Senior Thesis Final Report
AE 481W and AE 482

Marriott Hotel at Penn Square and
Lancaster County Convention Center

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Executive Summary

The Marriott Hotel at Penn Square and Lancaster County Convention Center is a new 412,000 SF facility being constructed where the former Watt & Shand department store was located. The 109 year old façade is being restored and incorporated into the new 19 story building. The hotel will consists of; 300 rooms, a 4,785 SF full service bar, a 9,621 SF ballroom which can also double as six meeting rooms highlighted by majestic two-tiered windows from the Watt & Shand façade, and 7,541 SF of amenities which include an exercise room, indoor pool and whirlpool spa. While the state-of-the-art convention center will consist of a 47,842 SF exhibit hall along with lobby areas, prefunction areas, a large ballroom, three boardrooms, and meeting rooms. The $170 million dollar project is scheduled to be constructed from May 2006 to Dec. 31st 2008.

The following report analyzes the redesign and implementation of; a structural steel joist floor system over a C.I.P. concrete system for the convention center, Ivany block for a cantilever retaining wall over a C.I.P. concrete pinned retaining wall, the redesign of the groundwater lift station system from a duplex 120 GPM system to a triplex 1020 GPM system, the use of laser scanning technology to document the existing Watt & Shand façade over traditional surveying techniques, the implementation of a combination minipile and caisson foundation system over a strictly caisson system, and the resequencing of construction activities for the proposed alternatives. Through the incorporation of the proposed redesigns the Marriott Hotel and Lancaster County Convention Center project would be able to open 5 weeks earlier due to schedule reduction. The increased construction costs of 0.15% ($256,306) to implement the proposed changes would easily and readily be offset by the revenue generated and reduced costs associated with the construction (construction loans, monthly consultants fees, etc..) by finishing construction 5 weeks early.

Introduction and Project Background

General Building Data

- Building Name: Marriott Hotel at Penn Square and Lancaster County Convention Center
- Location and Site: Penn Square in Lancaster, PA
- Building Occupant Name: Interstate Hotel running for Marriott International
- Occupancy or Function Types: Hotel/Convention Center/Museum/Restaurant
- Size: Total Area: 412,079 SF
  Hotel Facilities: 161,417 SF (13 Floors)
  Convention Center Facilities: 183, 917 SF
  Shared Space: 66,745 SF
- Number of Stories Above Grade: 19
- Height: 210' (from hotel lobby to roof) 236' (from convention entry to roof of hotel)
- Dates of Construction:
  - Phase 1: Site Prep: May 2006 – Oct. 2006
  - Phase 2: Construction: Oct. 1, 2006 – Dec. 30, 2008
- Cost Information: Total Cost: $169.7 million (inc. hard costs, FF&E, and soft costs)
  Hard Cost: $105,580,685
  Soft Cost: $15,431,741
  FF&E: $14,771,187
- Project Delivery Method: CM Agency
  (17 Multiple Prime Contracts)

Architecture

The full service Marriott hotel and state-of-the-art convention center is designed to enhance the historic and walkable character of Lancaster, Pennsylvania.[1] The historic, 109 year old, Watt & Shand department store façade is being kept and incorporated into the entrance and base of the new hotel tower. The architectural pre-cast concrete panels of the hotel tower are designed to harmonize with the existing terracotta and marble Watt

& Shand façade while also providing a high level of quality and beauty for the 19 story tower that will be seen high above the existing façade.

The hotel consists of; 300 rooms, a 4,785 SF full service bar, a 9,621 SF ballroom which can also double as six meeting rooms highlighted by majestic two-tiered windows from the Watt & Shand façade, and 7,541 SF of amenities which include an exercise room, indoor pool and whirlpool spa.

The convention center is being constructed with four existing historical structures at three of its corners (see 'Historical' section for additional information). The façade of the convention center is mainly comprised of brick, type 1: "Old Tavern Series" to compliment the existing historical brick structures.

The state-of-the-art convention center consists of a 47,842 SF exhibit hall along with lobby areas, prefunction areas, a large ballroom, three boardrooms, and meeting rooms.

Applicable Codes

Building: 2003 International Building Code

Mechanical: 2003 International Mechanical Code

Plumbing: 2003 International Plumbing Code

Electrical: 2003 International Electrical Code

Handicap Accessibility: ADA w/ AADAG Design Guidelines

Applicable Standards

2004 Marriott International Design Standards

Zoning:

Residential/Hotel: R-1

Assembly: A-2

Construction type 1B: reduction from 1A to 1B allowed using original construction type area allowances per 403.3.1 for high rise building.

Historical

The Hotel and Convention Center project is located in the heart of Downtown Lancaster at the southeast corner of Penn Square, where the former Watt & Shand department store was located. The former Watt & Shand was one of Lancaster's most significant examples of commercial architecture, with four imposing stories of buff brick with elaborate terra cotta and marble ornamentation. The oldest section of this Beaux Arts building, fronting on East King Street, dates from 1898 and was designed by C. Emlen Urban. The Watt & Shand department store was acquired by the Bon-Ton Stores in 1992 and closed as a department store in 1995.[2] Due to its historical importance to the Lancaster area, the four story façade is being kept and incorporated into the base and entrance of the new Hotel tower.

Along with incorporating a historical façade, the new Hotel and Convention Center is located in between five existing structures; an office building on King St., and four historical structures; the Montgomery House, the Smith House, the Thaddeus Stevens House and Kleiss Saloon. The project will integrate these structures (expect the office building) as museums. The preserved home of the Honorable Thaddeus Stevens and his confidante Lydia Hamilton Smith will be a multi-level 20,000 square foot museum and interpretive/education center. Among its variety of exhibits the underground portion of the site will feature a recently unearthed historic Underground Railroad feature, a converted water cistern utilized in the mid-nineteenth century to hide runaway slaves escaping to freedom. The historic site will be visually integrated into the Vine Street entrance and lobby of the convention center.[3]

Building Envelope:

The Hotel has two exterior wall types, the existing Watt & Shand façade that will be restored and architectural pre-cast panels to match the existing façade in color. The pre-cast panels are hung off the cast-in-place post-tensioned concrete floor slabs and 3 5/8" metal stud are used as backup to hang interior drywall and finishes. The roof of the Hotel tower is constructed of EPDM single ply membrane on a cast-in-place post-tensioned concrete slab with 4” of rigid and additional tapered insulation. Aluminum windows complete the hotel tower envelope; Traco 7900 series windows are specified.

The Convention Center is comprised of several different wall types. The main wall type is a brick face with metal stud back up, with the brick to match that of the connecting existing historical structures. Additionally, smaller areas of 3” EIFS and 3 5/8” CMU Veneer both with metal stud backups are located around the building exterior in the rear around the loading docks. The metal stud backup sizes vary from 3 5/8” to 6”. The main entrance into the Convention Center is an aluminum storefront wall type assembly. The same aluminum windows are also used on the Convention Center as the Hotel. Spanning the large open exhibit floor of the convention center are 153’ long bowstring steel trusses with acoustical metal decking on top of them and then 4” of rigid insulation and PVC roofing with integral decorative color material on top with applied battens at 5’ on center. Lastly, smaller sections of roof of the Convention Center, not over the main exhibit floor, are EPDM single ply membrane on acoustical metal deck with 4” of rigid and additional tapered insulation on top of a composite slab on metal deck.

Building Systems Summary

Demolition Work

The abandoned Watt & Shand department store became an eyesore to Lancaster City after its years of nonuse. As part of the Redevelopment Authority revitalization plan of Lancaster City they decided to use this city block located at the square of center city Lancaster as the site for the new Hotel and Convention Center. The demolition of the Watt & Shand building and the façade stabilization was completed under phase 1 Site Prep (May 2006 – Oct. 2006) of the project. The former Watt & Shand building consisted of a steel frame structure with concrete on metal deck. Asbestos was present in the 109 year old building, and was removed by an Asbestos Contractor hired by the Owner. The interior non-friable asbestos materials were removed from the building prior to demolition.

Structural Steel Frame:

Once at the lobby level of the project, the Convention Center transitions from cast-in-place concrete to structural steel. The steel frame is a braced frame utilizing diagonal HSS shapes for the bracing and varying W shapes used for columns. The floor beams are also W-shapes, varying in size depending on loading conditions with nelson studs welded to them to create a composite floor slab. The roof over the loading dock area is made up of W shape beams varying in size depending on the weight of the mechanical equipment in that area. The entrance roofs are comprised of HSS shapes, again varying in size. The main roof over the Convention Center is made up of 153' long bow string metal trusses comprised of WT, HSS, and L shapes. The trusses are to be prefabricated at Greiner Industries and delivered to site in three pieces. Once on site they will be field erected and then lifted into place.

The Hotel is a cast-in-place post-tensioned concrete structure, with the exclusion of the roof of the podium (Health Club Level) that consists of W-shape beams and bar joist. The three main joist sizes used are 24" K series to span 26', 28" K series to span 32', and 60" deep DLH series to span 85'.

Figure 1. Elevation of Project

Cast-in-Place Concrete:

The superstructure is mainly cast-in-place concrete. The concrete columns in the hotel are spaced at 27' (N-S) along the length of the tower and the spacing varies along the width from 8' – 17'. The floor slabs are 12-14" thick and are post-tensioned concrete. At the base of the tower, 7' thick transfer girders are used to span the hotel lobby. The Convention Center also utilizes the cast-in-place concrete until it reaches the exhibit floors, where it switches to structural steel. The concrete structure is entirely stick framed, and placed by means of pump trucks (when applicable), the tower crane with buckets, and a concrete stand pipe in the tower.

Precast Concrete/Curtain Wall:

The façade of the Hotel Tower is comprised of three different architectural panels; architectural precast panels, architectural carbon cast panels and architectural spandrel precast panels. The architectural precast panels comprise most of the façade, and vary in size. The most common size of the panel is 31'-7 3/8" x 8'-11 ¼".

These precast panels will be cast by High Concrete Structures, Inc. located in Lancaster, PA. The tower crane will be used to lift the panels into place on a second shift basis, so that the tower crane can be used for other construction activities throughout first shift and thus help to accelerate the schedule. The connection for the panel is a welded connection to steel angles incorporated into the concrete superstructure.

Mechanical System:

The mechanical system starts with 8 Boilers in a row in the main mechanical room (1658MBH/each) that are natural gas fired. Providing the cold water for the mechanical systems are the 2 (750 Ton) water cooled chillers coupled with 2 cooling towers that handle 2250GPM and produce 11,250 MBH of heat rejection. The hot and cold water is used in hydronic AHU's to provide heating and cooling to the public spaces of the hotel. Each hotel room is equipped with an energy recover unit, while the corridors are cooled with 100% outdoor air from roof top units. The Convention Center utilizes three D/X roof top units w/eru wheel each providing 1461 MBH total cooling and 1700 MBH of total heating to the main exhibit halls. Additionally, the hot water for the building is provided by 8 large gas-fired water heaters and storage tanks. The water heaters range in size from 500,000-1,700,000 BTU.

Electrical System:

The electric for the project is provided by 2 main service points, each 4000 AMP 480Y/277 Volts, 3PH., 4W. The lighting system uses mainly 277V fluorescent lamps for the public areas and 120V fluorescent lamps for the hotel rooms. The electrical system steps down to 208Y/120 on each of the floors in the building for the receptacles. The back up system for the project is a 2000HP generator with a 2000 gallon diesel storage tank and a 75 gallon day tank.

Masonry:

The majority of the masonry for the project is used as infill for the structural steel frame of the convention center. It is non-load bearing and provides backup for the different exterior finishes on the convention center including EIFS, brick and split face block.

Support of Excavation:

Given the nature of the site several different types of excavation support systems were needed for this project. The project is situated in between five existing structures and surrounded by four roads. The types of shoring and bracing systems used for this project include; soldier piles, timber lagging, steel sheet piles, underpinning, soil nailing, and trench boxes.

The Gearhart building, the existing structure adjacent to the hotel, required shot-crete and underpinning, as the bottom of the new hotel is lower then the existing neighboring structure. Along with the Gearhart building the entire Watt & Shand façade required underpinning support as the hotel basement is lower then the existing façade. Along the site parallel to East Vine St. soil-nailing and shot-crete was used to resist any movement of the soil underneath the roadway. Additionally, steel sheet piles and trench boxes are both used as needed during the excavation process of the construction process.

Client Information

Reason for Construction:

The Marriott Hotel at Penn Square and Lancaster County Convention Center is the most important regional economic development undertaking in decades, the project is expected to bring new hope, new jobs, and new financial strength to Lancaster City. The project is also designed to help increase Lancaster, PA popularity as one the most traveled tourist location on the East Coast. The Hotel and Convention project is just part of larger scaled revitalization to the city; other projects include the recently completed Clipper Magazine Stadium, the Lancaster Quilt Museum, the Pennsylvania Academy of music and the Pennsylvania College of Art & Design. Fittingly as part of the revitalization of the city, the project is incorporating the façade of the 109 year old Watt & Shand department store which has set vacant for several years in the heart of Lancaster City. To accommodate the Hotel and Convention Center, the city is building additional parking garages, renovating old parking garages and is cleaning up the city with new trash cans, street lights, street landscaping and much more.

In late 2000, the Lancaster County Convention Center Authority commissioned an independent study to evaluate and quantify the community benefits of the project. According to the analysis, the Hotel and Convention Center project will project several benefits to the city, they include:

- Create 520 to 590 construction jobs.
- Create 200 to 300 full-time jobs to staff the hotel and convention center.
- Increase Lancaster County tourism by an additional 114,000 to 147,500 visitors annually.
- Inject $150 million into the local economy during construction: $110 million in sales of Lancaster County-produced goods and services and $40 million in personal income.
- Inject $42 million per year into the local economy during operation: $31 million per year in sales of Lancaster County-produced goods and services and $11 million per year in personal income.

- Generate additional tax revenue for Lancaster City, Lancaster County, and the School District of Lancaster

The Owners of the Project:

The Hotel and Convention Center has two Owners; the Redevelopment Authority of the City of Lancaster (RACL) is the Owner for the Hotel, and the Lancaster County Convention Center Authority (LCCCA) is the Owner for the Convention Center. Additionally, the Historic Preservation Trust (HPT) is paying for the preservation work to the historical structures that will be integrated into the project as museums. LCCCA was formed in 1999 with the goal to bring the best possible Convention Center to Lancaster. The authority is comprised of a seven member volunteer board (appointed by Lancaster County and City Officials) and an Executive Director. RACL is also a public board that is designed to revitalize downtown Lancaster. For the Hotel and Convention Center project, RACL has deferred their decision making in regards to the Hotel to Penn Square Partners (PSP). Penn Square Partners comprises general partner Penn Square Corporation, which is affiliated with High Industries, Inc.; Fulton Bank; and Lancaster Newspapers, Inc. Penn Square Partners were formed in 1998, and it was not until 2001 that the public-private partnership was formed between PSP and LCCCA.

In the projects early design stages it was proposed to be two separate buildings. It was not until later that the design incorporated the Hotel and Convention Center together as one large building to enhance the use of both functions. Overall, RACL's cost is 47% while LCCCA's cost is 53% of the total project cost. HPT pays for approximately $3 million dollars worth of work incorporated into the cost of construction.

Cost, Quality and Schedule Expectations of the Owners:

The cost of the project is $169.7 million, including all the cost. The expectation to the Owners is to complete the project on budget, and not to exceed the contingency that is built into the total project cost during construction.

Time is of the essence during construction so that the Owners can open and use the building as soon as possible. The schedule calls for substantial completion to be Dec. 30th, 2008 and the Owners hope to have opening day in the middle of March, 2008.

Achieving the opening the day date is critical as marketing agents are currently making reservations and bookings for the Hotel and Convention Center. Achieving the scheduled opening day is so important that the Owners authorized the demolition of the Watt & Shand building to begin before the permanent financing was in place. Likewise all construction activities are to take place as expeditiously as possibly, thus three temporary roofs are planned during construction to expedite interior work.

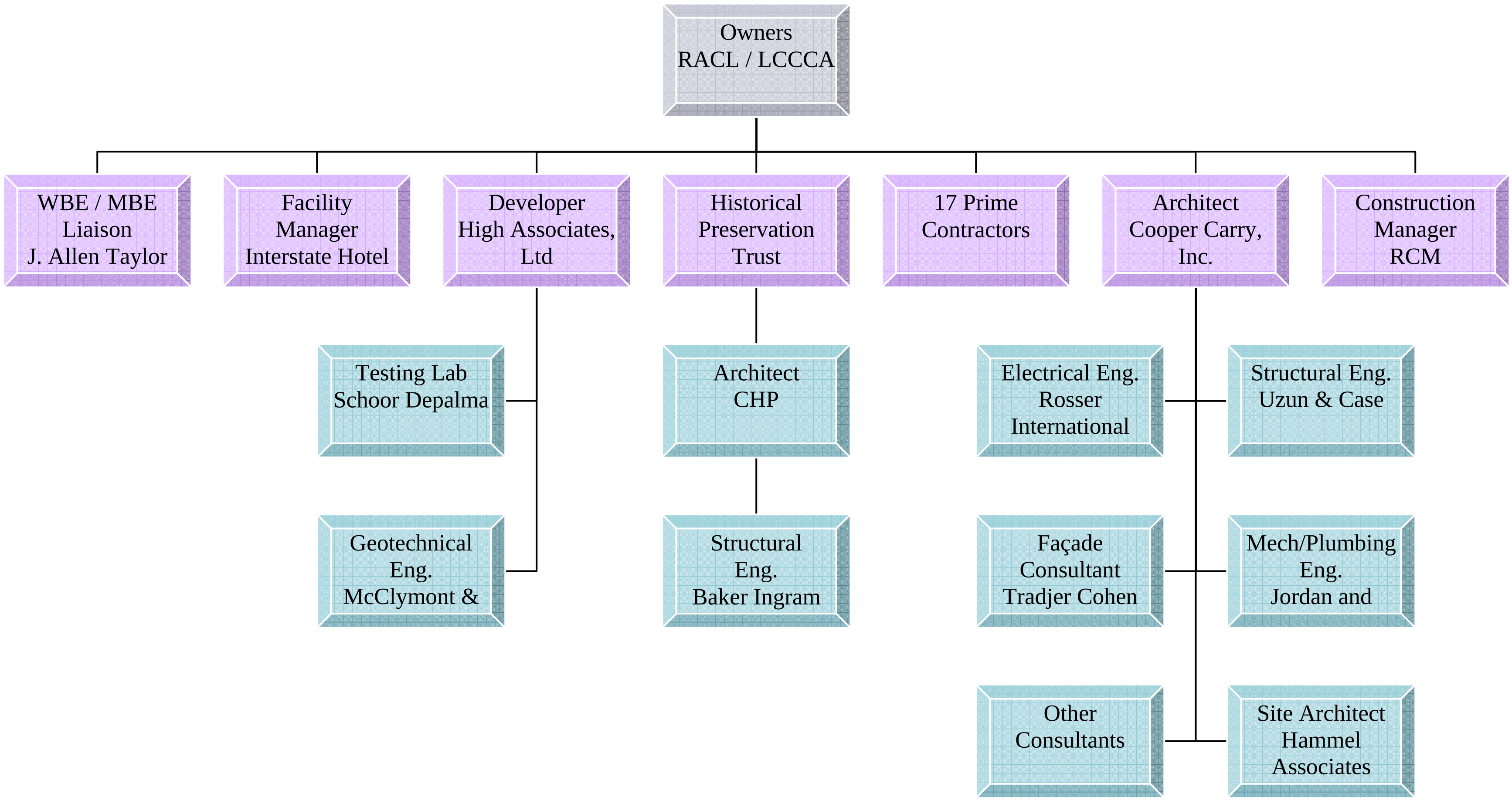
The quality of the project is also very important, which is why the Owners are constructing a Marriott Hotel. Even after the bids came in and the project was over budget, the following value engineering efforts were dedicated towards finding most cost effective means of construction while maintaining quality. For example, the pre-cast panel façade has been kept for the Tower throughout the value engineering efforts and not revised to a cheaper dryvit system.

