be visible without the visual aid of a model. The initial costs associated with creating a 4D model are easily justified by time and money that will be saved from discovering potential construction problems before they occur.

In addition to 4D modeling, it is important to create and implement a phasing plan that outlines the direction of work through the building for all construction. This plan can help to

guide the construction sequence when it may be vague within the schedule. For example, to be sure that all columns at the connection between the north and south building sections will be in place so that the following floor can be poured, special attention needs to be given to this area both in the schedule and in a phasing plan.

Creating a more cohesive schedule and the use of a 4D model on this project could have saved a large amount of time on the project by identifying problem areas that were not acknowledged until that point in construction was reached. For instance, erection of the steel pyramid would not have proceeded until the installation of the dome façade if the construction team had been able to accurately visualize the difficulties associated with working around and through the pyramid's steel web.

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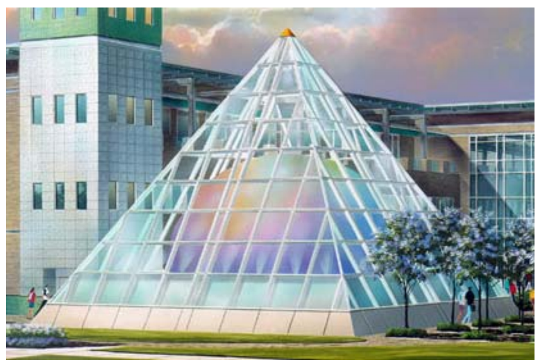
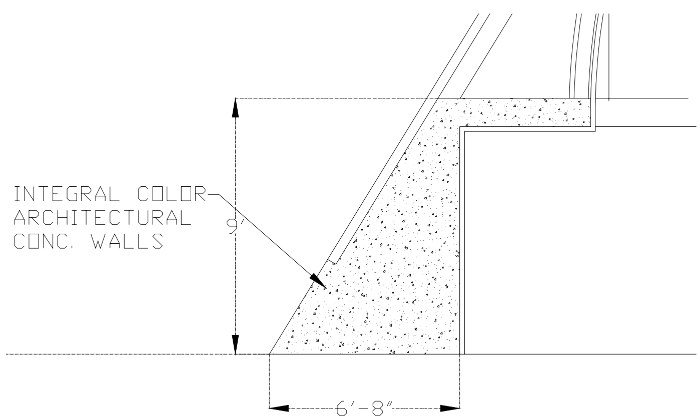
Planetarium Concrete - Structural & Construction Feasibility Analysis

Introduction

The New Science Building at Texas A&M International University in Laredo, Texas features a planetarium that is constructed of an architectural concrete structural base, a steel structural dome, and a four-sided glass pyramid that serves as the outermost protective envelope. The planetarium itself is housed within the dome. All four sides of the planetarium are symmetrical.



The architectural concrete supports the steel structure of the planetarium, and also acts as an integral part of the architectural feature. The base stands 9'-0" above the ground, and is 6'-8" thick at the bottom. The exterior façade of the base is angled to match the angled form of the glass pyramid. (To view the entire section of the planetarium, see Appendix C)



Because the erection of the steel for both the dome and the pyramid was difficult and required extremely small tolerances for proper installation, coordination between the concrete contractor and the steel erector was extremely important. However, little attention was given to this important issue, and in the end it delayed the schedule because the steel erector needed

much more time than expected to erect. The tolerances for the horizontal face of the concrete that the steel was supported by were less stringent than those needed for the steel. This was overlooked due to the lack of coordination prior to the creation of shop drawings.

Project Difficulties

The architectural concrete was designed to be an as-cast structure with a smooth finish. It was expected that after the formwork was removed there would be no need for further work to the exterior exposed concrete. However, after the formwork was removed, it became evident that those expectations were not achieved. The integral color was not uniform throughout the façade of the concrete, and the locations of the formwork seams were also visible.

Upon review of the concrete condition by the architect and owner, it was determined that the finish was unacceptable, and that spot repairs would not be cost effective. The decision was then made to repair the finish by applying grout to the entire exterior of the architectural concrete façade. This process would be very difficult and time consuming, due to the uniformity that both the architect and owner expected throughout.

Concrete Specifications

In order to determine whether or not there may have been any discrepancies regarding the design criteria for the architectural concrete, formwork, or installation of the concrete, the project specifications were compared to standard specifications provided by ACI (American Concrete Institute).

Standard Specifications

The Standard Specification for Cast-In-Place Architectural Concrete (ACI 303.1-97) provides specification guidelines acceptable for the design and installation of architectural concrete. Also utilized was the Specification for Structural Concrete (ACI 301-99), which goes into further detail regarding the structural aspect of the concrete, and is referenced many times within the Standard Specification for Cast-In-Place Architectural Concrete.

According to these specifications, for colored concrete, trial batches of the final design mix should be prepared with specified slump at the highest and lowest ambient temperatures anticipated during construction. This was not specified in the contract documents, and was not performed for the project.

Project Specifications

The project specifications provide information in more detail than the standard specifications, and also specify material types and manufacturers approved to be used for this project. All specifications for this project meet the requirements in the ACI standard specifications. However, of special interest are the materials specified for use, particularly the formwork, and the conditions of placement of the architectural concrete.

The architectural concrete finish for the project is specified as colored slick as-cast architectural concrete finish. Portland cement was specified as ASTM C 150, Type I or III light gray-butt cement, and aggregates were 3/4" maximum for course aggregate and clean local Medina River concrete sand for fine aggregate. Water-reducing and/or retarding agents (ASTM C494, Type A, Type D) was required, as well as a form release agent. Fly ash was not permitted.

The project specifications indicate the use of "slick as-cast colored concrete finish-smooth plastic laminate faced forms." The specific form type was "B-B plyform class 1" with high-pressure laminate, GP-50 (0.050" thick), Formica "lacquer" finish, shop fabricated. Form ties were to eliminated as much as possible. Cresset Chemical Company's "Crete-Lease 880" form release agent was also specified.

Mockups and pre-installation meetings were specified, however, due to time constraints, these items were not utilized, which likely contributed to the failure to achieve the expected finish. Instead, small samples of both the formwork and the architectural concrete were submitted. These samples did not accurately portray the imperfections that could occur on a significantly larger mass.

The architectural concrete was placed in mid-July, which in Southern Texas is extremely hot. This area of Texas is also a desert, which results in large temperature drops at night. This could affect the slump of the concrete as well as the finish. Because of the high temperatures, water can quickly evaporate from the concrete mixture, which in turn could alter the properties, including the color and texture of the cured concrete. If the formwork and rebar were not cooled prior to the placement of the concrete, there could have been differential heating and cooling throughout the concrete; this could also contribute to alterations in color and texture and also produce lift lines.

The formwork was specified to be well sealed at all joints using a silicone sealant and backup material to prevent leakage and fins. It was fairly evident that this was not done properly because the edges of the forms can be seen on the concrete finish.

Formwork Types

The architectural concrete was formed using conventional formwork. Conventional forms are most often used for frames and retaining walls, require hand-stripping (no cranes required), and create an as-cast concrete finish when used alone. They can be reused up to ten times. This type of system is more efficient in areas of high quality, low cost labor forces, because while the system itself is simple, it is important that it is constructed properly to ensure that the forms do not bust when applied with the concrete load and to maintain a high quality concrete product.

Form release agents are necessary to easily remove formwork from the concrete face without the need to pry or force the form from the concrete. It is important to choose an agent that will not react with the architectural concrete, and will not affect the appearance of the finish. The form release agent for this project did not contribute to the poor quality of the concrete finish.

As-cast concrete finishes typically show irregularity and usually contain surface defects. These finishes are usually used where appearance is not a factor, such as in warehouses. Architectural concrete requires careful selection of formwork that includes stiffer form liners, tighter joints, smoother finishes, and more care in implementing chamfers and rustications.

Upon inspection of different formwork types, it became clear that conventional formwork was the best choice for this project, considering its limited height and number of uses necessary for the forms. However, the smooth plastic laminate finish did not create the expected finish and therefore needs reconsideration.

Conclusion

The outcome of the finish of the architectural concrete for the planetarium could have been different if certain considerations were taken into account.

Fly ash is derived from burning coal, and is a valuable additive that makes concrete stronger, more durable and easier to work with. In making concrete, cement is mixed with water to create the “glue” that holds strong aggregates together. Fly ash works in tandem with cement in the production of concrete products. Concrete containing fly ash is easier to work with because the tiny glassy beads create a lubricating effect that causes concrete to flow and pump better, to fill forms more completely, and to use up to 10 percent less water. Because the tiny fly ash particles fill microscopic spaces in the concrete, and because less water is required, concrete using fly ash is denser and more durable. Fly ash also reacts chemically with lime that is given off by cement hydration, creating more of the glue that holds concrete together. That makes concrete containing fly ash stronger than concrete made only with cement. Fly ash is also a cost-effective resource. When fly ash is added to concrete, the amount of cement that is necessary can be reduced.

The use of fly ash in the architectural concrete could have improved the quality of the color and the finish by creating a mixture that was easier to work with in large quantities. The number of visible voids at the surface of the concrete could have also improved the quality of the finish. Fly ash requires less water for the concrete mix, but still increases the workability, so it might have been an advantage to use fly ash to combat the difficulties with pouring concrete in high temperatures.

A wide variety of environmental circumstances are deleterious to concrete, such as reactive aggregate, high sulfate soils, freeze-thaw conditions, and exposure to salt water, deicing chemicals, and acids. Laboratory research and field experience shows that careful use of fly ash is enormously useful in countering all of these problems. Texas rainfall is quite acidic, so the use of fly ash could also serve to protect the concrete from acid assault.

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Marina City in Chicago, IL is an Architectural Concrete Structure Made Using Fly Ash

The Sears Tower and River City are Buildings Constructed with Fly Ash

The finish was specified to be smooth as-cast with no working after the removal of formwork. This is an extremely difficult goal to achieve for a large mass of concrete. Many pieces were required for the formwork, which increased the number of joints, and thus the number of possible repairs needed to eliminate seepage lines. Also, a smooth finish makes all imperfections more visible. A textured finish, such as a fine sandblast, as shown below, could reduce the number of visible imperfections without compromising the intended vision of the structure.

Sandblast #1 Fine

[redacted]

Photo courtesy of www.symons.com

A mockup of a large mass of architectural concrete cast on a hot day in the summer could have brought to light any potential problems that might arise due to the temperature, finish, formwork type, and admixtures.

The formwork was specified as smooth plastic laminated plywood shored externally, with no ties. Because of the large mass of concrete with in the formwork, shoring the concrete was necessary, but supplementing the shoring with internal ties would reduce the amount of deformation of the forms, and reduce the amount of leakage at the joints. Ties were not used due to the appearance of the holes left behind at the surface of the concrete, which would require undesired repair. However, fiberglass ties could be used instead. These ties are made to match the color and texture of the concrete, and after removal of the forms, the ties are cut to the surface of the concrete, making them invisible.