Keys to Complete the Project to the Owners Satisfaction:

Much like any project, the keys to complete this project to the Owners satisfaction is to; complete the project on time, on budget, safely, while maintaining the quality that is intended for the Marriott name. While the construction of the building is critical to the success of the project as a whole, the marketing and advertising efforts are just as significant. Approximately 40 events are needed to be held in the Convention Center each year while filling roughly 66% of the rooms a night in the Hotel for the project to provide the financial return the Owners are expecting.

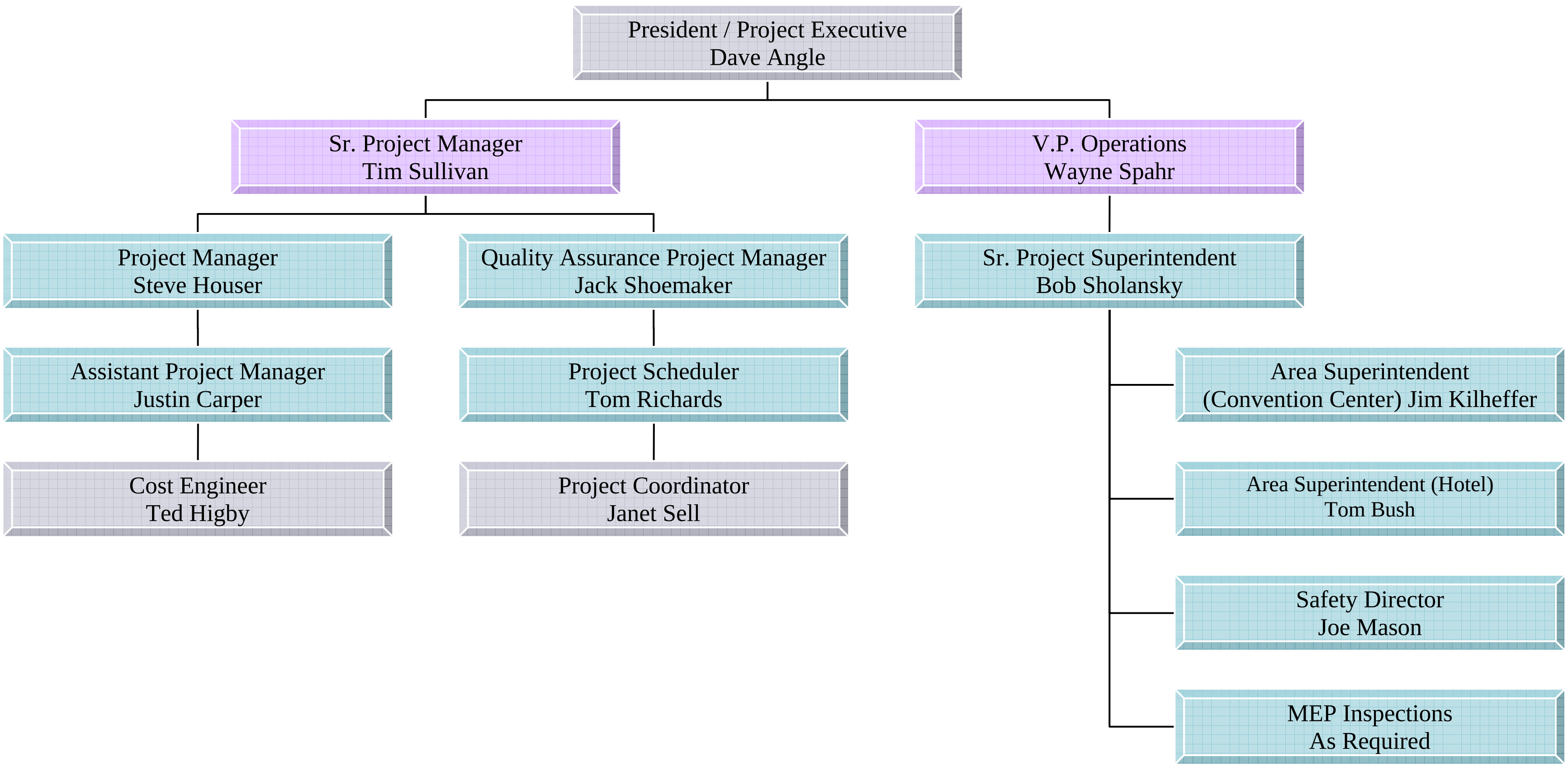
Project Delivery System Organizational Chart

The organizational chart shows the relationship and contract ties between the Owners, Architects, Engineers, Construction Manager, and Contractors for the project.



Staffing Plan

Staffing Plan for Reynolds Construction Management the CM Agent for the Project.



Staffing Plan Description

The President of Reynolds Construction Management (RCM) oversees the staff for the project. He gets involved with the schedule, progress meetings, Owner meetings and board meetings for the project.

The field supervision, located in trailers on site, is headed with the Dir. of Field Operations who commits two to three days a week on site at the project to oversee the staff and site progress. The Senior Superintendent is on site full time and oversees the entire project. Assisting him are two Area Superintendents, one specifically to oversee the Hotel construction and the other to oversee the Convention Center construction. RCM's safety director makes periodic visits to the site to check for any safety concerns. As the project progresses and MEP systems are being installed and ready for testing, RCM provides MEP inspectors to provide quality assurance on these critical systems for the Owner.

On the operations side, RCM has rented an office down the street from the project to allow the staff direct access to the site on a daily basis. This office is headed by the Senior Project Manager who oversees the management side of the project. Working with him is the Project Manager who assists by heading up the change management issues and any technical issues. The Cost Engineer also lends a hand with the change management issues, as he reviews the proposed change orders for the quoted amount and makes any necessary adjustments before RCM makes recommendations to the Owner about the proposed change order. The Assistant Project Manager is responsible for the documentation control, processing the submittals, shop drawings, and RFI's, along with keeping track of addendums, bulletins and responses to the RFI's. Working with the Assistant PM and his documentation control, the Quality Assurance Manager performs constructability reviews of all the documents being released by the Architect. He meets weekly with the Architect to discuss issues and come up with solutions, trying to resolve issues on paper before workers come across the issues in the field during construction. Additionally, RCM employees a full time Project Scheduler, he meets bi weekly with the SPM to update the construction schedule.

Site Plan Summary

The attached site plan briefly shows how the contractors will erect the superstructure for the project. Not shown on the plan is an off-site material storage area that the contractors use to store and stage material prior to delivery to the site. This off-site material storage area is located east of the site, approximately one mile east on E. King. St.

"Two Half's" to the Project

The project can be discussed in terms of the "North Half" of the site and the "South Half" of the site. The "North Half" is the hotel part of the project which is entirely a cast-in-place post-tensioned concrete structure except for the roof over the podium, which is made of deep long span joist. The "South Half" of the site is the convention center part of the project. The convention center is a cast-in-place concrete structure for the museum and convention entry levels, once to the exhibit levels it becomes a structural steel structure. The different materials of the structure greatly influence the means and methods of construction.

Superstructure Sequence

For the "North Half" of the site, a tower crane is to be used to handle materials to erect the cast-in-place concrete structure. The tower crane was sized and to enable a reach to the north-west corner of the building. Along with the tower crane, two material hoists will be used to also help transport men and materials up the tower during construction. The tower crane and hoists will be used to transport the forms and men to form the structure, which is to be all stick-formed (a few retaining walls in the convention center used gang forms). The concrete will be placed by a boom style pump truck for the lower floors of the building, then when it is no longer applicable to use a boom style concrete pump truck a permanent stand pipe will be installed into the tower of the building and concrete will be pumped up the building through the standpipe and then placed with a hose at the end of the stand pipe. During the placing of concrete for the lower floors the boom style pump truck will need to move around the site depending on the location of the required concrete pour. For the attached site plan, the concrete pump is located near the tower which will be near the location of the concrete standpipe.

The "South Half" of the site utilizes both a concrete and steel structure. As stated above, the museum and convention entry levels are cast-in place concrete. To erect the concrete in this area, a 100 ton mobile crane is used to transport formwork, and place concrete with a bucket for small pours (columns). A concrete pump truck is primarily used to place the concrete for the "South Half". Above the Exhibit hall floor the superstructure transitions to steel, to enable the open floor plan and long spans. To erect this steel the steel contractor will use a 240 Ton crane. The erection will require multiple mobilizations due to the project configuration. The first series of mobilizations will be to erect sequences 01 thru 10 (see Figure 2 Steel Erection Sequence below). The crane will mobilize at sequence 02 to erect sequence 01 and 02, then remobilize where sequence 03 is located to erect sequences 03 and 04, then the crane will move out of the building footprint to finish erecting sequences 05 thru 10, remobilizing as necessary. The second series of crane mobilizations will be required to erect the steel for the roof of the podium, sequences 11-13 and the Convention Center roof that is sloped away from the tower, sequences 14, 15, 16 and 17. Sequence 17 is located above the north-east corner of sequence 16. The attached site plan reflects the period when the 240 ton mobile crane mobilizes in sequence 02 to erect sequences 01 and 02. The deliveries of steel for the project will arrive on South Queen St. The steel will be picked directly from the truck when applicable and the trucks will need to back onto the site to allow the crane to reach them. A smaller crane/lift will also be used to remove the steel from the trucks to shake it out to field assemble larger pieces of steel mainly the large bow-string trusses that will arrive on site in three pieces.

Figure 2 Steel Erection Sequence

Site Plan

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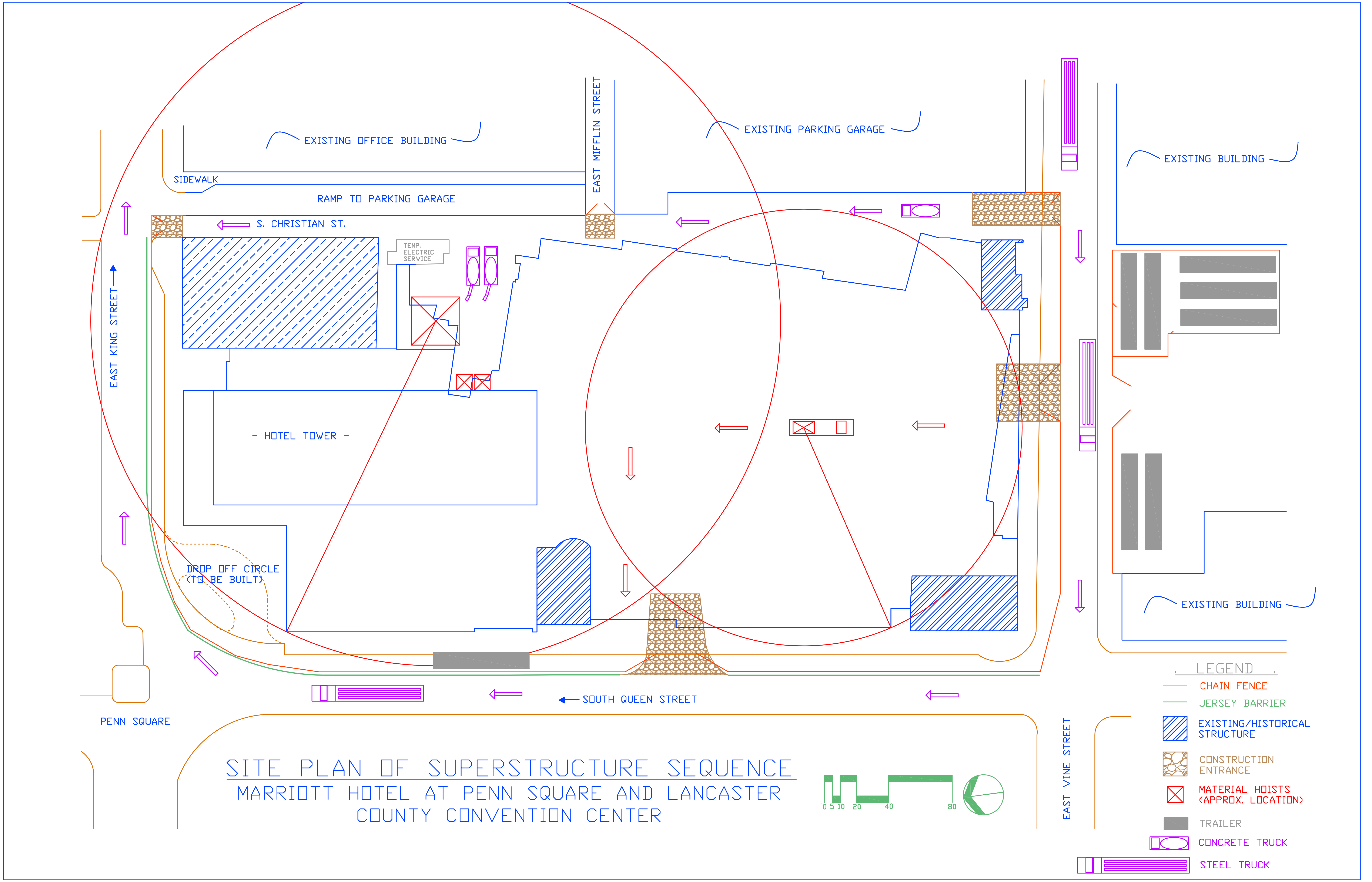

SITE PLAN OF SUPERSTRUCTURE SEQUENCE

MARRIOTT HOTEL AT PENN SQUARE AND LANCASTER COUNTY CONVENTION CENTER

Existing Conditions

The existing conditions section of the report encompasses a description of the project investigation areas which is an introduction to the summary of investigation areas. The summary of investigation areas is where the proposed changes are then analyzed. The following existing conditions section includes; an estimate summary for the project, a summary schedule, and a cash flow curve for the project.

Estimate Summary

The following chart depicts the contract values for each prime contractor. Contracts 8, 11, 12, and 13 were added under contract 4 under an addendum. These values sum to the total construction cost for the project (change orders not included).

	Bid Packages	Contract Amount	Cost/SF
	Abatement	$884,000	$2.15
	General Conditions	$821,180	$1.99
1	Demolition	$1,588,734	$3.86
2	Façade Stabilization	$3,063,000	$7.43
3	Caissons	$1,085,000	$2.63
4	General Trades	$37,100,000	$90.03
5	Site & Utilites	$2,909,000	$7.06
6	Concrete	$16,200,000	$39.31
7	Precast Concrete	$2,554,500	$6.20
9	Steel	$7,986,000	$19.38
10	Roofing	$2,055,885	$4.99
14	Laundry Equipment	$393,675	$0.96
15	Food Service Hood	$50,000	$0.12
16	Conveying system	$2,427,142	$5.89
17	Plumbing	$4,444,444	$10.79
18	Fire Protection	$1,197,800	$2.91
19	HVAC	$10,969,000	$26.62
20	Electrical	$8,757,000	$21.25
21	Telecommunication/AV	$1,488,000	$3.61
	Subtotal	$ 105,974,360	$257.17

Summary Schedule

The design process for the project started in July of 2002, and continued to the middle of April 2004. It was at this point the project faced difficulties in obtaining financing to fund the public and private venture. Many believed the project was not ever going to make it past the design phase, though in October 2005 the Owners proceeded to demolish the existing Watt & Shand building. The Owners also continued to begin construction activities immediately after the demolition phase even before the permanent financing was in place for the project. This was done to show the public that the project will be constructed and to gain support for the project during what was a controversial time.

After the year and half of dormancy the project faced, the construction phase began and like any Owner they want the building to be usable and open as soon as possible to begin making money on their investment. As seen on the attached summary schedule, the project has been broken down into several different areas, labeled A-J. These areas are located in the Convention Center and in the podium/shared space. The schedule shows a “Shell” and “Finishes” activity for each area. The “Shell” term is used to encompass any excavation work, forming, placing, reshoring, mechanical rough-ins, exterior walls, roof and any work to provide a structure that is “dried-in”. The “Finishes” term is used to encompass any drywall, painting, ceiling, sprinkler heads, light fixtures, wall coverings, fixtures, hardware, etc… work to provide a usable building that provides the ability to use the room for its intended function. Once the project reaches the Hotel tower the schedule is broken down into floors. The schedule again shows “Finishes” and “Shell” activities. Due to the size, and time constraints for construction, the finishes activities will follow the shell construction up the tower and temporary roofs will be constructed at certain locations. Additionally, the drywall (finishes) package has been divided among two separate contractors to allow for finishes to meet the schedule and to allow for concurrent work in the convention center and hotel. The substantial completion date for the project is December 31, 2008.

Refer to the schedule on the following page.

Summary Schedule

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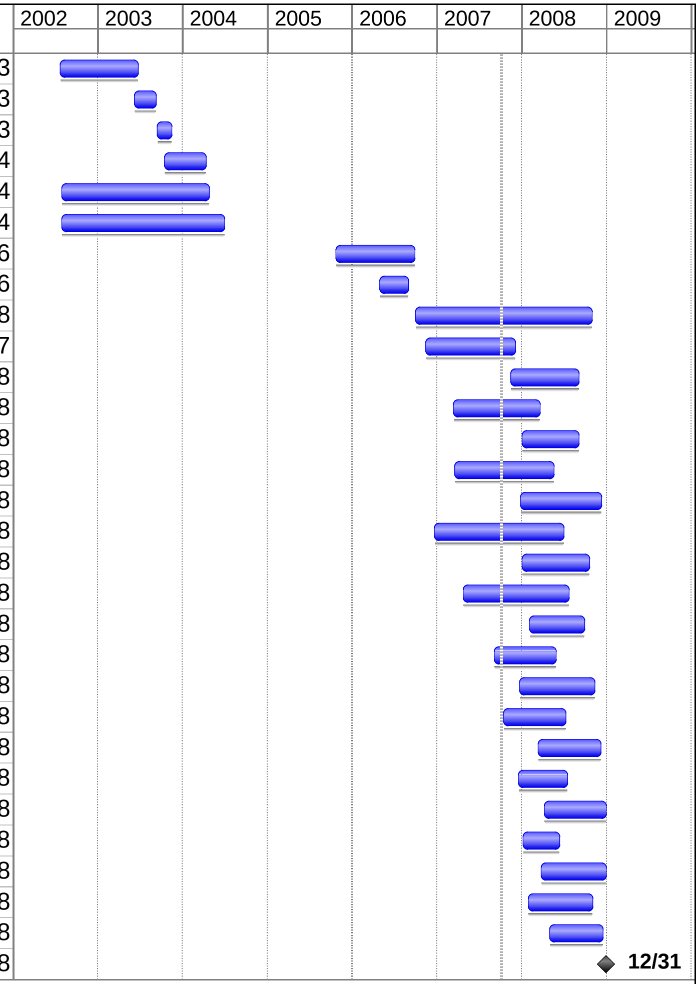
ID		Task Name	Duration	Start	Finish
1		Conceptual Design	241 days	Wed 7/24/02	Wed 6/25/03
2		Schematic Design	68 days	Mon 6/9/03	Wed 9/10/03
3		Design Development	46 days	Mon 9/15/03	Mon 11/17/03
4		Construction Documents	127 days	Fri 10/17/03	Mon 4/12/04
5		Permits and Approvals	454 days	Wed 7/31/02	Mon 4/26/04
6		Procurement of Construction Services	502 days	Wed 7/31/02	Thu 7/1/04
7		Abatement and Demolition	245 days	Mon 10/24/05	Fri 9/29/06
8		Façade Stabilization	90 days	Mon 5/1/06	Fri 9/1/06
9		Site Work	545 days	Mon 10/2/06	Fri 10/31/08
10		Area A Museum Level Shell	277 days	Wed 11/15/06	Thu 12/6/07
11		Area A Museum Level Finishes	211 days	Fri 11/16/07	Fri 9/5/08
12		Area B Convention Entry Shell	268 days	Wed 3/14/07	Fri 3/21/08
13		Area B Convention Entry Finishes	176 days	Fri 1/4/08	Fri 9/5/08
14		Area D Exhibit Hall Shell	306 days	Tue 3/20/07	Tue 5/20/08
15		Area D Exhibit Hall Finishes	250 days	Fri 12/28/07	Thu 12/11/08
16		Area C Exhibit Hall "B" Level Shell	399 days	Fri 12/22/06	Wed 7/2/08
17		Area C Exhibit Hall "B" Level Finishes	207 days	Fri 1/4/08	Mon 10/20/08
18		Area E Mech. Room and Laundry Area Shell	327 days	Wed 4/25/07	Thu 7/24/08
19		Area E Mech. Room and Laundry Area Finishes	170 days	Tue 2/5/08	Mon 9/29/08
20		Area F Hotel Lobby Area Shell	191 days	Thu 9/6/07	Thu 5/29/08
21		Area F Hotel Lobby Area Finishes	233 days	Mon 12/24/07	Wed 11/12/08
22		Area G Ballroom "A" and "B" Shell	193 days	Tue 10/16/07	Thu 7/10/08
23		Area G Ballroom "A" and "B" Shell	193 days	Thu 3/13/08	Mon 12/8/08
24		Area I Meeting and Admin Area Shell	152 days	Wed 12/19/07	Thu 7/17/08
25		Area I Meeting and Admin Area Finishes	191 days	Wed 4/9/08	Wed 12/31/08
26		Area J Health Club Level Shell	114 days	Tue 1/8/08	Fri 6/13/08
27		Area J Health Club Level Finishes	201 days	Wed 3/26/08	Wed 12/31/08
28		Hotel Tower Level 6-19 Shell	198 days	Thu 1/31/08	Mon 11/3/08
29		Hotel Tower Level 6-19 Finishes	164 days	Fri 5/2/08	Wed 12/17/08
30		Project Substantial Completion	0 days	Wed 12/31/08	Wed 12/31/08

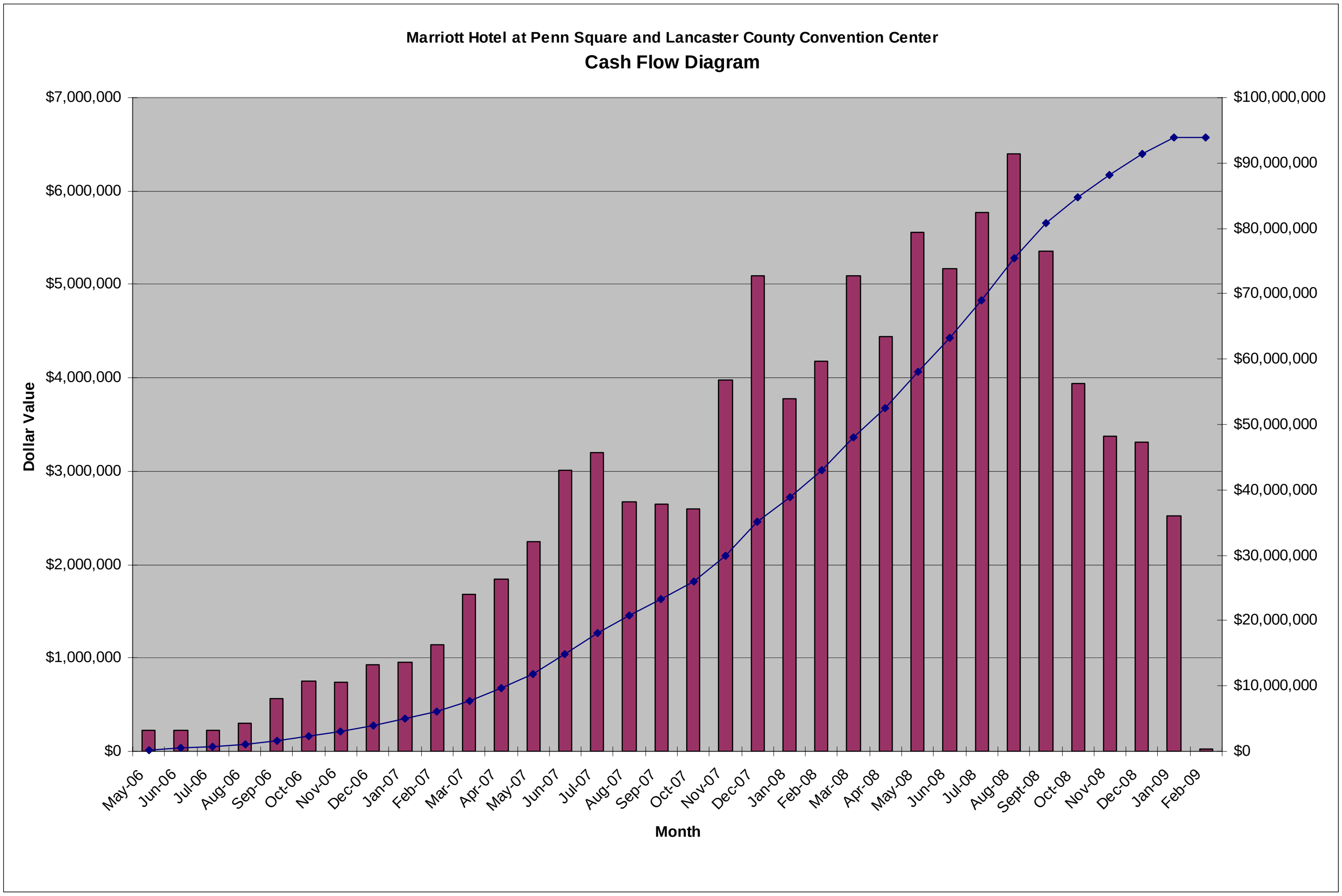


Marriott Hotel at Penn Square and
Lancaster County Convention Center
Lancaster, PA

Task
Split
Progress
Milestone
Summary
Project Summary
External Tasks
External Milestone
Deadline

Cash Flow Diagram

The cash flow diagram below depicts the sum of the contractor's monthly requisitions throughout the project and the cumulative costs, both actual to date and projected. The cash flow diagram only includes construction costs.



Description of Project Investigation Areas

Introduction

The convention entry and museum levels for The Marriott Hotel and Convention Center Project faced construction delays due to unforeseen site conditions and requirements in sequencing to place a reinforced concrete slab by not having the museum level slab on grade complete. The Analysis Description section of this report will focus primarily on the convention entry area of the convention center portion of the project, see figure 3 View from the Tower Crane of Southern Half of Site below for a visual representation of the area.

Problem Background

Dewatering System Redesign

During the excavation in the lowest part of the site, the museum level, a natural spring was discovered. This spring provided significantly larger water flows then what the current permanent dewatering system could handle. A delay in construction was encountered while a redesign was finalized for the dewatering system.

Convention Entry Level

The convention entry level is the level above the museum level in the convention center. The museum level, as mentioned above, encountered unexpected delays with the discovery of a natural spring. The museum level also encountered issues and delays with the unearthing of historical artifacts and structures near the Kleiss Saloon (in particular a brick floor that is to be incorporated into the design). The delays encountered in the museum level directly affect the ability to proceed with the convention entry level, as in cast-in-place concrete construction the slab below needs to be complete to enable the forming of the slab above.

Proposed Solutions

Structural System Redesign

Problem Statement:

The convention entry level is a cast in place concrete structure; can the load requirements for this area be met with a structural steel system, specifically a composite metal joist system? With a structural steel frame, what sequencing delays and how much of a delay to the schedule could have been avoided due the required sequential steps in placing an elevated concrete structural slab that was not met due to unforeseen issues in the lowest level of the building (museum level)?

Can the currently implemented cast-in-place concrete pinned foundation walls will be redesigned to a cantilevered retaining wall using a 16" Ivany block system? Can the Ivany block wall support the loads of the joists that will be framed directly into it? What are tangible advantages in utilizing a block retaining wall system that almost eliminates the need for formwork (faster construction) and allows for complete backfill of the wall before the floor system is in place?

Proposed Solution:

A composite metal joist framing system will be designed to support the required loads of the exhibit level, see Figure 3 Composite Joist System below for a detail of a generic composite joist system. The majority of the convention center is already a steel structure and in designing the convention entry to be steel, schedule reduction can be achieved. See Figure 4 Convention Entry below for a picture of the convention entry level concrete with the exhibit level steel being erecting above it. A cast-in-place concrete structure mandates a specific sequence of construction activities and any delay to a part of the sequence will delay the entire process. A steel structure offers more flexibility for the sequence of construction and most importantly does no rely on the museum level or under slab work to be totally complete. As mentioned previously, the museum level faced unforeseen issues and redesign issues creating delays in the completion of the under slab and slab work. Due to these issues in the museum level the entire convention center superstructure was delayed.

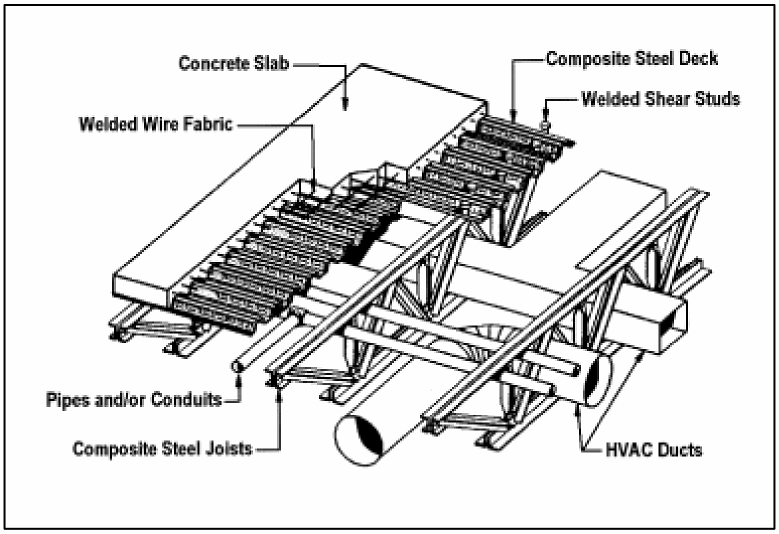


Figure 3 Composite Joist System

A steel structure would have been very beneficial to break the schedule ties between the museum level and the rest of the superstructure and significant time could be saved and construction sequencing would greatly improve. See Appendix A for floor plans of the Museum, Convention Entry and Exhibit Levels, the elevated structural concrete is highlighted in yellow. An 18" deep composite joist system will adequately support the loads of the exhibit hall. The 30'x30' column grid currently used for the concrete structure will be revised to 20'x40' to provide more efficiency in the steel system, limit the girder depth by using a smaller span, and avoid the most architectural conflicts in using a 20'x40' instead of a 20'x30', 25'x40' etc… The floor plan of the convention entry level will be analyzed for the incorporation of the proposed column grid and resolution to the conflicts will be proposed.

Figure 4 Convention Entry

Research Steps:

1. Gather loading requirements for the floor systems in the spaces of interest.
2. Determine the best steel alternative for the space allotted (composite joists)
3. Design the proposed steel structure
4. Perform a detailed costs for the structural system and compare to the cast-in place concrete structure
5. Develop a schedule for the erection of the steel and compare to the schedule for concrete
6. Analyze the architectural conflicts in changing from a 30'x30' bay size to 20'x40'
7. Design the Ivany block cantilever retaining wall to replace the exisiting cast-in-place concrete pinned foundation wall utilizing 'RAM Advance' retaining wall designer.
8. Compare the cost of the proposed block foundation wall system.

Sources of Information:

1. Baker Ingram & Associates
2. Providence Engineering Corporation
3. Uzun and Case Engineers

4. 1st Ed. CJ Series Standard Specifications for Composite Joists; Weight table and bridging tables code of standard practice by SJI (Steel Joist Institute)
5. RAM Advanse
6. http://ivanyblock.com/
7. Steel Construction Manual, Thirteenth Ed.

Plumbing Redesign:

Problem Statement:

In the Museum Level, the lowest level of the project a natural underground spring was encountered during the excavation process. The additional water adds additional requirements to the original ground water lift stations designed.

Proposed Solution:

The existing groundwater lift stations will be redesigned to accommodate the additional loads of the underground spring. See Appendix F for a plan of the existing ground water lift station design.

Research Steps:

1. Obtain a copy of the hydro-geological study reports.
2. Analyze the existing groundwater lift station design.
3. Design a new ground water lift station system to accommodate the required loads.
4. Compare new design to the original.

Sources of Information

1. W.G. Tomko the plumbing contractor.
2. Heating, Ventilating, and Air Conditioning, Analysis and Design, 6th Ed.
3. The hydro-geological study report.
4. City of Lancaster, Department of Engineering

Construction Sequencing/Planning

Problem Statement:

What will there be cost savings and schedule reduction by implementing the following: the minipile foundation system instead of caissons; using an Ivany block for the cantilever retaining wall design instead of the pined concrete wall; utilizing a steel superstructure instead of the cast in place concrete.

Proposed Solution:

Minipiles require more holes to be drilled then caissons but the holes are much smaller and can be drilled considerably faster. The use of minipiles provide an advantage in karst topography by utilizing fractured and layered rock to provide skin friction resistance instead of requiring consistent bedrock for a caisson to 'end-bear' on. The load requirements for the structure can be met with a mini-pile system.

The minipile foundation system can be installed faster then the caisson system, by the ability to drill more yet smaller holes then fewer and larger holes given the karst topography of the site. See the Minipile Research section of the report for further explanation.

In utilizing an Ivany block wall system as a cantilever retaining structure instead of the cast in place concrete pinned connection retaining wall several benefits can be experienced. First, the Ivany block wall system will eliminate a majority of the forming and shoring work to install the concrete retaining wall saving time and money. Secondly, the Ivany block wall will be designed as a cantilever retaining wall instead of a pinned connection. This allows for the soil to be completely backfilled before the floor system diaphragm is in place thus creating significant room on site and allows for the overlap of more trades saving time. Lastly, the Ivany wall will be used to support the exterior composite joists, aiding in the design of the retaining structure, adding lateral support to the structure and eliminating the need for exterior columns.

In redesigning the convention entry level to be a steel structure there will no longer be a need for shoring and reshoring in the area and the flow of materials and workers will be improved. The steel structure can be erected in this area regardless of the unforeseen conditions in the museum level, and can be independent of the progress in that area to a certain extent. Overall, a steel structural system for the convention entry level will save time and provide a less crowded work site. See figure 5 View from Tower Crane of Southern Half of Site below for an aerial view of the museum, convention entry and exhibit levels.

Research Steps:

1. Implement the minipile analysis results from the Minipile Research section of this report into the sequencing and planning.
2. Develop a new sequence and schedule of activities to include excavation, micropile/caisson construction, retaining wall construction, and thru steel erection.
3. Compare the cost, schedule and site access to that of the existing design.

Sources of Information:

1. See Minipile Research section for minipile information
2. Reynolds Construction Management for scheduling and sequencing information
3. The steel contractor on the project for steel production rates and sequencing/erection plan.

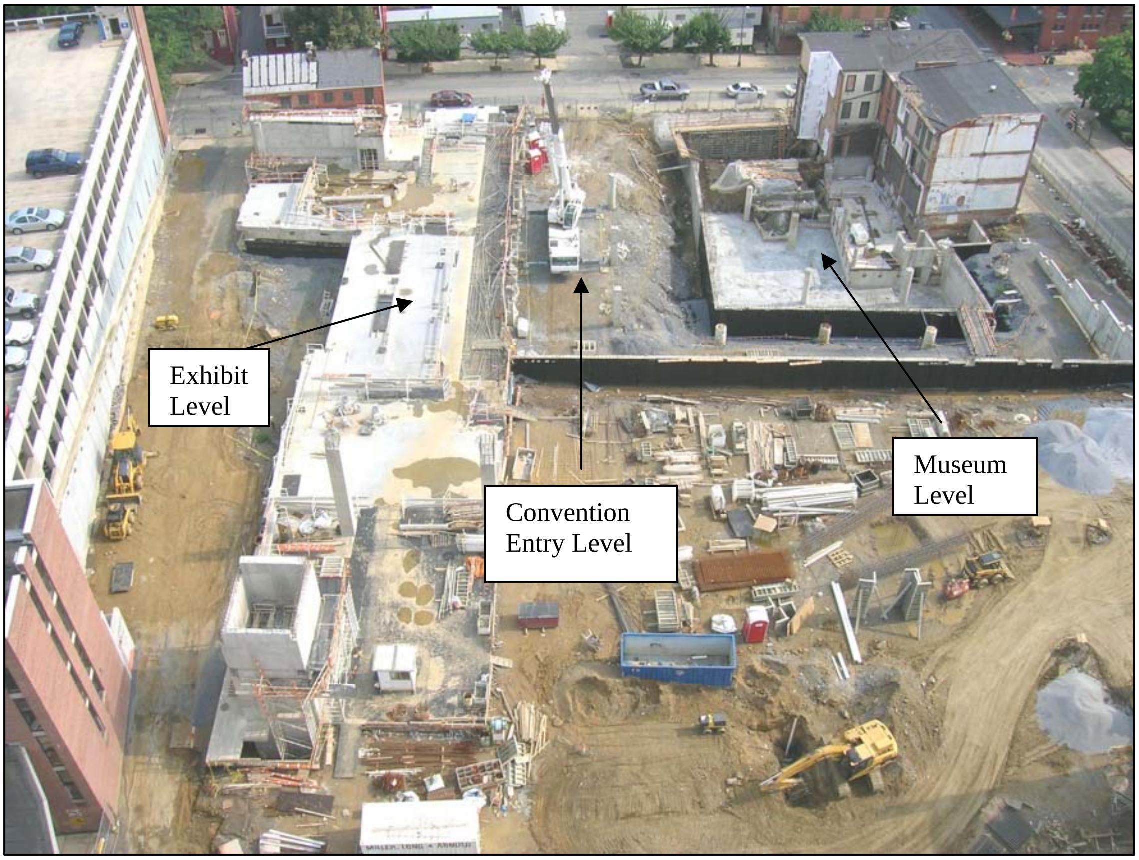


Figure 5 View from Tower Crane of Southern Half of Site

Structural Redesign: Composite Joist Design – AE Breadth Study

Analysis Steps and Solution:

- Gather loading requirements for the floor systems in the spaces of interest.