The smooth plastic laminated plywood could be changed to a plywood form with a plastic liner. The liners come in many textures (as seen above) and are reusable up to 100 times depending on liner material. One-use liners are extremely inexpensive and five-use liners are comparable in price to that of using the plastic laminated forms as discussed above.

Coordination between the concrete contractor and the steel erector is vital to construction as intricate as the planetarium. Before the creation of the shop drawings for each contractor, coordination meetings need to occur, both organized and facilitated by the construction manager, to eliminate any potential problems that may arise from something as simple as tolerance differences.

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Recommendations:

1. Use plywood formwork with a textured plastic liner in lieu of smooth plastic laminated plywood. Use a form release agent that will not affect the appearance of the concrete finish.

2. In addition to the use of shoring, provide fiberglass ties to support the mass of concrete and reduce the amount of leakage between forms. Ensure that all form joints are properly sealed to prevent leakage.

3. Consider the use of fly ash in the design of the architectural concrete. Fly ash contains properties that may help resolve the problems encountered.

4. Be sure that any additives, such as water reducing agents and curing compounds, will not alter the finished appearance of the concrete.

5. Provide a large-mass mockup of the architectural concrete using same materials and methods of placement to ensure the quality of the final product. Be sure to pour the concrete for the mockup at the same temperature as is expected for the actual pour.

6. Maintain similar temperatures for concrete, rebar, formwork, and any other affected materials at all times when concrete is being poured to eliminate color and texture variations and lift lines.

7. Coordinate all interested parties, particularly the concrete contractor and steel erector, before the production of shop drawings, to ensure that all parties are aware of others' requirements for construction so that delays and additional costs can be avoided.

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Planetarium Acoustical Analysis

Introduction

During the construction of the planetarium, the owner's representative had concerns regarding the echo that he heard whenever he entered the planetarium. He was extremely uncertain about the outcome of the space, and was in need of some assurance that the echoes would be gone when the planetarium was finished.

For a long time during construction, the planetarium consisted mostly of hard surfaces, included lath and plaster for the surface of the dome, concrete floors, and gypsum board covered metal stud walls. Because of this the echo heard in the room was substantially greater than would be heard after the finishes were in and the seats were filled with students.

The planetarium is a domed structure, and therefore can reverberate more than usual because the shape allows for more deflections of sound. Concave ceiling and wall surfaces often require treatment to prevent annoying sound reflections which reduce intelligibility of direct sound, such as what the owner heard. Sound energy can be concentrated in certain areas (focusing is more noticeable for low frequencies because most materials are less sound absorbing at those frequencies) or reflected along smooth concave surfaces (creep echo).

The planetarium was designed with a sound-transparent liner for the sky images to be projected on. This allows sound to transmit through the screen and be reflected or absorbed by the material behind it (in this case, gypsum board).

The planetarium space is planned for use both as a classroom/lecture hall and as a cinema for films concerning astrology. The owner was most concerned that during lectures any other noises would be easily heard and accentuated, and that during films the audio would be hard to understand because the echoes he heard were so long. A reverberation time analysis would have been beneficial to assure the owner that the acoustical quality of the planetarium would be acceptable.

On the outside corners of the structure, on the other side of the hallway that runs around the perimeter of the planetarium, are three mechanical rooms that serve the planetarium mechanically and electrically, and also provide audio visual systems. The owner was also concerned that the noise from these rooms would be easily heard through the mechanical room walls, the hallway, and the walls to the planetarium. A sound transmission class rating of the mechanical room walls would be able to alleviate any concerns regarding the noise that would be audible in the planetarium.

Acoustical Analysis

Reverberation Time

Reverberation time is the time required for the sound level in the room to decay 60 dB, or in other words, it is the time needed for a loud sound to be inaudible after turning off the sound source.

The calculation of reverberation time using the Sabine equation assumes that the sound in the room be diffused. In practice, reverberation time equations are good enough to describe the sound build up and attenuation in the room. The optimum reverberation time for different rooms depends on the volume of the space, the type of the room, and the frequency of the sound. In general terms, the optimum reverberation time for rooms with speech programs is less then the optimum reverberation time for rooms with music performance.

The sound absorption coefficient describes the efficiency of the material or the surface to absorb the sound. The ratio of the absorbed sound energy to the incident energy is the sound absorption coefficient. For architectural purposes, sound absorbing materials and constructions can be divided into four types of materials depending on the way the absorption is mainly performed: Turning the sound energy into heat such as fiberglass and carpet, vibrating with a specific frequency when the sound hits the surface such as lightweight panels and 5/8" gypsum board (These materials absorb the sound effectively on a narrow band of frequencies), turning the sound energy into heat in the neck of the cavities such as sound blocks (This construction has a good absorption on low frequencies), and allowing the sound to go through such as some types of grid systems and lay-in ceiling with sound leakage above it.

The most common way to measure sound absorption coefficient is to lay a piece of the material in a reverberant room (a room which has very long reverberation time) then measure the RT so the coefficient can be derived from Sabin equation (the original version of RT calculation). There is a standard that details this procedure. The value of the coefficient for the same material varies with the type of the mounting in the test room.

A reverberation time calculation was performed to determine the adequacy of the finish materials in the planetarium to absorb or reflect sound. Because the space is intended to be used as both a lecture hall and a cinema, the optimum reverberation time was determined to be between 0.7 seconds and 1.2 seconds at 500 Hz. The midpoint of that range, 0.95 seconds was used to maintain an appropriate time for both usage types. From that information optimum reverberation times were determined for both high and low frequencies (1.24 seconds at 125 Hz and 0.76 seconds at 4000 Hz).