The following loads were used in the design of the alternative structural system. The loads were provided as part of the construction documents for the project. As seen the loads for the exhibit level floor are quite significant as to allow for cars, motorcycles, boats and whatever else large items would be required for a convention.

2.00 STRUCTURAL DESIGN LOADS:

OCCUPANCY OR USE	LIVE LOAD
EXHIBIT SPACE (FOR SLABS AND BEAMS)	350 PSF
EXHIBIT SPACE (FOR COLS AND PUNCHING SHEAR DESIGN)	250 PSF
GUEST ROOM LEVELS	40 PSF
LOBBIES	100 PSF
STAIRS	100 PSF
CORRIDORS	80 PSF
BALCONIES	60 PSF
MECHANICAL ROOM	*150 PSF
ELEVATOR MACHINE ROOM/KITCHEN	*150 PSF
ROOF	20 PSF
PARTITION DEAD LOAD	20 PSF
STORAGE	125 PSF
MISC. DEAD LOAD	**5 PSF
MISC. DEAD LOAD (PARKING AREAS)	**5 PSF
PARKING AREAS	50 PSF

NOTE: LIVE LOAD REDUCTION IS TAKEN IN ACCORDANCE WITH THE APPLICABLE CODE.
* OR ACTUAL WEIGHT OF EQUIPMENT.
** ALLOWANCE INCLUDES ELECTRICAL, PLUMBING, MECH., ETC.

SNOW LOADS:

GROUND SNOW LOAD	30 PSF
EXPOSURE FACTOR	Ce = 1.0
IMPORTANCE FACTOR	I = 1.1
THERMAL FACTOR, TYP.	Ct = 1.0
THERMAL FACTOR, LOADING DOCK ROOF	Ct = 1.2
FLAT-ROOF SNOW LOAD, TYP.	23.1 PSF
FLAT-ROOF SNOW LOAD, LOADING DOCK ROOF	28 PSF

WIND LOADS:

BASIC WIND SPEED (3 SEC. GUST)	90 MPH
IMPORTANCE FACTOR	I = 1.15
EXPOSURE	B
INTERNAL PRESSURE COEFFICIENT	+/- 0.18

NOTE: SEE S9.1 FOR ROOF JOIST AND ROOF DECK LOADS

- Determine the best steel alternative for the space allotted (composite joists).

An 18" deep composite joist was selected to carry the required floor loads for the convention entry and museum level. In limiting the structural members to a depth of 18" the existing ceiling height utilized with the concrete structure will not need to be changed. The 14' floor to floor height for the convention entry level has a 10'-3" ceiling as the highest ceiling level (for the main lobby).

The proposed steel structure with 18" deep joists and beams can maintain the 10'-3" ceiling height by:

14'-0" Floor to floor height
- 5" Decking and slab on deck
- 18" Joists (and girders)
- 16" Duct (deepest used on the floor)
- 6" Ceiling (drywall with high-hat light fixtures)

10'-3" Ceiling height = No Change

Note: The plumbing and electrical requirements would be mainly constructed with in the 18" deep joist space along with the 6" ceiling space and thus any transitions between the two spaces.

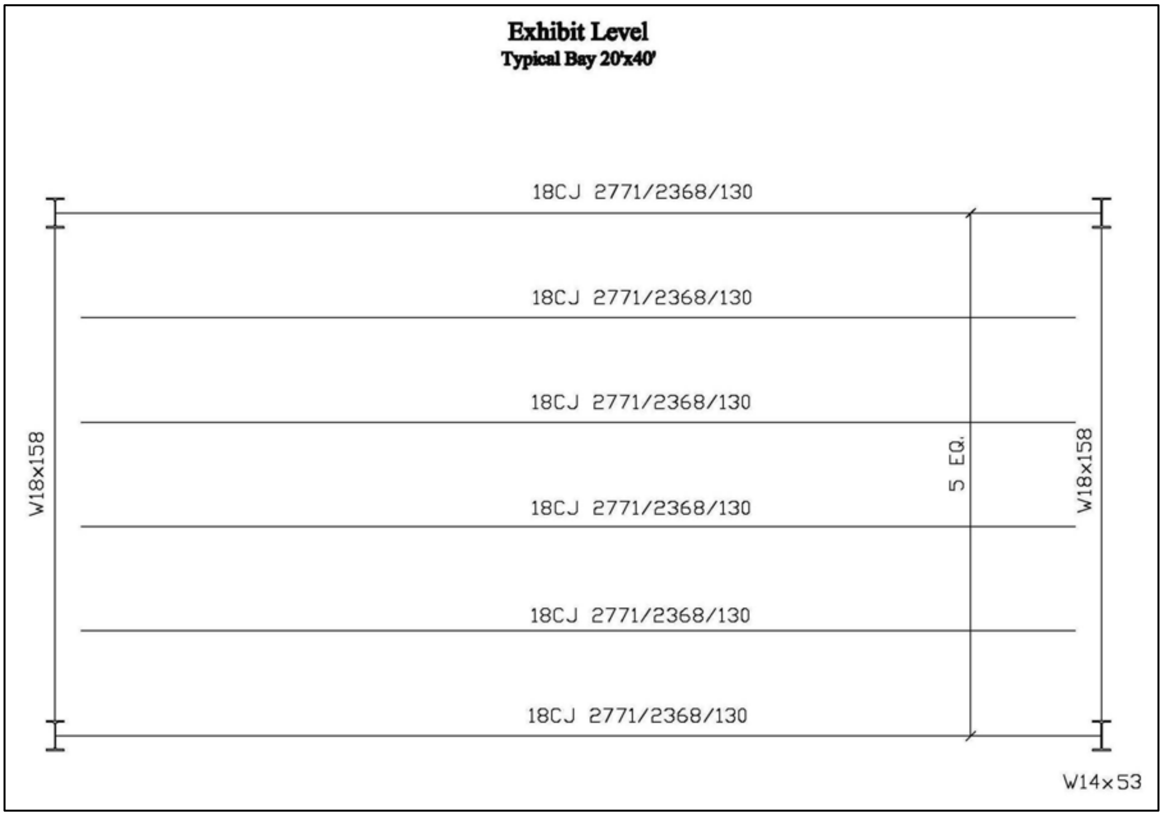
The 10'-3" ceiling height can be met even with the deeper structural system; 18" deep joist + 5" slab on deck vs. 13" cast in place flat plate concrete with drop panels. To achieve the ceiling height required the ductwork can be run entirely under the joist and girders, while the piping and electrical systems be run through the joist openings. An 18" joist has openings that allow for 7" round, 6x6 square and 4x9 rectangular duct sizes, these opening shall be adequate for electrical and piping systems. Additional openings may need to be cut / fabricated into the W-shape girders for plumbing construction to maintain the proper pitch and flow.

- Design the proposed steel structure.

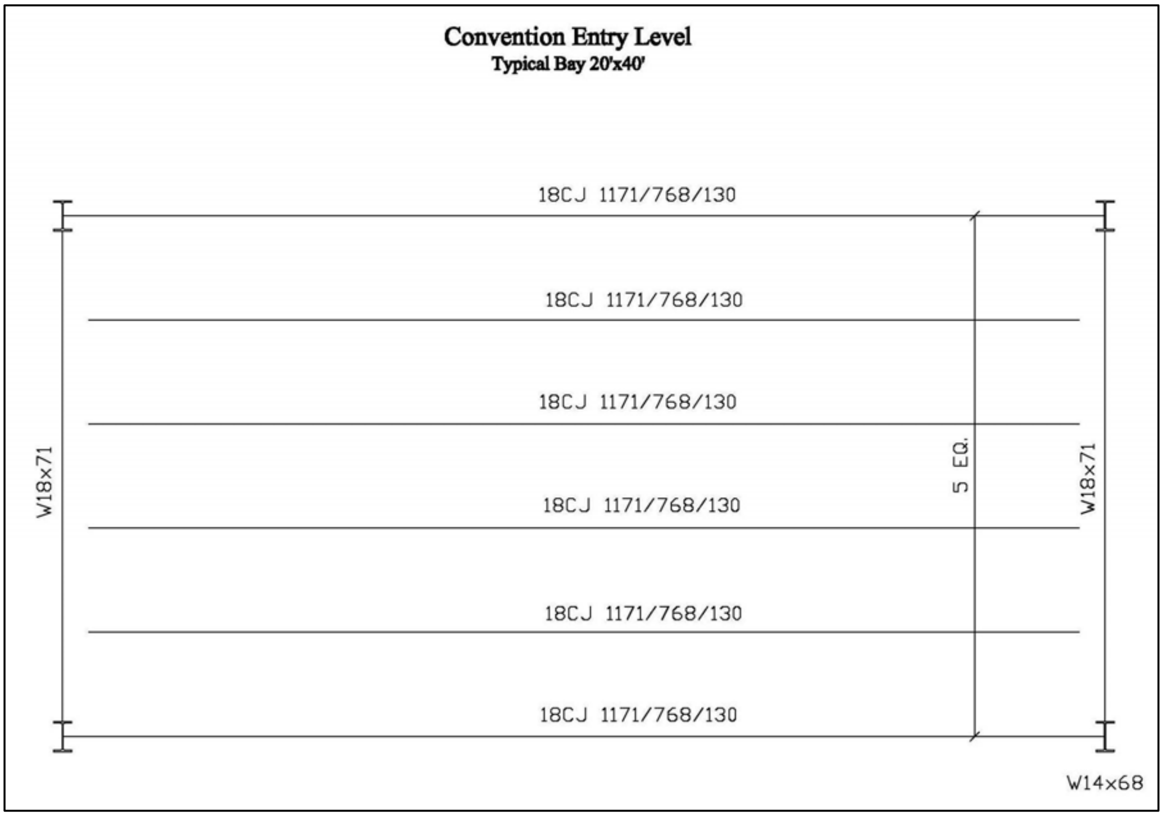
The proposed composite joist floor system was designed using the 1st Ed. CJ Series Standard Specifications for Composite Joists; Weight table and bridging tables code of standard practice by SJI (Steel Joist Institute). An excel spread sheet was utilized to work out the calculations and to allow for multiple trials to be run efficiently maximizing the joist efficiency (depth, spacing, decking etc…). The Steel Construction Manual, 13th Ed. was also used to size the columns and girders to support the composite joists and again an excel spread sheet was used to compute the design requirements for the girders and columns from the joist design information.

Two separate designs were completed, the first for the 'Exhibit Level' floor system and the second for the 'Convention Entry' floor system (above the museum level). Both designs were completed using 3" metal deck, 2.5" concrete thickness, 4,000psi normal weight concrete, 4' joist spacing, 18" deep joist and a 20'x40' bay size. The joist, girder and column sizes varied for each floor as the loading conditions were drastically different. The exhibit level floor system requires the support of a 350psf live load for the convention center activities while the convention entry floor system requires a 100psf live load.

The proposed exhibit level floor system design utilizes 18CJ 2771/2368/130 composite joists with 80-3/4" shear studs, W18x158 girders, and W14x53 columns that support the single 14' story height. The following diagram depicts the typical bay design for the exhibit level floor. See Appendix C for the structural system design calculations for the exhibit level floor system including the vibration analysis using the SJI method.



The proposed convention entry level floor system design utilizes 18CJ 1171/768/130 composite joists with 42-5/8" shear studs, W18x71 girders, and W14x71 columns that support the convention entry floor system along with the exhibit level floor system from above. The following diagram depicts the typical bay design for the convention entry level floor. See Appendix C for the structural system design calculations for the convention entry level floor system including the vibration analysis using the SJI method.



- Perform a detailed estimate for the structural system and compare to the cast-in place concrete structure.

The following page summarizes the estimates for both the existing cast-in-place concrete structure and the proposed steel structure for the convention entry and exhibit levels. The steel superstructure costs an additional $102,361 over the concrete structure, which works out to be approximately an additional $3.06/SF for the 33,500SF of elevated exhibit and convention entry floor systems. See Appendix E for the quantity take offs and detailed estimates for the proposed structural system vs. the existing structural system.

The additional cost can be outweighed by the significant schedule savings achieved in utilizing a steel structure over the existing cast-in-place concrete structure (see 'Construction Analysis: Re-sequencing Study – AE Depth Study' section of this report for more information). Along with schedule savings in utilizing the steel structure it also facilitates a cleaner more efficient work space. The existing concrete structure mandates the use of shoring and re-shoring which greatly prohibits the flow of material, workers and thus progress underneath the elevated structural slab, where as there are no obstructions underneath the steel frames slab on deck. This provides a much cleaner more efficient workflow and greater opportunity for the overlapping of trades by starting MEP trades and finishing trades sooner after the completion of the structure.

Structural Estimate Summary

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Marriott Hotel at Penn Square and Lancaster County Convention Center
Structural System Cost Comparison: Proposed Steel vs. Existing Concrete

Steel System

	Item	Amount (Tons)	Unit Cost ($/Ton)	Total
051223.77.0500	**Column Total:**	**17.41**	**$2,000**	**$34,816**
051223.73.0400	**Base Plate Total:**	**0.71**	**$1,000**	**$708**
051223.76.0500	**Beam Total:**	**57.82**	**$2,200**	**$127,204**
052123.50.7100	**Joist Total:**	**193.24**	**$3,000**	**$579,720**
053113.50.3400	**Metal Decking w/ Slab:**	**38525 SF**	**$10/SF**	**$385,250**
053113.75.1750	**Spray Fire Proofing**	**38525 SF**	**$2/SF**	**$77,050**
			Total:	**$1,204,748**

Concrete System

	Item	Concrete (CY)	$/CY	Total
033105.35.0411	**Columns**	641	$137.00	$87,817
033105.35.0200	**Elevated Structural Slabs**	1479	$113.00	$167,127

	Item	Placing (CY)	$/CY	Total
033105.70.0800	**Columns**	641	$64.50	$41,345
033105.70.1500	**Elevated Structural Slabs**	1479	$45.25	$66,925

	Item	Finishing (SF)	$/SF	Total
033529.30.0350	**Elevated Structural Slabs**	38525	$0.37	$14,254

	Item	Formwork (SF)	$/CY	Total
031113.25.6650	**Columns**	12466	$8.50	$105,961
031113.35.2150	**Elevated Structural Slabs**	38525	$11.15	$429,554

	Item	Shoring (Each)	$/Each	Total
031505.70.0500	**Elevated Structural Slabs**	930	$15.80	$14,694

	Item	Reshoring (SF)	$/SF	Total
031505.70.1500	**Elevated Structural Slabs**	33500	$1.60	$53,600

	Item	Rebar (Tons)	$/Ton	Total
032110.60.0250	**Columns**	14.89	$2,000.00	$29,780
032110.60.0400	**Elevated Structural Slabs**	48.71	$1,875.00	$91,331

Total **$1,102,388**

Steel System Cost an Additional: $102,361

- Develop a schedule for the erection of the steel and compare to the schedule for concrete.

See the 'Construction Analysis: Re-sequencing Study – AE Depth Study' section of this report for complete detail on the re-sequencing and schedule saving achieved in utilizing the proposed alternative structural designs.

- Analyze the architectural conflicts in changing from a 30'x30' bay size to 20'x40'

The column grid changes can be seen on the following pages containing the floor plan of the original 30'x30' grid and then that of the proposed 20'x40' grid. The revision to the bay size allows for the steel to be more efficient, in spanning the joists the longer distances, and allowing for the girder depth to be kept to the 18" depth of the joists. The convention entry facilitated itself to the 40' bay dimension as the main width of the floor is 120', thus instead of (4) 30' bays, it can easily be modified to (3) 40' bays.

As seen on the following pages, the proposed 20'x40' poses minimal conflicts to the original design. The proposed grid contains two conflicts, one being with an entry door and the second with a column in the middle of the Reception room (C86). Both conflicts are minimal and can be mitigated with slight adjustments. The proposed grid actual improves the layout of the current architectural floor plan. In the Exhibit Staging room (C53) the columns that were originally located within the room and have been moved to align with the wall to allow for a more open floor space.

Existing Convention Entry Floor Plan – 30'x30' Bay

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1 A2.2B ENLARGED PLAN - CONVENTION ENTRY LEVEL - PART B
1/8" = 1'-0"

Issued For Bid

Proposed Convention Entry Floor Plan – 40'x 20' Bay

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1 A2.2B ENLARGED PLAN - CONVENTION ENTRY LEVEL - PART B
1/8" = 1'-0"

PL-BSMT.DGN

Issued For Bid

- Design the Ivany block cantilever retaining wall to replace the existing cast-in-place concrete pinned foundation wall utilizing 'RAM Advanse' retaining wall designer.

Ram Advanse 'Retaining Wall' was used to aid in the design of the block cantilevered retaining wall design. The two controlling load cases were analyzed in the design of the wall. First, the wall during construction where the wall is cantilevered, completely backfilled (with 125pcf soil per the project specifications) and a construction load of 25 lb/ft^2 applied to the soil behind the wall. Secondly, the load case of the completed wall where the wall is completely backfilled, the joist is framed into the wall and applying a load, and the slab on grade with its 250lb/ft^2 load applied behind the wall. The load case of the finished wall (with the joist load and slab on grade load) controlled the design of the wall.

The design of the wall assumed the following: The joists were constructed with a pocket depth of 8" thus not applying an eccentricity to the wall. The wall is constructed with 3,000psi concrete and 60ksi steel.

See the following pages for the RAM Retaining Wall printouts for the design of the retaining wall under each load condition and the detail of the existing pinned foundation wall design using cast-in-place concrete. See Appendix B for a complete printout of the RAM Retaining Wall design reports.

Existing Retaining Wall Design Detail

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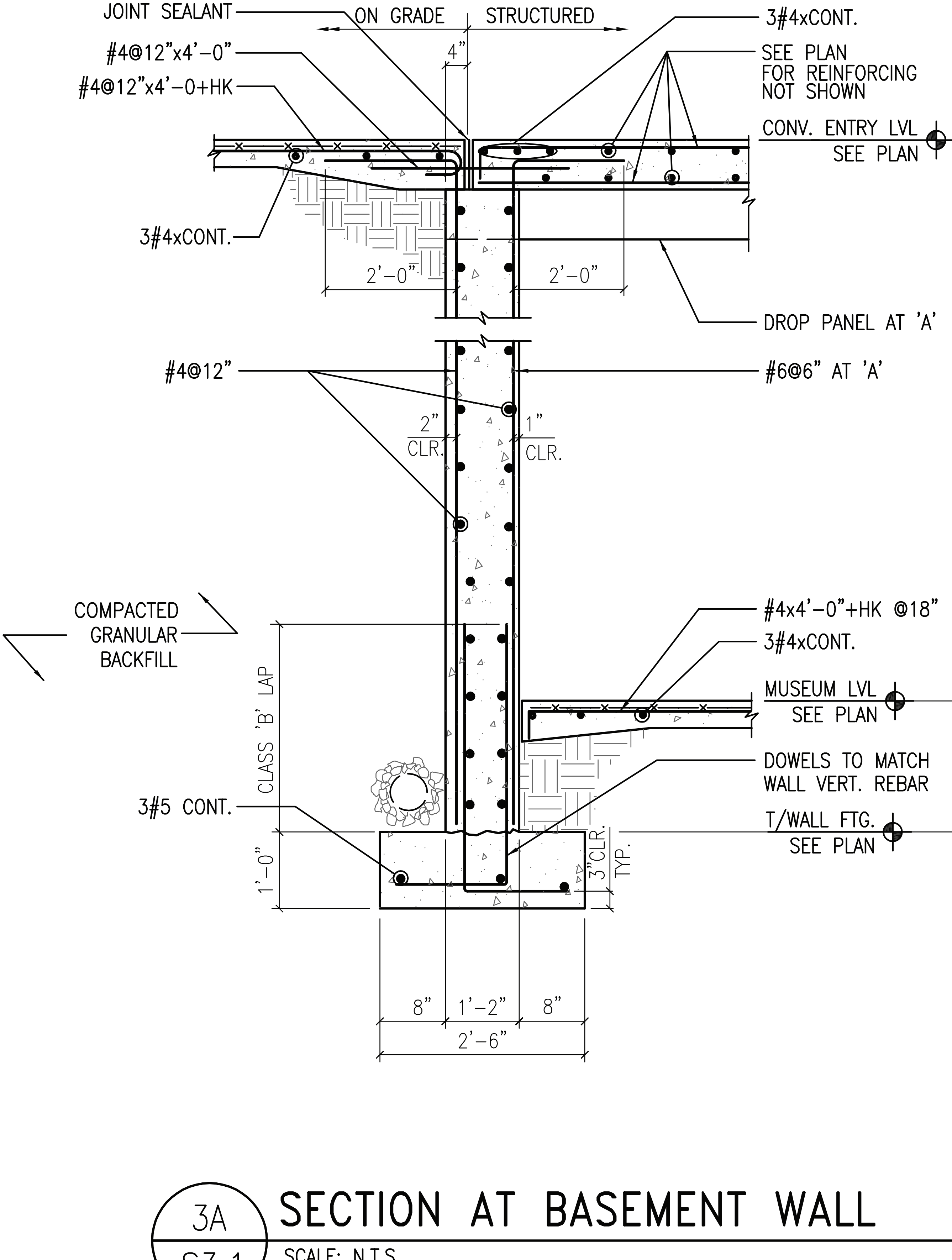

3A
S3.1

SECTION AT BASEMENT WALL

SCALE: N.T.S.

Proposed Cantilevered Retaining Wall Design Details

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RAM Retaining Wall

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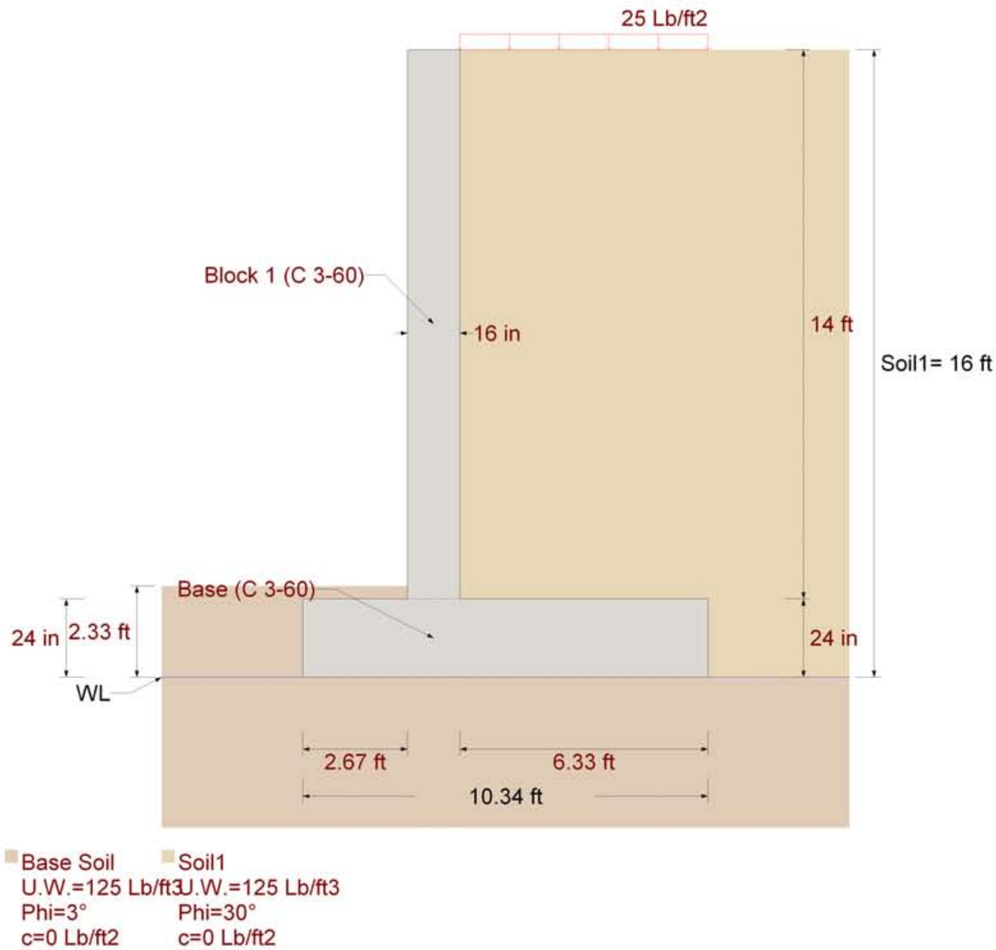

RAM Retaining Wall

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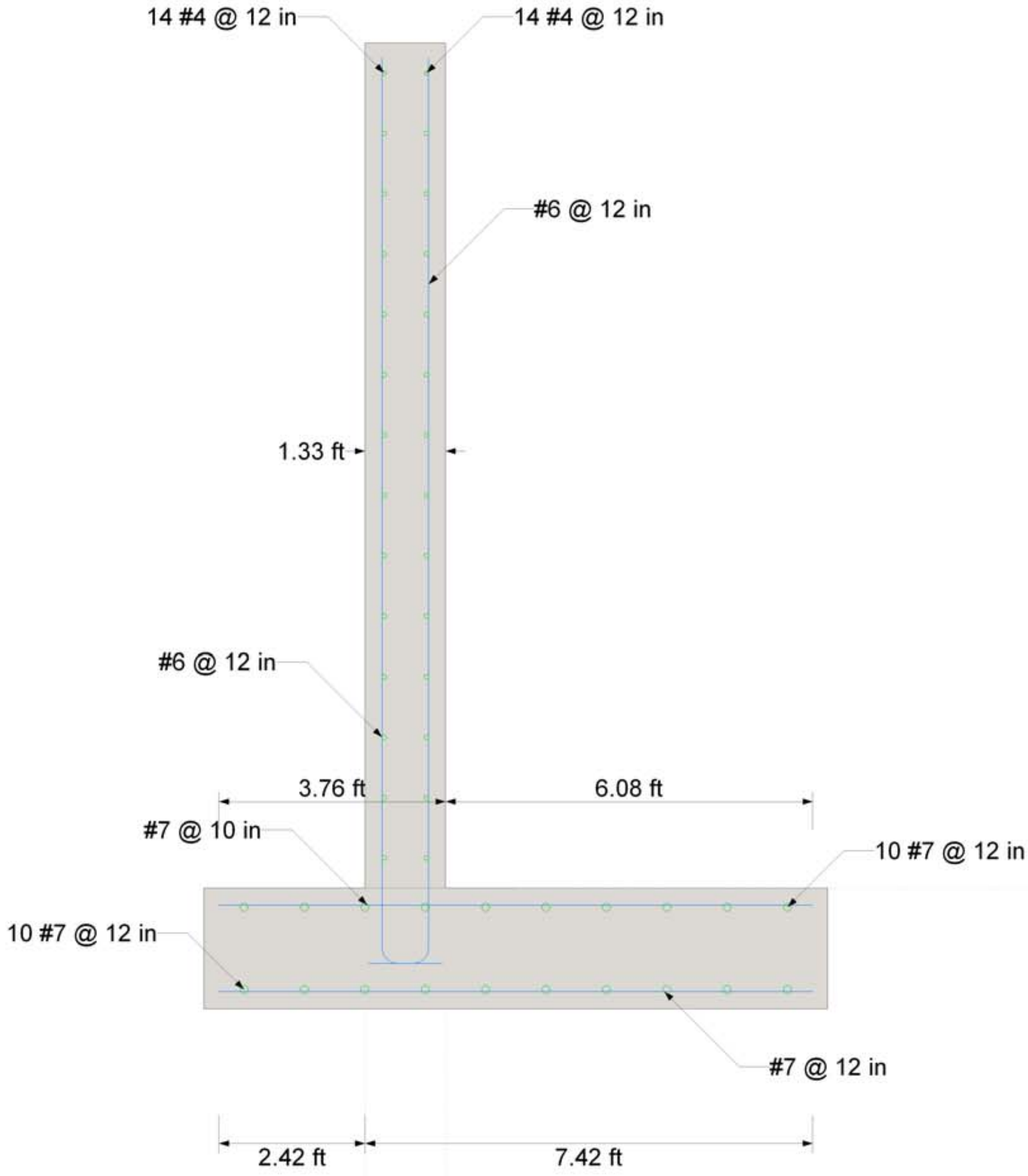

Proposed Pinned Retaining Wall Design Details

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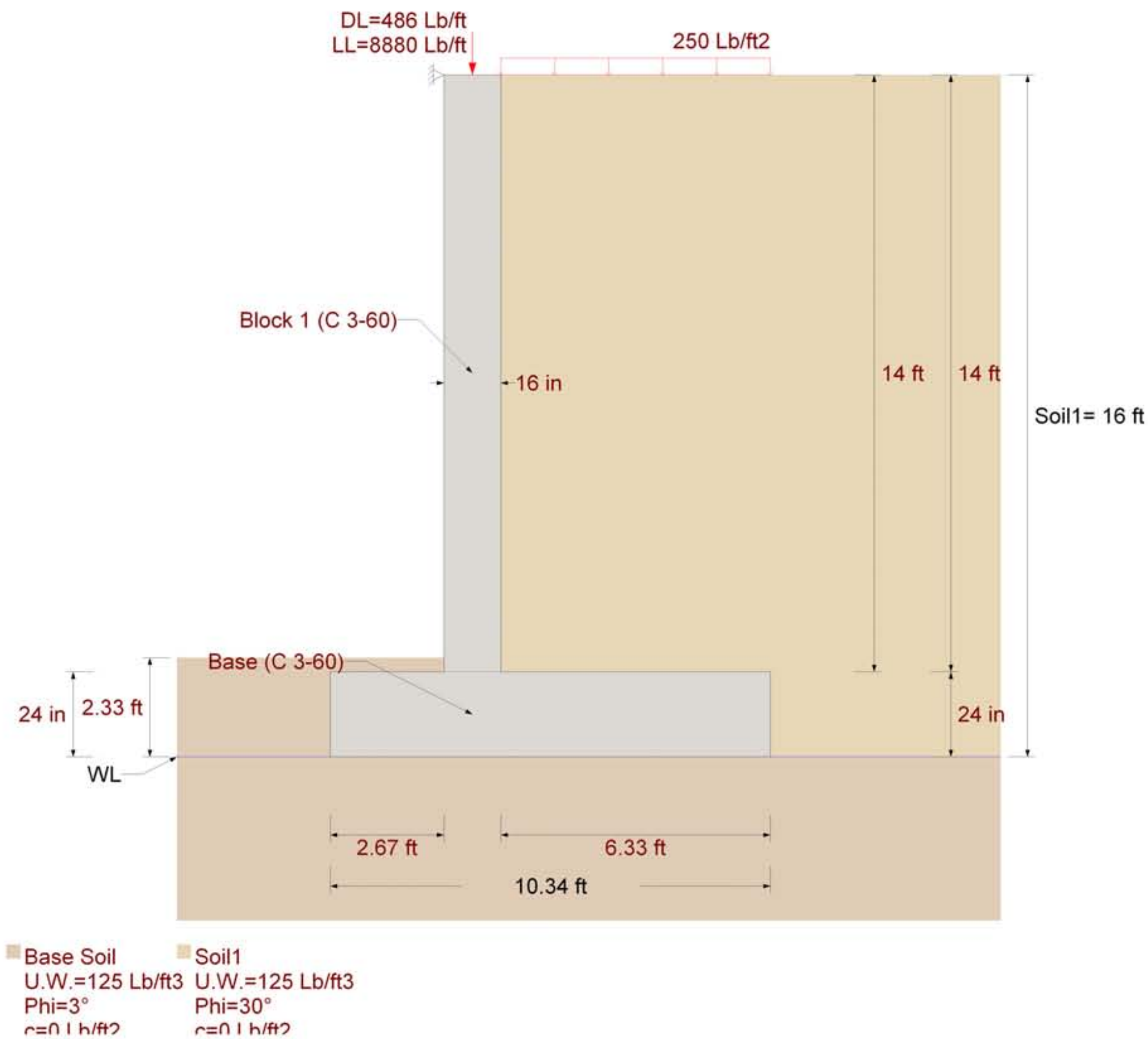
DL=486 Lb/ft
LL=8880 Lb/ft
250 Lb/ft2
Block 1 (C 3-60)
16 in
14 ft
14 ft
Soil1= 16 ft
Base (C 3-60)
24 in
2.33 ft
24 in
WL
2.67 ft
6.33 ft
10.34 ft
Base Soil
U.W.=125 Lb/ft3
Phi=3°
c=0 Lb/ft2
Soil1
U.W.=125 Lb/ft3
Phi=30°
c=0 Lb/ft2

BENTLEY **RAM Retaining Wall**

File name:E:\Structural Breadth\Pinned\Trevors Retaining Wall (2).rtw
Units system: English
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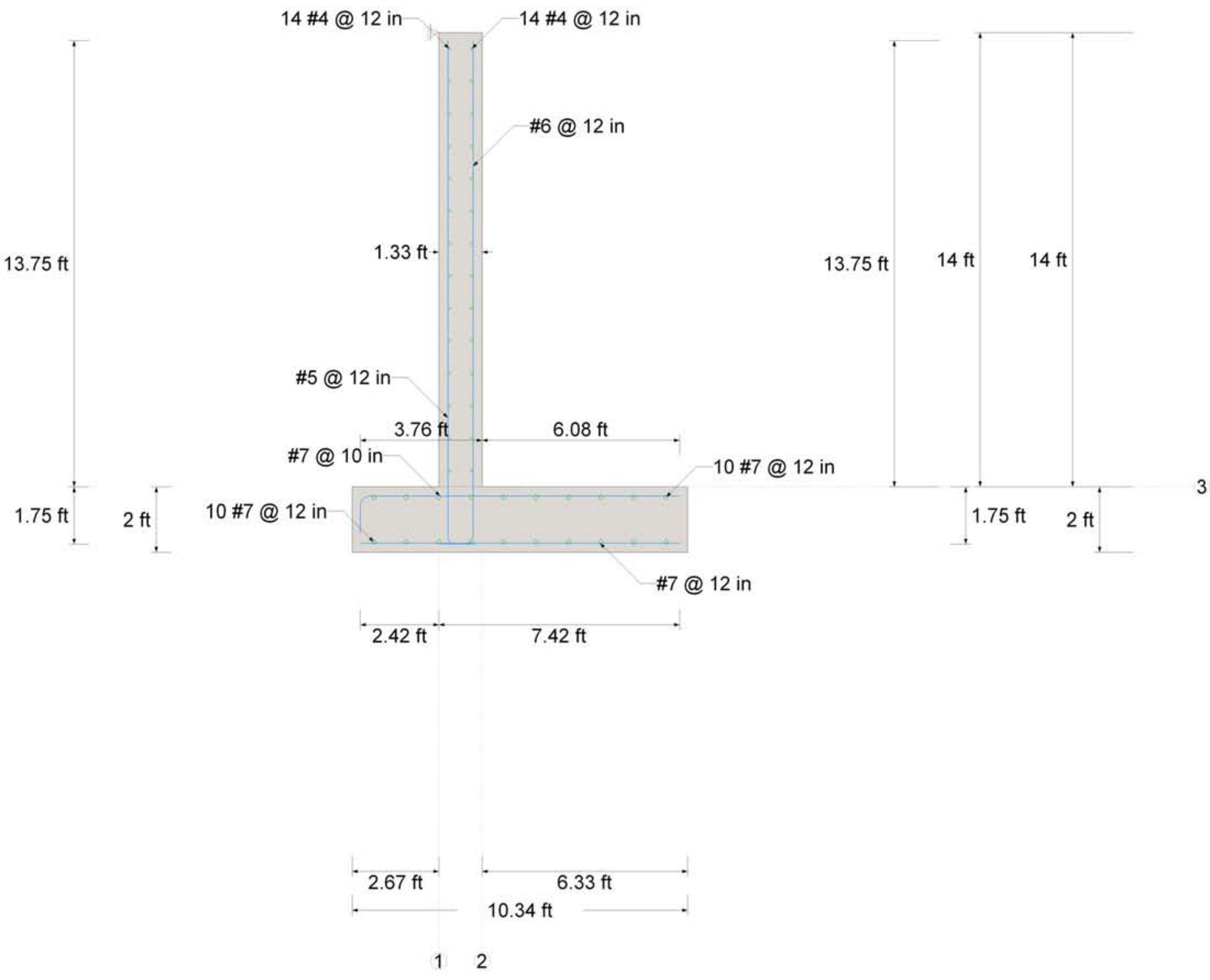

- Compare the cost of the proposed block foundation wall system.

The design of a cantilever retaining wall requires more rebar then that of a pinned retaining wall to resist the soils pressure. The additional rebar can be justified based on the savings obtained in eliminating the cast in place concrete elevated structural slabs which has a significant amount of edge reinforcing to obtain the required bond to transfer loads into a pinned retaining wall. Also, a block wall nearly eliminates the requirement of forming and finishing compared to a cast-in-place concrete wall and thus cost and schedule saving can be achieved.