From these reverberation time values, optimum sabin values could be found through the equation a = 0.05V/t where V is the volume of the space and t is the optimum reverberation time that was found above.

The actual sabin values for the planetarium space were determined next by calculating the surface area of each material used within the space to include walls, the domed roof, floor, seats, and audience. The walls are designed to be covered entirely with sound absorbing acoustical panels, the dome will be covered with gypsum board, the floor will be carpeted, and the seats will be upholstered. The sound absorption coefficients of each material were multiplied with each respective surface area to determine the sabin value. The values were next summed to produce an overall sabin value at each frequency (125 Hz, 500 Hz, and 4000 Hz).

The calculated sabin values were similar to the optimum values, and the corresponding reverberation times were 1.3 seconds at 125 Hz, 0.95 seconds at 500 Hz, and 0.80 Hz at 4000 Hz. The expected reverberation times match the optimum times extremely closely. This concludes that the planetarium space will perform as required for both a lecture hall and a cinema (See Appendix D for calculations).

Sound Transmission Class Rating

Sound transmission class (STC) is a single number used to characterize the air-borne isolation properties of a partition. The STC is determined from the measured TL of a partition at different frequencies. These measured values are then compared with standardized STC contours.

A transmission loss calculation was performed to determine the ability of the walls of the mechanical rooms to prevent sound from entering the planetarium space. The mechanical room walls are constructed of metal studs with 3" acoustical batt insulation between the studs and two layers of 5/8" gypsum board on each side of the studs. Each room has one flush solid core wood door with a hollow metal frame.

To calculate the transmission loss, the transmission loss values for each material were used to calculate the composite transmission loss of the entire wall. Composite transmission loss is calculated from TL = 10 log ∑S/∑tS where S is the surface area of the material and t is the sound transmission coefficient of the material.

The composite transmission loss of the wall for rooms 101C and 101F was 40 dB and 41 dB for room 101E at 500 Hz. TL values were obtained for 6 frequencies in order to create a curve to obtain an STC rating. The transmission loss calculations can then be transferred to a sound transmission class graph where the curve for these values can be compared to a standard STC curve. A high STC rating means better the sound insulation of the wall. The STC rating for all three rooms is 42, which is very good. Sound

penetration from the mechanical rooms into the planetarium space will not be an issue (See Appendix D for calculations).

Conclusion

Despite the owner's concerns for the acoustical quality of the planetarium, the space will be acoustically adequate for its intended purposes. In fact, the space is extremely close to its optimal performance. The owner can be assured that when the space is completed, there will be no noticeable echo when the room has an audience, and little, if any, mechanical room noise will transfer into the planetarium space. No revisions need to be implemented into the design.

Conclusions

4D Model Analysis

Even though 4D modeling has a long way to go in user friendliness and compatibility with related programs, strides are being taken by software manufacturers to correct these problems. 4D modeling is a tool that is being used more and more in the construction industry, and eventually will become a construction staple, similar to scheduling and estimating programs such as Primavera, Microsoft Project, Lotus, and Timberline.

4D models can be an invaluable asset for the construction of large projects, especially for those with unique construction. Inaccuracies in the schedule may not be visible without the visual aid of a model. The initial costs associated with creating a 4D model are easily justified by time and money that will be saved from discovering potential construction problems before they occur.

In addition to 4D modeling, it is important to create and implement a phasing plan that outlines the direction of work through the building for all construction. This plan can help to guide the construction sequence when it may be vague within the schedule. For example, to be sure that all columns at the connection between the north and south building sections will be in place so that the following floor can be poured, special attention needs to be given to this area both in the schedule and in a phasing plan.

Creating a more cohesive schedule and the use of a 4D model on this project could have saved a large amount of time on the project by identifying problem areas that were not acknowledged until that point in construction was reached. For instance, erection of the steel pyramid would not have proceeded until the installation of the dome façade if the construction team had been able to accurately visualize the difficulties associated with working around and through the pyramid's steel web.

Planetarium Concrete - Structural & Construction Feasibility Analysis

The outcome of the finish of the architectural concrete for the planetarium could have been different if certain considerations were taken into account.

Fly ash is derived from burning coal, and is a valuable additive that makes concrete stronger, more durable and easier to work with. In making concrete, cement is mixed with water to create the "glue" that holds strong aggregates together. Fly ash works in tandem with cement in the production of concrete products. Concrete containing fly ash is easier to work with because the tiny glassy beads create a lubricating effect that causes concrete to flow and pump better, to fill forms more completely, and to use up to 10 percent less water. Because the tiny fly ash particles fill microscopic spaces in the

concrete, and because less water is required, concrete using fly ash is denser and more durable. Fly ash also reacts chemically with lime that is given off by cement hydration, creating more of the glue that holds concrete together. That makes concrete containing fly ash stronger than concrete made only with cement. Fly ash is also a cost-effective resource. When fly ash is added to concrete, the amount of cement that is necessary can be reduced.

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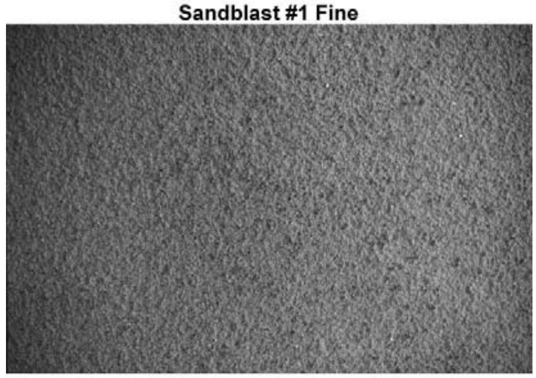
Marina City in Chicago, IL is an Architectural Concrete Structure Made Using Fly Ash

The Sears Tower and River City are Buildings Constructed with Fly Ash

The finish was specified to be smooth as-cast with no working after the removal of formwork. This is an extremely difficult goal to achieve for a large mass of concrete. Many pieces were required for the formwork, which increased the number of joints, and thus the number of possible repairs needed to eliminate seepage lines. Also, a smooth finish makes all imperfections more visible. A textured finish, such as a fine sandblast, as shown below, could reduce the number of visible imperfections without compromising the intended vision of the structure.