The coordination to construct the Ivany block wall system is minimal as; there is already a masonry contract for the project, and secondly the mason (bricklayers) lay the block, place the steel, and pour the concrete all in one continuous process for the construction of the proposed block foundation walls.

See the following sheets for a detailed takeoff and estimate of the existing foundation wall design and of the proposed block cantilevered retaining wall design. The Ivany block retaining wall provides a savings of $289,125 over the cast-in-place concrete wall.

Foundation Wall Estimate

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Marriott Hotel at Penn Square and Lancaster County Convention Center
Foundation Retaining Wall Comparison: Cast-in-Place vs. Ivany Block

Retaining Wall Estimates

Utilized Cast-in-Place Concrete Wall System

A2020 110 Walls, Cast in Place

Reinforcing Quantity Take Off

		Rebar #	Spacing	Length of Rebar/Ft. of Wall	Rebar (lb/ft)	Total (lbs/ft)
Wall	Horizontal	4	12"	28	0.668	18.7
	Vertical	6	6"	56	1.502	84.1
	Dowels	6	6"	24	1.502	36.0
Footing	Horizontal	5	(3 total)	3	1.043	3.1
					Total	142.0

Concrete Quantity Take Off

	Height (ft)	Thickness (ft)	Area (ft^3)	CY/LF
Wall	14	1	14	0.5
Footing	1	2.5	2.5	0.1
			Total	0.6

	Wall Height (ft)	Placing Method	Concrete (CY/LF)	Reinforcing (lbs/lf)	Wall Thickness (inch)	Cost per L.F.		
						Mat.	Inst.	Total
8260	14	pumped	0.519	25.19	12	81	170	251
8400*	14	pumped	0.6	142.0	12	225	425	650

*extrapolated cost data to account for additional concrete and reinforcing per linear foot

A2020 110 1500 8400*

Foundation wall, cast in place, pumped, 14' high, 12" thick

Estimate includes: Formwork, Reinforcing, Unloading and Sorting Rebar, Concrete (3,000), Placing, Finish Walls (one side).

Quantity (LF)	**$/LF**	**Total**
2250	650	**$1,462,500**

Proposed Ivany Block Wall System

B2010 111 Reinforced Concrete Block Wall - Regular Weight

Reinforcing Quantity Take Off

		Rebar #	Spacing	Length of Rebar/Ft. of Wall	Rebar (lb/ft)	Total (lbs/ft)
Wall	Horizontal	4	12"	28	0.668	18.7
	Vertical	6	12"	28	1.502	42.1
	Dowels	6	12"	12	1.502	18.0
Footing	Horizontal	7	(20 total)	20	2.044	40.9
	Horizontal	7	10"	24	2.044	49.1
					Total	168.7

Concrete Quantity Take Off

	Height (ft)	Thickness (ft)	Area (ft^3)	CY/LF
Footing	1.75	10.34	18.095	0.7
			Total	0.7

	Type	Size (in)	Strength (psi)	Reinforcing (lb/ft)	Wall Thickness	Cost per L.F.		
						Mat.	Inst.	Total
6550	Solid	2-4x8x16	2,000	33.59	16"	5.1	12.3	17.4
6560*	Solid	16x8x16	3,000	168.7	16"	12.65	24.6	37.25

*extrapolated cost data to account for additional concrete strength and reinforcing per linear foot

B2010 111 8400*

Ivany Block Wall, 14' high, 16" thick, filled solid, pumped.

Quantity (LF)	**Height (ft)**	**Area (SF)**	**Cost per SF**	**Total**
2250	14	31500	37.25	**$1,173,375**

Ivany Block System Saves:	**$289,125**

** Estimates exclude excavation.

Plumbing Redesign: Groundwater Lift Station Redesign – AE Breadth Study

Analyze Steps/Solution:

- Obtain a copy of the hydro-geological study reports.

A copy of the new hydro-geological study report dated April 12, 2007 was obtained from Reynolds Construction Management to perform the plumbing redesign. The report was completed by McClymont & Rak Geotechnical Engineers, a local agency near the Lancaster project, whom also performed the initial hydrogeological study on Oct. 4, 2005.

The purpose of the hydro-geological study is to compute the steady flow and peak flow of groundwater into the buildings permanent dewatering system, expressed in gallons per minute, so the permanent dewatering system can be sized. The engineer can then size and stage the pumps, using the results of the hydro-geological study.[12]

- Analyze the existing groundwater lift station design.

The existing permanent dewatering system utilizes a submersible duplex system with each pump rated for 60 GPM, single phase 115 V electricity, 3000 rpm and 13 ft of head. The pre-cast concrete basin for the duplex system is 60" interior diameter. Under the slab the design utilizes 4" perforated PVC pipe to drain water to the lift station. Along with the under slab drainage the design calls for 6" perforated pipe behind the foundation walls to drain water.

The partial plan found on the next page depicts the original deign for the remediation of ground water in the museum level.

Existing Museum Level Underground Plumbing Plan

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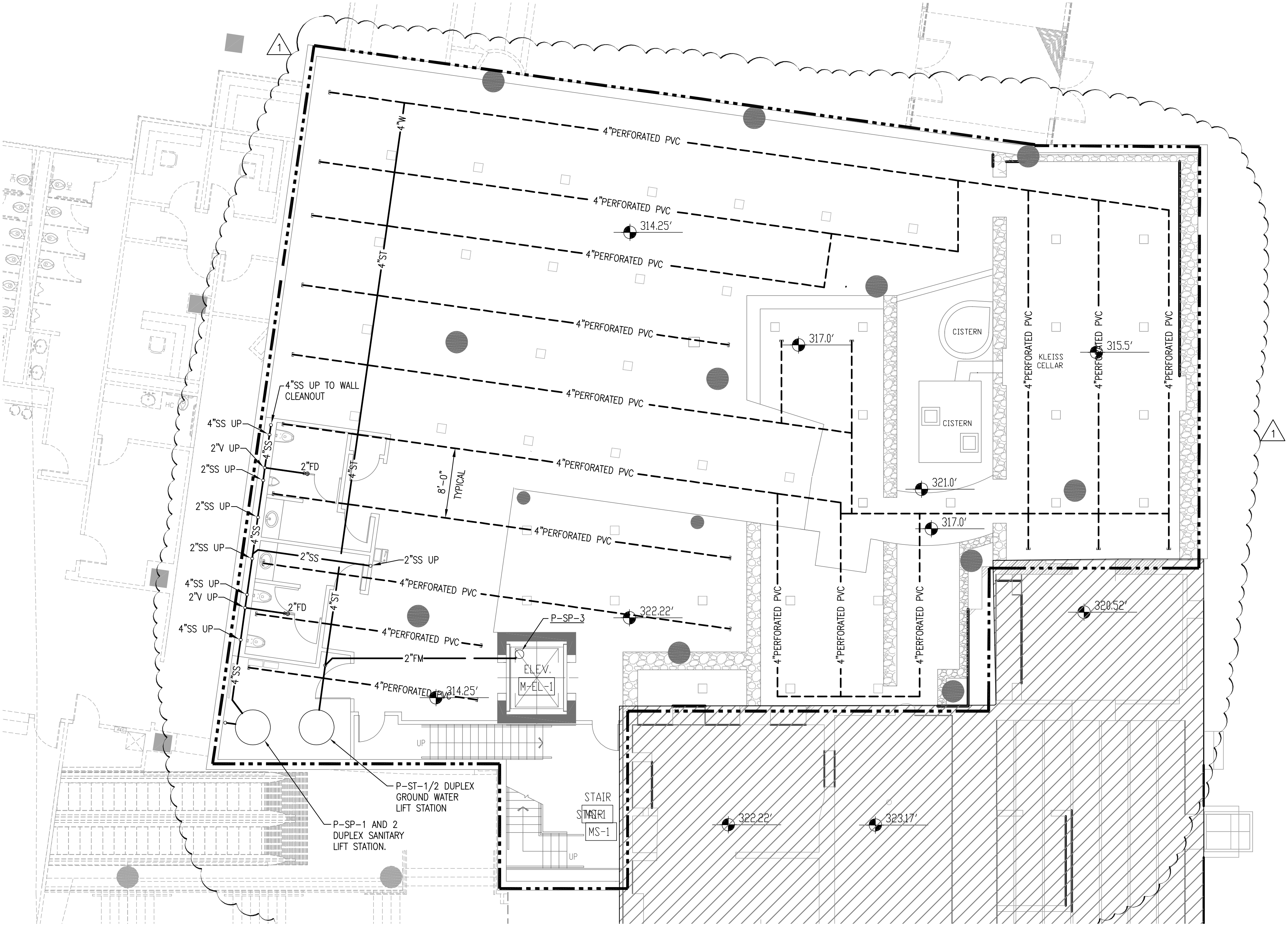
4"PERFORATED PVC
314.25'
4"W
4"ST
KLEISS CELLAR
315.5'
CISTERN
CISTERN
317.0'
321.0'
317.0'
8'-0"
TYPICAL
4"SS UP TO WALL CLEANOUT
4"SS UP
2"V UP
2"SS UP
2"FD
2"SS UP
2"SS UP
2"SS
2"SS UP
4"SS UP
2"V UP
2"FD
4"SS UP
4"SS
2"FM
P-SP-3
ELEV.
M-EL-1
322.22'
320.52'
322.22'
323.17'
UP
STAIR
MS-1
P-ST-1/2 DUPLEX GROUND WATER LIFT STATION
P-SP-1 AND 2 DUPLEX SANITARY LIFT STATION.
1

- Design a new lift station system to accommodate the required loads.

The hydro-geological study from the geotechnical engineer recommends the design of the groundwater lift station system to be designed for a constant flow of 340 gallons per minute and a peak flow of 820 gallons per minute (for times of exceptional flow).[12]

The proposed new design for the ground water lift station utilizes a three pump system. All of the three pumps (triplex) are sized to handle the 340 gallons per minute. The design uses five suspended float balls to control the triplex pump system, arranged vertically in the pre-cast concrete basin. The bottom float is an 'all-off' control that turns all the pumps off when there is minimal water in the basin; the second float controls the duty pump that turns on first anytime water reaches the specified level; the third float controls the 1st stand-by pump that turns on anytime more water enters the basin then the duty pump can handle individually; the fourth float controls the 2nd stand-by pump that turns on anytime more water enters the basin then the first two pumps can control; and lastly the fifth float is a high water level alarm – and does just that.

Along with the larger sized pumps and the addition of a third, the proposed design increases the sizes of the under slab and behind footing drain sizes. The under slab PVC drains are proposed to be 6" perforated PVC pipes to handle the additional flow, and the behind footing drains are to be 10" perforated PVC pipes. See figure 6 Flow rates for schedule 40 pipe sizes below for a chart depicting the different flow rate capabilities for different sizes of PVC pipe. The 6" pipe was selected for the under slab drainage system to handle the additional water flow requirements, allow for an appropriate factor of safety, and to reduce the risk of hydrostatic pressure building up underneath the museum level slab on grade. The museum level slab is not designed to resist hydrostatic pressure thus the necessity for the under slab drainage system. The under slab and behind footing drains are to be constructed in clean ¾-inch crushed rock to prevent any clogging of the perforated drain system.

Sch 40 Pipe Size	ID (range)	OD	**GPM** (with minimal pressure loss & noise)	**GPH** (with minimal pressure loss & noise)	**GPM** (with significant pressure loss & noise)	**GPH** (with significant pressure loss & noise)
2"	1.95-2.05"	2.38"	55 gpm	3300 gph	200 gpm	12,000 gph
3"	2.90-3.05"	3.50"	120 gpm	7200 gph	425 gpm	25,650 gph
4"	3.85-3.95"	4.50"	200 gpm	12,000 gph	600 gpm	36,000 gph
6"	5.85-5.95"	6.61"	500 gpm	30,000 gph	800 gpm	48,000 gph

Figure 6 Flow rates for schedule 40 pipe sizes[16].

The Museum Level is approximately 18 feet below the groundwater level during the periods of extraordinary rainfalls.[hgs] The design calculations for the proposed groundwater lift station system can be seen in Appendix G. Appendix G includes the equations and charts used to complete the design along with the excel spreadsheet titled ‘Groundwater Pump Design’ that was used to compute the equations to allow for multiple trials of varying combinations. The groundwater pump design process first calculates the head loss due to friction of the pipe, the pumps push the removed water through approximately 70 ft of four inch pipe to reach the city’s’ storm water system. Then the total dynamic head is calculated for the system and lastly the pump is sized.

To provide a check for the calculations each pump has a specific chart associated with it. The pump(s) selected for the redesign were Weil 2525, 4in discharge submersible pump, and the corresponding pump chart is seen below, as figure 7 Weil 2525 Pump Diagram. As seen in the figure below with a red highlight, 340gpm was selected from the chart and a vertical line was drawn to the 15 HP line, then a horizontal line was drawn to the left to the total head column to achieve a number approximately 92’ of total head for the pump. The total head of 92’ is greater then that required as seen in the calculations.

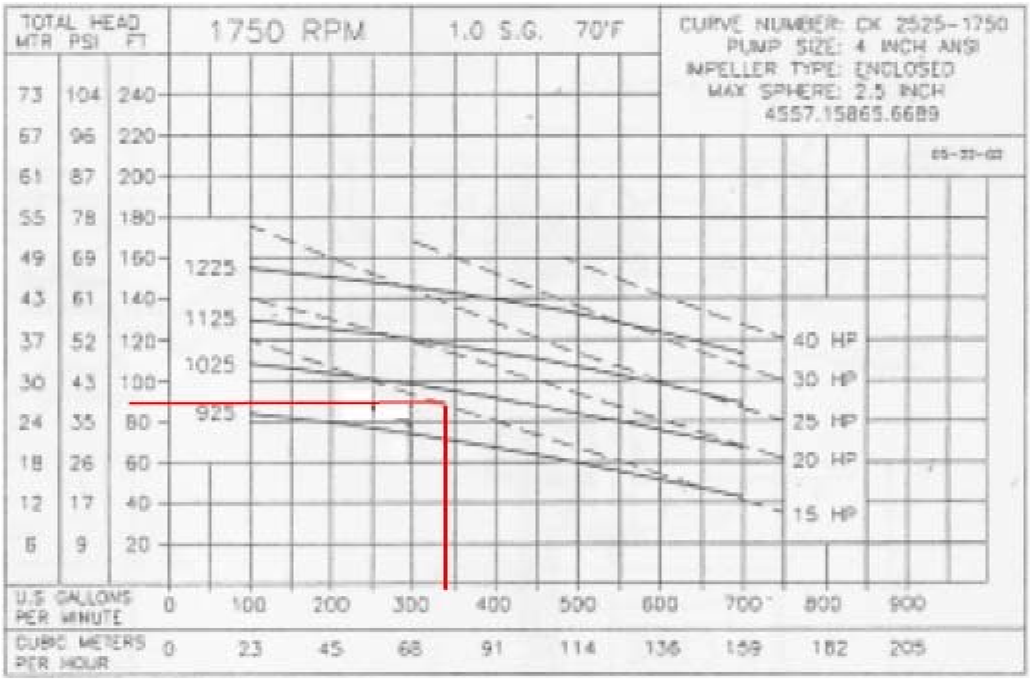

Figure 7 Weil 2525 Pump Diagram

The proposed design can be seen on the following two sheets. The next page, titled 'Triplex Groundwater Pump System Details' outlines the design of the pre-cast basin with the three pumps inside along with the five suspended multiple floats. Also on the sheet is an elevation detail of the suspended multiple floats arrangement and a bill of materials for the design. The following page includes a new plan for the museum underground to incorporate the changes in the design. In the plan, the 4" perforated PVC underground drains have been changed to 6" perforated PVC. Due to the increase in size of the pre-cast basin from 60" to 96", to include an additional pump, the pit has been relocated in the mechanical room to allow for the additional space requirements, and the corresponding under slab drain have been rerouted to the new location.

Trevor J. Sullivan
Construction Management
AE Faculty Consultant: Dr. Horman

Proposed Groundwater Lift Station System Details

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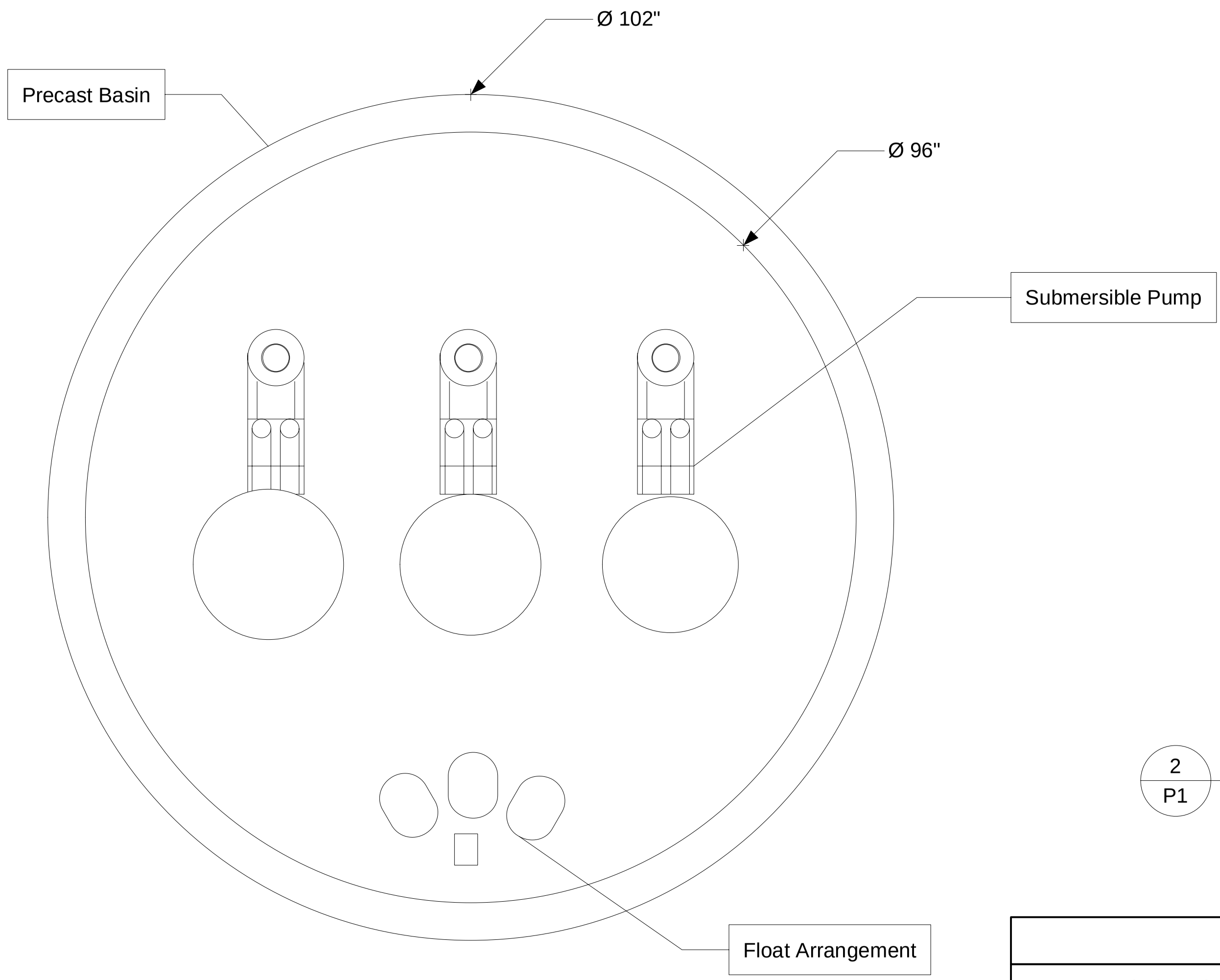
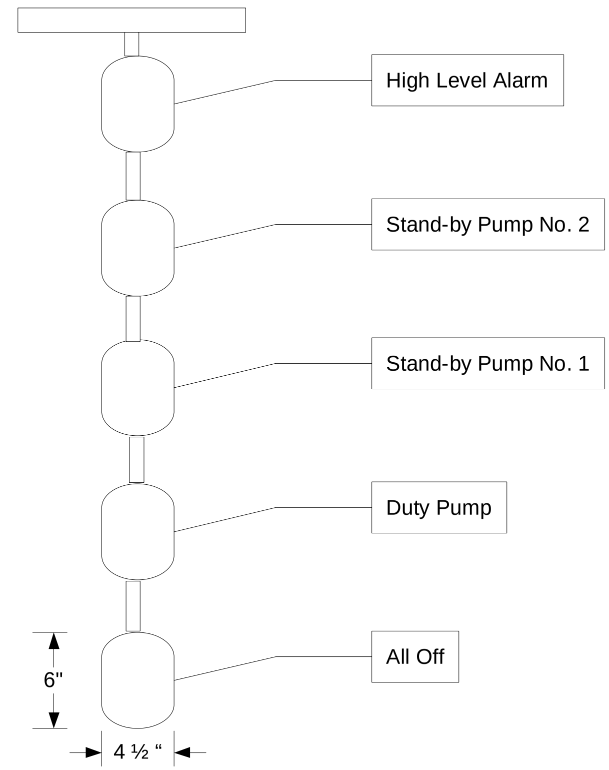