Sandblast #1 Fine



[redacted]

Photo courtesy of www.symons.com

A mockup of a large mass of architectural concrete cast on a hot day in the summer could have brought to light any potential problems that might arise due to the temperature, finish, formwork type, and admixtures.

The formwork was specified as smooth plastic laminated plywood shored externally, with no ties. Because of the large mass of concrete with in the formwork, shoring the concrete was necessary, but supplementing the shoring with internal ties would reduce the amount of deformation of the forms, and reduce the amount of leakage at the joints. Ties were not used due to the appearance of the holes left behind at the surface of the concrete, which would require undesired repair. However, fiberglass ties could be used instead. These ties are made to match the color and texture of the concrete, and after removal of the forms, the ties are cut to the surface of the concrete, making them invisible.

The smooth plastic laminated plywood could be changed to a plywood form with a plastic liner. The liners come in many textures (as seen above) and are reusable up to 100 times depending on liner material. One-use liners are extremely inexpensive and five-use liners are comparable in price to that of using the plastic laminated forms as discussed above.

Coordination between the concrete contractor and the steel erector is vital to construction as intricate as the planetarium. Before the creation of the shop drawings for each contractor, coordination meetings need to occur, both organized and facilitated by the construction manager, to eliminate any potential problems that may arise from something as simple as tolerance differences.

Recommendations:

8. Use plywood formwork with a textured plastic liner in lieu of smooth plastic laminated plywood. Use a form release agent that will not affect the appearance of the concrete finish.

9. In addition to the use of shoring, provide fiberglass ties to support the mass of concrete and reduce the amount of leakage between forms. Ensure that all form joints are properly sealed to prevent leakage.

10. Consider the use of fly ash in the design of the architectural concrete. Fly ash contains properties that may help resolve the problems encountered.

11. Be sure that any additives, such as water reducing agents and curing compounds, will not alter the finished appearance of the concrete.

12. Provide a large-mass mockup of the architectural concrete using same materials and methods of placement to ensure the quality of the final product. Be sure to pour the concrete for the mockup at the same temperature as is expected for the actual pour.

13. Maintain similar temperatures for concrete, rebar, formwork, and any other affected materials at all times when concrete is being poured to eliminate color and texture variations and lift lines.

14. Coordinate all interested parties, particularly the concrete contractor and steel erector, before the production of shop drawings, to ensure that all parties are aware of others' requirements for construction so that delays and additional costs can be avoided.

Planetarium Acoustical Analysis

Despite the owner's concerns for the acoustical quality of the planetarium, the space will be acoustically adequate for its intended purposes. In fact, the space is extremely close to its optimal performance. The owner can be assured that when the space is completed, there will be no noticeable echo when the room has an audience, and little, if any, mechanical room noise will transfer into the planetarium space. No revisions need to be implemented into the design.

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Credits & Acknowledgements

I would like to thank the following people for their help in facilitating the successful completion of this thesis project:

Texas A&M International University

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Mark Wohlfarth, Constructors & Associates

Mark Harrington, Constructors & Associates

Louis Guirre, Constructors & Associates

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4D Model Analysis

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Planetarium Concrete – Structural & Construction Feasibility Analysis

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Planetarium Acoustical Analysis

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Appendix A

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Estimate of Probable Cost

New Science Building - Texas A&M In - Jan 2003 - TX - Laredo

Prepared By : Nicole Griffith
Prepared By Firm : Penn State

Building Sq. Size : 80000
Site Sq. Size : 6098

No. Of Buildings : 1
No. Of Floors : 3
Project Type : NEW
Building Use : Educational
Exterior Walls : Masonry/Brick/Bloc
Interior Walls : Metal Stud/Drywall
Foundation : Cast Pile
Roof Type : Built-up
Floor Type : Terrazzo

Building Costs

Code	Division Name	%	Sq. Cost	Projected
00	Bidding Requirements	0.00	0.00	0
	Bidding Requirements	0.00	0.00	0
01	General Requirements	9.47	24.38	1,950,318
	General Requirements	9.47	24.38	1,950,318
02	Site Work	15.92	40.99	3,279,165
	Site Work	15.92	40.99	3,279,165
03	Concrete	11.49	29.59	2,367,177
	Concrete	11.49	29.59	2,367,177
04	Masonry	3.80	9.79	783,147
	Masonry	3.80	9.79	783,147
05	Metals	3.68	9.47	757,823
	Metals	3.68	9.47	757,823
06	Wood & Plastics	6.57	16.92	1,353,817
	Wood & Plastics	6.57	16.92	1,353,817
07	Thermal & Moisture Protection	4.30	11.07	885,675
	Thermal & Moisture Protection	4.30	11.07	885,675
08	Doors & Windows	5.13	13.19	1,055,554