1 P1 Triplex Groundwater Lift Station Detail

Plan



2 P1 Suspended Multiple Float Arrangement

Elevation

Triplex Groundwater Pump System			
Capacity/Head			340 GPM at 92' TDH
Pump	3	Weil 2525	4" discharge with cast iron impeller, cast iron casing
Motor	3	Weil 2525	15 HP, 460 volt, 3 phase, 1750 RPM
Controls	5	S20NO	Suspended mercury float switch level controls
Basin	1	by others	96" I.D. precast concrete basin with access hatch

Triplex Groundwater Pump System Details

Museum Level	Redesign	Marriott Hotel and Lancaster County Convention Center Project	Scale: NTS	APPROVED

Proposed Museum Level Underground Plumbing Plan

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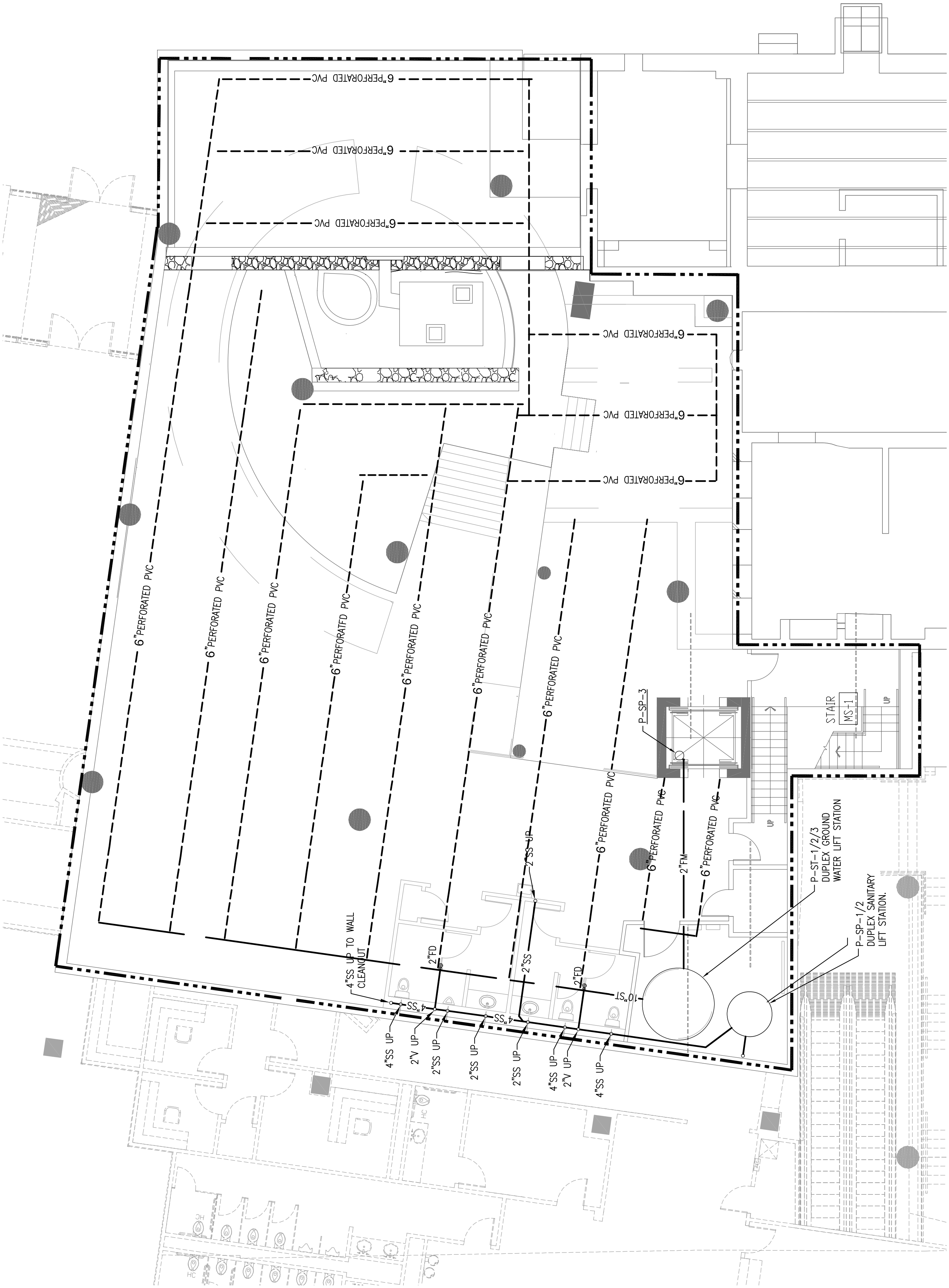
6"PERFORATED PVC
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6"PERFORATED PVC
6"PERFORATED PVC
6"PERFORATED PVC
6"PERFORATED PVC
P-SP-3
STAIR
MS-1
UP
UP
2"FM
2"SS UP
P-ST-1/2/3
DUPLEX GROUND
WATER LIFT STATION
P-SP-1/2
DUPLEX SANITARY
LIFT STATION.
4"SS UP TO WALL
CLEANOUT
2"FD
2"SS
2"FD
10"ST
4"SS
4"SS
4"SS UP
2"V UP
2"SS UP
2"SS UP
2"SS UP
4"SS UP
2"V UP
4"SS UP

- Compare new design to the original.

The new design for the groundwater lift station as outlined above included, larger under slab drains, larger behind footing drains, larger pumps, more pumps, a larger pre-cast basin, and more control floats. The time to discover the problem of the additional groundwater, mitigating the additional groundwater temporarily, designing a new system, approval and ordering of the new system, and installing the new system all add time to the schedule. The delay in the museum level is very costly to the schedule as it delays the ability to place a concrete structure above it and thus proceed with the construction. Through implementing the proposed alternative steel structure and the new sequencing as outlined in the Construction Depth portion of this paper the impacts of these delays can be reduced.

The additional items and larger items to the redesign of the groundwater lift station design have a cost increase over the existing lift station design. Along with the additional plumbing costs, increased electrical requirements to the system and extra excavation of rock also add cost to the redesign. Figure 8 Groundwater Piping Design Estimate below outlines the additional costs to the plumbing contractor.

Groundwater Piping Design Estimate

Item	Description	Size	Quantity	Unit Cost	Cost
Pipe*			LF		
Carbon Steel	Plain Sch. 40	8"	80	$85.00	$6,800
Carbon Steel	Plain Sch. 40	4"	175	$30.00	$5,250
PVC	Sch 40 Perforated	6"	825	$10.00	$8,250
PVC	Sch 40 Perforated	8"	250	$15.00	$3,750
Equipment					
Pre-cast Basin	96" diameter	1	1	$5,000.00	$5,000
Submersible Pumps	340 GPM	1	3	$15,000.00	$45,000
				Total	**$74,050**

* includes an allowance in the unit price for fittings.

Additional Plumbing Costs Total $74,050

Figure 8 Groundwater Piping Design Estimate

Laser Scan Surveying Research

Background

The use and implementation of laser scan surveys is a relatively new practice considering laser scan technology was developed in the mid 1990's. Simply, laser scan technology enable the setup of a small machine on a tripod to rotate and scan to gather enough information to accurately produce drawings or a 3D model of the building or structure. Traditional survey techniques require a survey crew to measure distances, angles and elevations. The process of surveying using traditional techniques is far more time consuming and also has larger tolerances then that of laser scanning.

Problem Identification

As mentioned previously, the project maintains and utilizes the existing façade of the Watt & Shand department store into the new building. The façade is 4 stories above grade and approximately 900 ft. long. Parts of the façade are over 100 years old. Extensive stabilization and façade monitor processes have been implemented on the project, though a lack of detail was taken in locating the exact dimensions and makeup of the façade. The lack of knowledge as to the specific location of the façade led to a major structural redesign as all of the caissons needed to be relocated to accommodate the drill rig near the façade to drill the required holes.

Structural Redesign

The locations of the interior concrete columns were designed too close to the existing façade to allow the caisson rig to drill the caissons in the required location. A major structural redesign took place to move the concrete columns in from the façade one foot as to avoid the conflict. At the surface it sounds like a simplistic solution that should be a major conflict though, in moving the location of the caissons the columns through the entire 19 stories of the structure needed to be adjusted to accommodate the change. The contractors need drawings to build off, thus waiting for reissued correct drawings created a major delay for the project along with increased cost. The caisson and column relocations changed dimensions on almost every page of the architectural and structural drawings (hundreds of sheets).

Additionally, a few of the conflict caissons were also redesigned into large spread footings to accommodate site conditions of bearing under the existing façade. Significant time was spent by the architect and structural engineer to complete the required redesign. The construction of the spread footing (while cheaper then the caissons) took significantly longer and added delays.

Traditional Survey

Surveying has advanced significantly within the past few years, as total stations are very common. Total stations allow for the user to input a CADD drawing of the building and perform layout very accurately, fast and with few individuals – though this does not help to document an existing building or façade. An EDM is still required to document an existing structure. The EDM can shoot and record points accurately by the user; though it only records the points inputted by the user and can be a lengthy process depending on the amount of detail required. This method collects data one point at a time.

Laser Scan Surveys

The machine seen in figure 9 Laser Scanning Equipment, illustrates a typical laser scan machine used by an individual to gather data on the location of an existing structure.

Figure 9 Laser Scanning Equipment (Cyrax 2500)

The laser scanner works on similarly to the EDM but collects data at a much more rapid rate. Instead of a point-and-press EDM collecting measurements one at a time, a laser scanner automatically and rapidly captures a vast swath of points, horizontally and vertically to build up a 3D image.[10] The machine is able to obtain points as far as 200 feet away, horizontally or vertically, thus the need for a hoist or lift can be eliminated.

Within a few minutes a laser scan machine can obtain enough data points to create a drawing or model in Figure 10 Laser Scan Façade Output. The machine collects

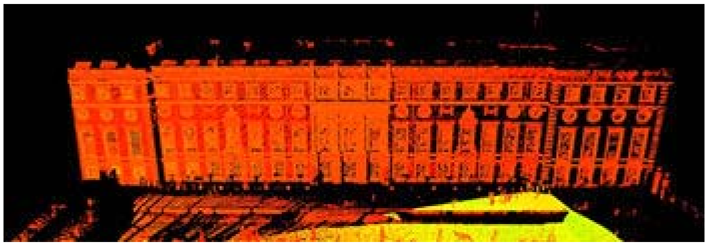


Figure 10 Laser Scan Façade Output

enough data to accurately dimension the facades features, such as window reveals, mullions, soffits, and cornices.[10]

Proposed Solution

The accuracy, quantity and speed to collect data with laser scanning techniques will pay for its self by avoiding conflicts and redesign issues on a project with existing structures to remain, especially with the integration of a historical façade.

Research Steps

The following steps were followed to research laser scan surveys:

1. Review case studies of projects that utilized laser scan surveys.
2. Research contractors that provide laser scan services.
3. Review and obtain cost and time impacts of redesign issues due to lack of knowledge pertaining to façade location.
4. Obtain costs for a laser scan survey for the project and analyze the benefits against the costs.

Results

In changing the location of the columns by the façade throughout the height of the building it required the concrete contractor to add additional steel reinforcing at the edge of slabs and to cantilever the beams to make up the difference. These changes added roughly $40,000 to the cost of the project. Additionally, the dimensional changes needed to be reflected on nearly all the drawings for the project. The endeavor to edit dimensions on nearly all the drawings for the project took 3 months to complete. While the structural drawings were completed first to allow for work to continue as much as possible the 3 months was not a direct delay to the project, though still had significant impact on progress and overall flow of the project – not forgetting the coordination, cost, time to print, distribute and organize nearly a completely new set of drawings into the old.

Figure 11 Laser Scan Survey Comparison, seen below, illustrates the summary of findings in implementing a laser scan survey against the experienced design delays and additional construction costs.

Laser Scan Survey Comparison				
	Initial Cost	Additional Costs due to Redesign	Delays due to Redesign	Savings
Traditional	$500	$40,000	3 months	-
Laser Scan	$27,500	-	-	$13,000

Figure 11 Laser Scan Survey Comparison

A surveyor was hired to locate points in the historical structures on site. The fee for the service was $6,000 which included the location of points and elevation in the four historical structures onsite along with only 4 spot elevations pertaining to the façade. The $6,000 contract value was divided among the number of spot elevations in the scope of work and $500 was concluded to be the equivalent cost for the 4 spot elevations on the Watt & Shand façade.

Pricing to complete a laser scan survey for the existing façade was obtained from Quantapoint® for comparison purposes. Quantapoint® has an office located in Pittsburgh, PA that could provide the required services in Lancaster. A laser scan survey for the scope of work to include only the Watt & Shand façade was obtained from Quantapoint® and revealed that it would cost $12,500 for mobilization and data collection, and another $15,000 budgeted for the production of drawings of moderate detail of the façade at 5 cross sections to show horizontal profile and elevations. The onsite survey work could be completed in a day with the drawings produced in four weeks. Another advantage of laser scan data collection is that if more detail is required by request later for any design or construction reason, the surveyor can provide the additional information without spending a day to travel to site and gather more information as the laser scan system would have already obtained the information during the first collection. Flexibility in the cost of the laser scan systems in achieved by dictating the level of detailed required in the drawings produced.

Conclusions

When a project is to include the renovation, addition to, restoration, or inclusion of a historical or existing structure the use of a laser scan survey needs to be considered. The Watt & Shand façade as used in this analysis was over 100 years old; it was not perfectly plumb or straight making the design and construction difficult with limited location information about it. Accurate data collection can be achieved by traditional methods with an EDM by collecting data points one point at a time, though the process is very slow. As seen in the case of the Watt & Shand façade, too few data collection points were obtained by means of traditional EDM methods, though with the use of a laser scan survey the entire facade would have been obtained and the exact dimensions and locations could have been modeled. The speed, accuracy and quality of drawings able to be produced by means of laser scanning need to be heavily weighted in the decision of how to survey the existing structure. Additionally, the ability to model the structure in 3D makes it versitile with new BIM requirements for many projects. The data collected can also be used at a later time, to produce an as-built drawing or to provide additional data points about an area. It is clearly seen, as in the case of the Watt & Shand facade, that the first cost of the laser scan would have paid for itself within the first three months of construction and prevented significant redesign work creating delays.

The use of laser scan surveys have been documented to help clients beat their project schedules by 15% or more with a greater than 100% return on investment.[9]

The Future of Laser Scans

The US General Services Administration (GSA) is currently encouraging the use of laser scanning technology on a project-by-project needs basis. With the capability of laser scanning to document a high resolution detailed model with little processing time the GSA is utilizing this technology for; historical documentation of building, facility condition documentation, construction as-built development, and BIM development. GSA is currently researching and developing case studies to be used to document the best practices fro laser scanning and will include a laser scanning best practices guide in Series 3 of the BIM Guide Series.[11]

It can clearly be seen in the case study with the Watt & Shand façade, that the use and implementation of a laser scan survey would have greatly saved time and money. The new laser scanning technology is developing hand-in-hand with current BIM development and within the next few years laser scanning will be a very familiar practice in the construction industry as a tool improving the accuracy, schedule and costs of construction.

Minipile Foundation Research

Background

On any project site work is on the critical path. The time spent on the construction of the foundations directly affects the overall schedule of the project. It is very important for the success of a project to be able to identify the best appropriate foundation system to be used. There are two main types of foundation systems, shallow and deep. Among the deep foundation systems there are caissons, piles and minipiles. A critical issue researched further in this report is the minipile system and the opportunities available in using the system.

The first patent for the minipile (or micropile) foundation system was obtained in 1952 by Dr. Lizzi of Naples, Italy[7]. Minipiles are small diameter piles typically ranging from 5-12" diameters while macropiles range from 12-24". Alternatively, caisson diameters can range from 24" up to 90+". Today minipile systems are generally thought of as a foundation system primarily for confined spaces such as building additions, underpinning and inside existing structures though minipiles are able to support large compressive loads and large uplift loads thus making them applicable to new construction. The term pile in minipile is misleading as minipiles are drilled into the ground like a caisson and not driven into the ground like a standard pile. The minipiles are drilled in clusters of 2, 3, 4, or 6+ and then capped with a pile cap to distribute the load between each pile. The smaller diameters of the micropiles enable them able to be drilled much faster then caisson holes. Also the machines required to drill micropiles are smaller then caisson drill rigs and thus provides more room on site.

The information researched in this paper is beneficial to developers, engineers, and contractors alike to become educated about the option of micropiles and can then consider using the method on further projects. It is important to for developers and geotechnical engineers to be aware of the potential construction advantages of micropiles as then they themselves can propose the system on their next project to the engineer. The ultimate goal is to improve the construction industry by implementing new techniques.