	Doors & Windows	5.13	13.19	1,055,554
09	Finishes	10.66	27.43	2,194,532
	Finishes	10.66	27.43	2,194,532
10	Specialties	1.17	3.01	241,023
	Specialties	1.17	3.01	241,023
11	Equipment	0.28	0.72	57,773
	Equipment	0.28	0.72	57,773
12	Furnishings	0.13	0.35	27,725
	Furnishings	0.13	0.35	27,725
13	Special Construction	0.00	0.00	0
	Special Construction	0.00	0.00	0
14	Conveying Systems	1.31	3.37	269,608
	Conveying Systems	1.31	3.37	269,608
15	Mechanical	12.21	31.43	2,514,672
	Mechanical	12.21	31.43	2,514,672
16	Electrical	13.87	35.69	2,855,540
	Electrical	13.87	35.69	2,855,540
	Total Building Costs	100.00	257.42	20,593,548

Site Costs

Code	Division Name	%	Sq. Cost	Projected
	Total Site Costs	100.00	0.00	0
	Total Project Costs	20,593,548		

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General Conditions Estimate

CSI Code	Expense	Budget	Rate	Cost/Month
	Labor Cost Summary			
21310	Superintendent	$276,788	$38.00/hr	$15,377
21320	Project Manager	$167,872	$43.00/hr	$9,326
21350	Field Engineer	$167,085	$38.00/hr	$9,283
21370	Field Admin	$72,360	$27.00/hr	$4,020
Labor Costs		**$684,105**		**$38,006**
	Field Expense Summary			
21411	Mobil/Demobil	$3,500		$195
21508	Temp Toilets	$4,750		$264
21511	Temp Elect	$34,000		$1,889
21512	Temp Water	$2,550		$142
21525	Tools/Sheds	$2,375		$132
21543	Safety Supplies	$7,455		$414
21580	Project Signs	$500		$28
21740	Laborers/Cleaning	$90,000		$5,000
21745	Trash Haul	$27,600		$1,533
21750	Final Cleaning	$12,150		$675
21830	Field Office Supplies	$8,900		$494
21831	Doc. Postage & Deliv.	$3,493		$194
21832	Blueprinting	$7,049		$392
21835	Field Comm	$44,330		$2,463
21860	Field Off. Equip. Lease	$10,000		$556
21870	Field Trailer Lease	$13,300		$739
21940	Travel/Ent/Conf Exp	$15,000		$833
21942	Mileage Exp	$3,419		$190
21943	Temp Housing	$96,475		$5,360
21999	Corp. Safety Alloc.	$17,033		$946
Field Expenses		**$403,879**		**$22,439**

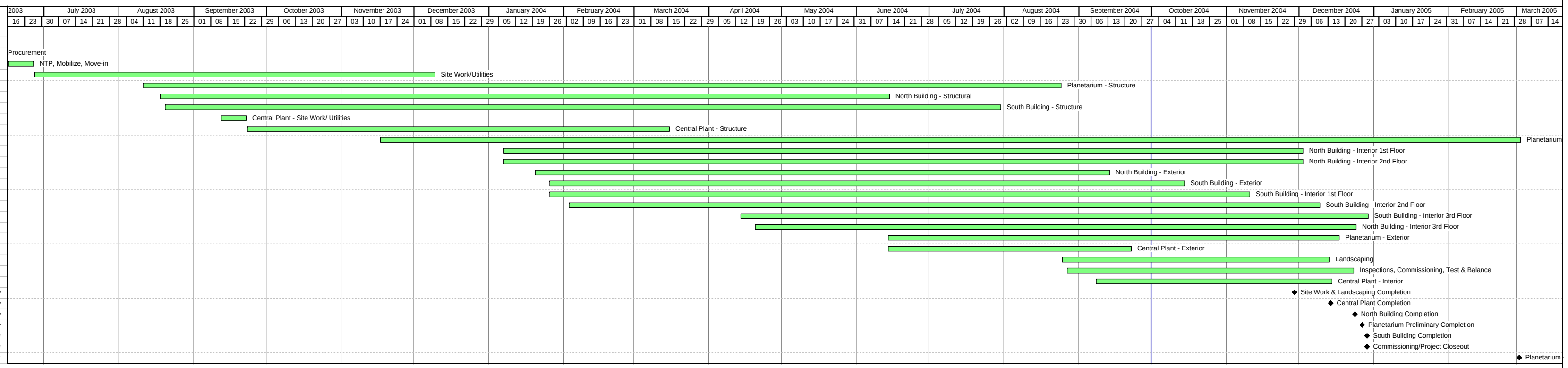
Total Cost to Complete	**$1,087,984**	**$60,445/Month**

The New Science Building - Texas A&M International University

Summary Schedule

07-Apr-05 16:18

Activity ID	Activity Name	Original Duration	Start	Finish
A1000	Design Phase	170	03-Jun-02	24-Jan-03
A1010	Bid Won	0	17-Mar-03	
A1011	Procurement	65	17-Mar-03	13-Jun-03
A1020	NTP, Mobilize, Move-in	9	16-Jun-03	26-Jun-03
A1030	Site Work/Utilities	118	27-Jun-03	09-Dec-03
A1150	Planetarium - Structure	272	11-Aug-03	24-Aug-04
A1050	North Building - Structural	216	18-Aug-03	14-Jun-04
A1100	South Building - Structure	248	20-Aug-03	30-Jul-04
A1190	Central Plant - Site Work/ Utilities	7	12-Sep-03	22-Sep-03
A1191	Central Plant - Structure	125	23-Sep-03	15-Mar-04
A1180	Planetarium - Interior	338	17-Nov-03	02-Mar-05
A1070	North Building - Interior 1st Floor	237	07-Jan-04	02-Dec-04
A1080	North Building - Interior 2nd Floor	237	07-Jan-04	02-Dec-04
A1060	North Building - Exterior	170	20-Jan-04	13-Sep-04
A1110	South Building - Exterior	189	26-Jan-04	14-Oct-04
A1120	South Building - Interior 1st Floor	208	26-Jan-04	10-Nov-04
A1130	South Building - Interior 2nd Floor	223	03-Feb-04	09-Dec-04
A1140	South Building - Interior 3rd Floor	186	14-Apr-04	29-Dec-04
A1090	North Building - Interior 3rd Floor	179	20-Apr-04	24-Dec-04
A1170	Planetarium - Exterior	135	14-Jun-04	17-Dec-04
A1200	Central Plant - Exterior	73	14-Jun-04	22-Sep-04
A1040	Landscaping	79	25-Aug-04	13-Dec-04
A1220	Inspections, Commissioning, Test ...	85	27-Aug-04	23-Dec-04
A1210	Central Plant - Interior	70	08-Sep-04	14-Dec-04
A1041	Site Work & Landscaping Completion	0		29-Nov-04*
A1211	Central Plant Completion	0		14-Dec-04*
A1091	North Building Completion	0		24-Dec-04*
A1181	Planetarium Preliminary Completion	0		27-Dec-04*
A1141	South Building Completion	0		29-Dec-04*
A1221	Commissioning/Project Closeout	0		29-Dec-04*
A1182	Planetarium - Owner's Completion	0		02-Mar-05*



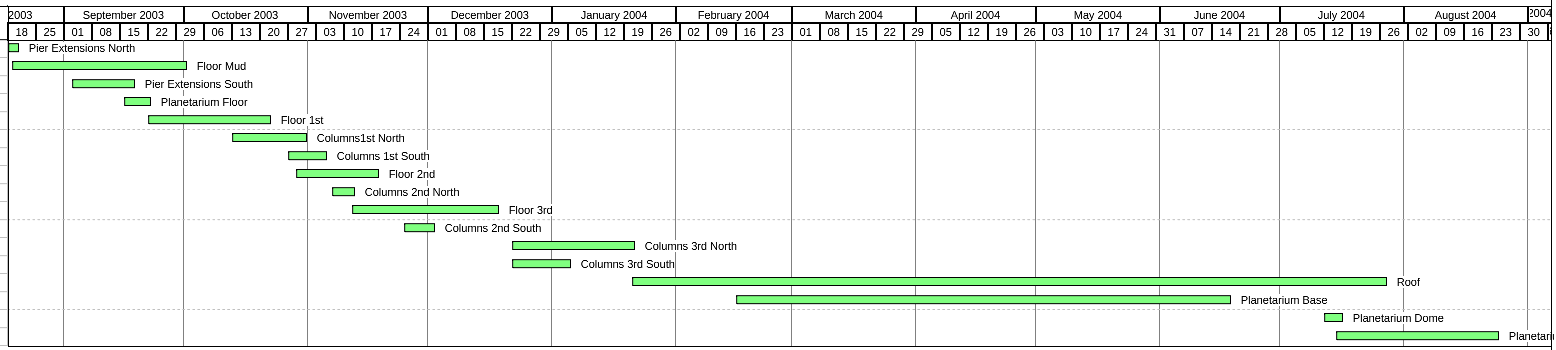
Actual Work
Remaining Work
Critical Remaining Work
Milestone
Summary

TASK filter: All Activities

Appendix B

Structure Schedule | TAMIU Science Building | Nicole Griffith

Activity ID	Activity Name	Original Duration	Start	Finish
A1000	Pier Extensions North	3	18-Aug-03	20-Aug-03
A1010	Floor Mud	32	19-Aug-03	01-Oct-03
A1100	Pier Extensions South	12	03-Sep-03	18-Sep-03
A1140	Planetarium Floor	5	16-Sep-03	22-Sep-03
A1020	Floor 1st	23	22-Sep-03	22-Oct-03
A1050	Columns1st North	15	13-Oct-03	31-Oct-03
A1110	Columns 1st South	8	27-Oct-03	05-Nov-03
A1040	Floor 2nd	15	29-Oct-03	18-Nov-03
A1060	Columns 2nd North	4	07-Nov-03	12-Nov-03
A1070	Floor 3rd	27	12-Nov-03	18-Dec-03
A1120	Columns 2nd South	6	25-Nov-03	02-Dec-03
A1080	Columns 3rd North	23	22-Dec-03	21-Jan-04
A1130	Columns 3rd South	11	22-Dec-03	05-Jan-04
A1090	Roof	135	21-Jan-04	27-Jul-04
A1150	Planetarium Base	90	16-Feb-04	18-Jun-04
A1160	Planetarium Dome	5	12-Jul-04	16-Jul-04
A1170	Planetarium Pyramid	29	15-Jul-04	24-Aug-04



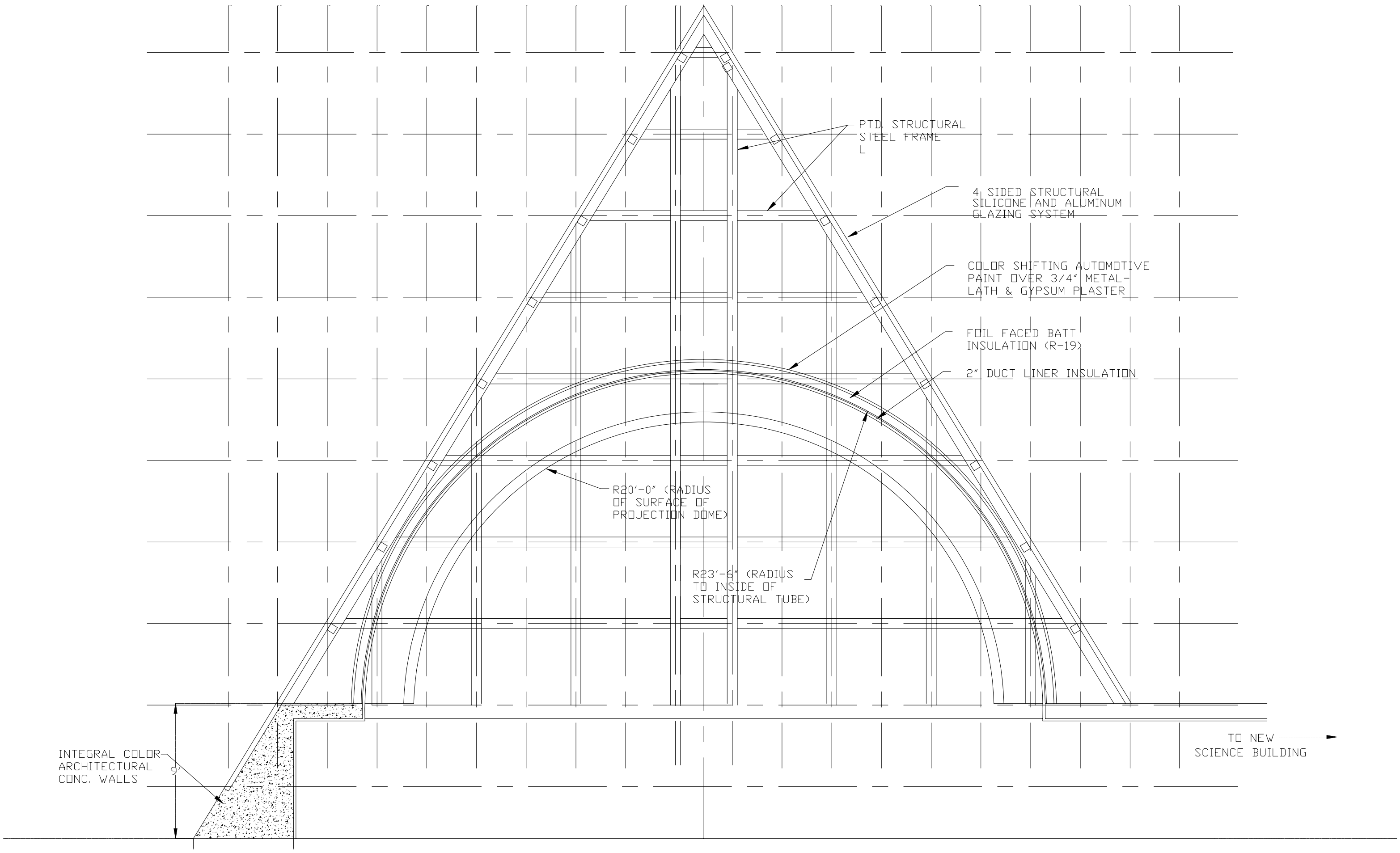
Actual Work | Summary
Remaining Work
Critical Remaining Work
Milestone

TASK filter: All Activities

Appendix C

Nicole Griffith
Construction Management Option
The New Science Building
Texas A&M International University
Laredo, TX

Planetarium Section



Appendix D

Nicole Griffith
Construction Management Option
The New Science Building
Texas A&M International University
Laredo, TX

Reverberation Time

Optimum Reverb. Time = 0.7 to 1.2 seconds (lecture/cinema)
use 1.24 s @ 125 Hz, 0.95 s @ 500 Hz, 0.76 s @ 400 Hz

a=0.05V/T
1113.0 Sabins @ 125 Hz
1452.8 Sabins @ 500 Hz
1816.0 Sabins @ 4000 Hz

		125 Hz		500 Hz		4000 Hz	
Material	**Area (ft²)**	**α**	**Sabins**	**α**	**Sabins**	**α**	**Sabins**
Walls							
2" Fabric Wrapped Acoustical Wall Panels	857.74	0.6	514.64	0.82	703.35	0.38	325.94
Painted Wood Base	45.29	0.15	6.79	0.1	4.53	0.07	3.17
Roof							
1/2" Gypsum Board	867.47	0.29	251.57	0.05	43.37	0.09	78.07
Floor							
Carpet	1134.64	0.02	22.69	0.14	158.85	0.65	737.52
Seats & Audience	675.18	0.39	263.32	0.8	540.14	0.87	587.41
Totals			**1059.01**		**1450.24**		**1733.11**

Reverb. Time = 0.05V/a = **1.3 s** @125 Hz, **0.95 s** @ 500 Hz, **0.80 s** @ 4000 Hz
OK

Nicole Griffith
Construction Management Option
The New Science Building
Texas A&M International University
Laredo, TX

Transmission Loss at Mechanical Rooms

2 layers 5/8" gypsum wallboard each side (6 1/8" thick total with metal studs),
3" acoustical batt insulation full height,
7'x3' solide sore wood door with metal frame

Transmission Loss

Partition	**125 Hz**	**250 Hz**	**500 Hz**	**1000 Hz**	**2000 Hz**	**4000 Hz**
Walls (#23)	34 dB	41 dB	51 dB	54 dB	46 dB	52 dB
Door (#45)	29 dB	31 dB	31 dB	31 dB	39 dB	43 dB

Composite TL = $10\log \sum S / \sum tS$ where S = area and t = sound transmission coefficient

Composite TL

125 Hz	**250 Hz**	**500 Hz**	**1000 Hz**	**2000 Hz**	**4000 Hz**
40 dB	38 dB	40 dB	40 dB	44 dB	50 dB

STC = 42 Acceptable