Problem Identification

Currently in the United States, micropiles are not commonly used even though they have some distinct advantages. Why are minipiles not used more frequently? In which new building applications do minipiles provide the largest advantage? Is there significant schedule saving to justify a potentially higher cost to use minipiles? Will the cost of minipiles decrease as they become better known and used more frequently?

The Marriott Hotel and Convention Center is located in central Pennsylvania, the study of minipiles in this report will be focused on this region and immediate surrounding areas.

Karst Topography

The central Pennsylvania region has karst topography. The term karst is defined as an area of limestone terrane characterized by sinks, ravines, and underground streams.[6] Figure 12 below outlines the areas of karst topography in Pennsylvania. Karst topography makes it difficult to meet intact rock requirements for large diameter holes, as the rock drops off suddenly, can be fractured and can also be layered, see figure 13 Karst Topography Cross Section below. A key reason why minipiles offer greater flexibility in karst then caissons is that minipiles resist forces by skin friction and are not end bearing. The skin friction design allows for the piles to spread out the load over several small sections of rock rather then specifying a certain amount of competent rock to bear on. In this regard, the existence of a major karstic feature just under the pile tip should not adversely affect the minipile performance, as it would of a large-diameter end bearing caisson.[7]

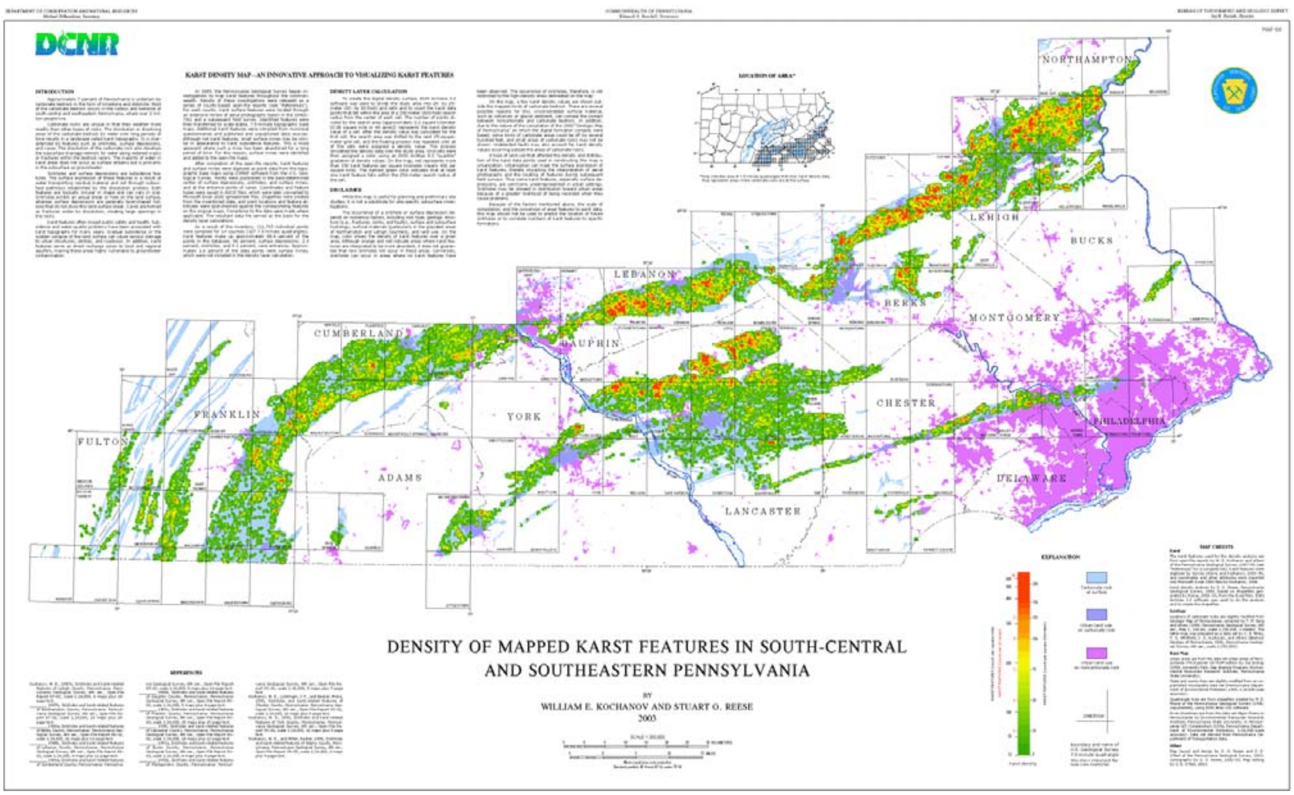


Figure 12 Pennsylvania Karst Topography Map

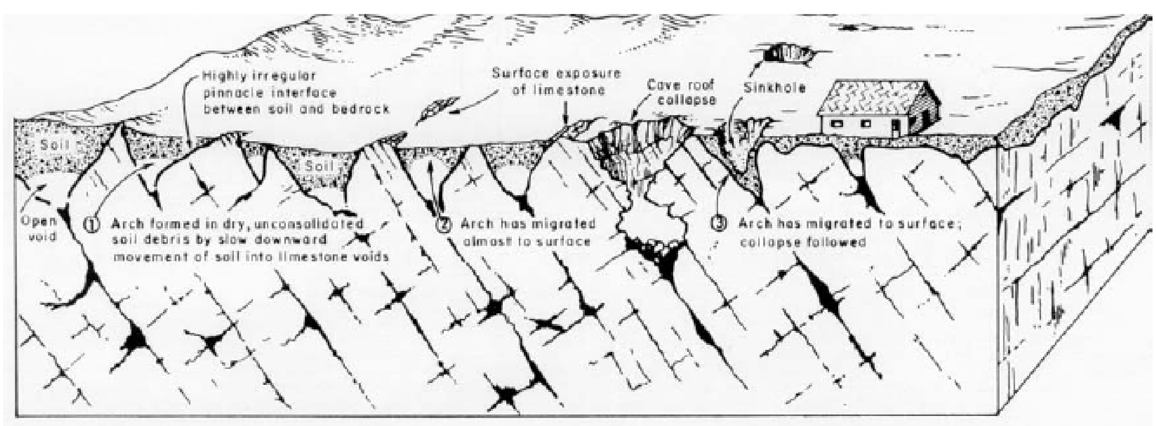


Figure 13 Karst Topography Cross Section

Caisson Construction

The Convention Center project utilizes 200 caissons for the foundation system of the structure. In the specifications intact rock requirements needed to be met for each caisson drilled. Many of the caissons also required special requirements to account for uplift forces; such as drilling a smaller diameter caisson deeper through the bottom of a larger hole and the use of rock anchors at the bottom of the caissons. For theses caissons the caisson contractor needed to set up the drill rig for a large diameter caisson, reach the required depth then switch to a smaller diameter bit to continue to drill for the same caisson, then further drilling is required by the concrete contractor to install the rock anchors. Additionally, for several of the caissons rock was encountered at a very shallow depth, approximately 10 feet, and the structural engineer still required the depth to be increased, thus the caisson contractor spend significant time drilling large diameter holes in rock. In an effort to save money from drilling large holes in rock, the foundations for some of the caissons were redesigned to be large spread footings, which decreased the rock removal required but also took significantly longer then to drill caissons.

Proposed Solution

Minipiles have distinct advantages, they are conducive for small spaces such as interior renovations (low head room situations), can also be drilled at an angle for lateral loads, support of excavation and underpinning. Advances in minipiles have enables them to be designed to carry significant loads which allows them to also be used for new construction applications. The smaller diameter hole the minipile requires poses advantages over caissons in rock situations and karst topography where the rock is fractured and uneven.

Research Steps

The following steps were followed to research the minipile foundation system:

1. Research further information about micropile systems from ISM (International Society for micropiles), IWM (International Workshop on Micropiles) and related code, design and guideline manuals for micropiles.

2. Assembled cost and schedule information from case studies of projects that have utilized micropiles.
3. Gather input from developers, construction managers, general contractors and specialty contractors and specialty design engineers on their experiences (or lack of) with minipile construction. High Real Estate, Reynolds Construction Management, Clark Foundations, Hayward Baker Geotechnical Consults, HAAS Engineers, Schnabel Foundation Engineers, and Shelly Foundations contributed to the input and data for the case study analysis.
4. Apply the research and data to the Marriott Hotel and Lancaster County Convention Center project.

Results

Several key factors have to be considered when applying minipile technology in karst. Of prime concern is how the load is to be carried by the rock, given that the most troubling issue with karstic rock is its inconsistency.[7] While the design of a minipile system is a very complicated process with several factors, for the purpose of the analysis in this study a 300K capacity 8" minipile was selected. As mentioned above minipiles can range in size from 5-12" and macropiles from 12-24". The load carrying capacity for minipiles range from 40-800K and macropiles capacities range from 500-3400K. The choice to use an 8", 300K minipile came from geotechnical engineers and structural engineers input based off their experience in the area, in particularly a geotechnical engineers experience with 300K minipiles in Exton, PA that required a 10' bond length with rock. Given the locality (same karst topography) and required loads to support for the project, 300K was used. See Appendix A for the design calculations of the 300K minipile.

The required loads for each caisson of the project can be seen in Figure 14 Caisson to Minipile Load Comparison. The chart shows the equivalent number of minipiles it would require to replace each caisson diameter.

Caisson to Minipile Load Comparison			
Caisson Diameter	Min. Required Capacity	8" Minipile Load Capacity	# of Minipiles per Group
36"	565K	300K	2
42"	770K	300K	3
54"	1200K	300K	4
60"	1500K	300K	5
66"	1900K	300K	7
72"	2260K	300K	8
84"	3080K	300K	11
90"	3535K	300K	12

Figure 14 Caisson to Minipile Load Comparison

The existing design for the caisson foundation system utilizes 204 total caissons, of which 126 are 36” diameter and 41 are 42” diameter. As seen in Figure AAA, it would require 12 piles to support the loads required for one 90” caisson. Having 12 piles in a pile group is extremely cluttered and inefficient. For the analysis only 36” and 42” caissons were analyzed to be converted to minipiles and the remaining caisson sizes to remain in the proposed redesign due the over cluttering and inefficiencies in having too many piles per pile group. Additionally, 82% of the caissons are 36” and 42” diameters.

Based off contractor input an 8” minipile with a 300K capacity cost $125/ft and six holes could be drilled per day. Analysis was completed for the basis of all 36” and 42” caissons to be converted to 8” minipiles, and likewise for only the 36” caissons to be converted to 8” minipiles. Figure 15 Minipile and Caisson Schedule Analysis displays the schedule savings in utilizing the respective minipile and caisson foundation system. The savings is very significant, 10 weeks for 36” and 42” caissons to be minipiles and 16 weeks for only 36” caissons to be minipiles. As seen in the bar chart the significant schedule savings is not solely based off minipiles being constructed faster, but by constructing the minipiles and the respective remaining caissons concurrently. The 16 weeks saving is achieved by converting only 36” caissons to minipiles which allows for a balanced/equivalent time to construct the remaining caissons. Even by adding a second drill rig for the caissons, only 13 weeks (maximum) saving could be achieved – and this option would also increase the cost for the caisson contractor.

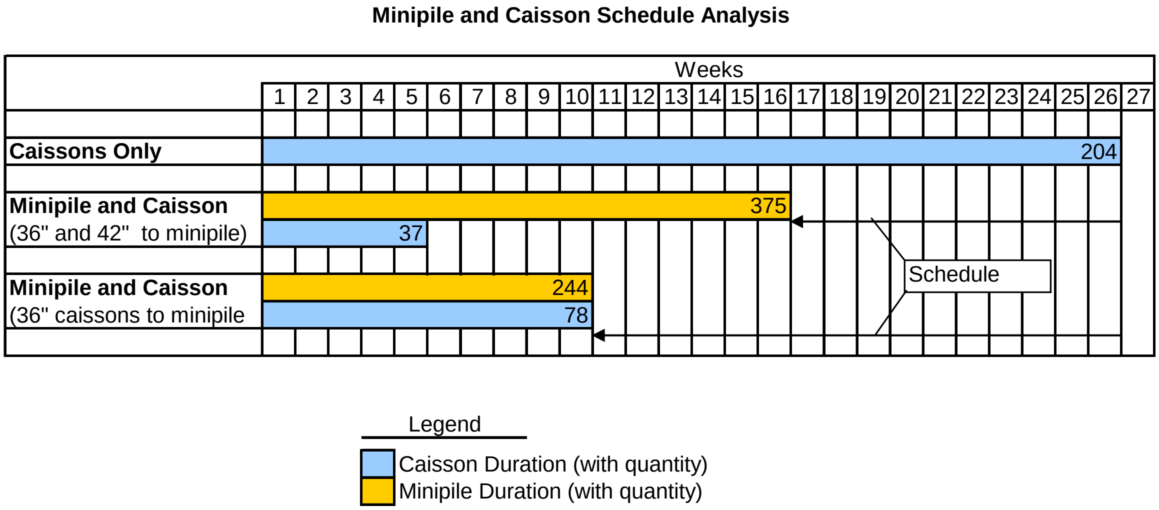


Figure 15 Minipile and Caisson Schedule Analysis

The site while confined to a city block is still large enough to allow for both operations to occur simultaneously as during the foundation work can be managed by the "two-halfs" of the project; the larger diameter caissons are mostly located under the hotel tower, while the smallest 36" diameter caissons are located under the convention center half of the site.

The 16 week schedule savings of utilizing a minipile foundation system comes at a higher cost then the all caisson design. Figure 16 Minipile and Caisson Analysis Summary displays the cost difference for each system along with the schedule savings. See Appendix A for a complete detailed estimate for the different foundation systems.

Minipile and Caisson Analysis Summary				
Description	Cost	Cost Difference	Schedule (weeks)	Schedule Difference
All caissons (existing system)	$1,084,140	---	26	---
36" caissons converted to minipiles	$1,466,160	$382,020	10	-16
36" and 42" caissons converted to minipiles	$1,783,980	$699,840	16	-10

Figure 16 Minipile and Caisson Analysis Summary

Initially an increase of $382,000 to a $1,084,000 contract seems absurd, though in saving the 16 weeks of saving experienced with the foundation work correlates to a faster completion schedule. The 16 week schedule savings can not be directly applied to the opening for the hotel due to sequencing of trades and coinciding work with underground utilities and foundation walls. From the 'Construction Analysis: Re-sequencing Study – AE Depth Study' section of this report which analyzes the schedule sequencing for the proposed alternatives in this report the schedule can be reduced at least one month by the implementation of the combination caisson/minipile foundation system along with the other proposed alternatives analyzed in this report. Looking at the hotel alone; based off 66% occupancy (200/300 rooms) for 5 weeks at $200/night would generate $1,400,000 worth of revenue to the owners. The additional cost for the minipile system can be justified by the schedule savings.

Note: The pile cap construction is included into the unit cost of the pile and the schedule.

Conclusions

The information researched in this paper is beneficial to developers, engineers, and contractors alike to become educated about the option of micropiles and can then consider using the method on further projects. It is important to for developers and geotechnical engineers to be aware of the potential construction advantages of micropiles as then they themselves can propose the system on their next project to the engineer. The ultimate goal is to improve the construction industry by implementing new techniques. It is ultimately the choice of the owner to decide if spending additional money to reduce construction time is advantageous for their situation. As is the case study, it is very beneficial to finish construction early to open the hotel and convention center and begin a revenue stream to make money and not pay construction loans any longer then necessary.

Owners and designers typically can not look past the initial cost of construction, such as caissons being cheaper then minipiles. Particularly when caissons are a widely used system and specialty contractors are readily available to complete the work and have vast experience. Caissons typically offer a cheaper system and given the correct soil conditions are also the faster system. Though given a karst topography the rock structure is very difficult to predict, and even more difficult with limited test boring and delayed borings due to an existing structure being on site. Contractors, engineers and developers all need to be optimistic if they want to obtain work. Given a scenario where an engineer proposes a caisson foundation system that has a lower first cost against an engineer who proposes a minipile foundation system that has a higher first cost. An owner and developer would 99 percent of the time select the caisson contractor due to the lower cost and be optimistic that they are able to find and bear on competent rock outlined in the geotechnical report. It is for this reason that minipiles are not as commonly used for new construction applications even though given a karst topography the higher initial cost can be out weighted by a faster construction schedule.

Minipile systems are still a relatively new construction process and as more contractors begin to perform the service it is believed that the cost for the system will decrease and can become more competitive with a caisson system. During an interview with the project management team of Reynolds Construction Management on the Convention Center project, they projected that "in a few years they would be seeing a lot more use of the minipile foundation system." It is also worth noting that during the interview (research) process it was clearly seen that geotechnical engineers and construction managers believe in the advantages and future development of minipiles with structural engineers seem very unconvinced of using minipiles for more then interior renovation work.

In conclusion, given karst topography as in central Pennsylvania a minipile foundation system should be considered by the foundation engineer to propose different options to the owner of the project. The faster construction schedule is a valuable option to many owners.

Construction Analysis: Re-sequencing Study – AE Depth Study

Background

The old adage "time is money" directly applies to the construction industry, be it paying construction workers an hourly wage to perform a task or in completing the construction of a new facility to open and generate revenue. In reducing the time it takes to construct a project it reduces the project costs by reducing the number of hours an hourly construction worker is being paid, construction loans, monthly consultants fees, etc… and by enabling the facility to be open sooner to generate revenue.

Problem Background

During the construction of the Lancaster County Convention Center project unexpected delays were encountered during the excavation phase with the discovery of a historical brick floor near the Kleiss Saloon and an underground spring. The brick floor needed to be excavated carefully, protected and incorporated into the new construction. The underwater spring required the permanent dewatering system to be redesigned to increase the maximum capacity. These delays being located in the lowest level of the site (the museum level) directly prevented progress in construction. To construct a cast-in-place concrete structure the slab needs to be in place before the formwork can be erected to place in order to place any floors above it. With unexpected issues encountered in the lowest level of the project delays were encountered.

The cast-in-place concrete retaining walls used in the museum and convention entry levels of the project were designed as pinned retaining walls. A pinned retaining wall can not be backfilled to the full height without the top floor diaphragm in place to resist some of the soil pressure. For the retaining walls utilized on the project they were allowed to be backfilled to half their height before the floor diaphragm installed. The ability to backfill to half the height is better then not being allowed to backfill at all, though it still creates problems for a congested urban site. The extra soil needed to backfill the wall needs to be stored on site while space is lost due to the required stepping/banking of excavation away from the retaining walls.

Proposed Solution

The construction analysis focused on this section includes a schedule analysis study for the implementation of a combination minipile and caissons foundation system, utilizing Ivany block for a cantilever retaining wall design instead of the pinned concrete wall, and utilizing a steel superstructure instead of the cast in place concrete.

Results

Minipile Foundations:

See the 'Minipile Foundation Research' section of the report for an in depth analysis on the use and implementation of the minipile system towards this project.

The minipile system provides schedule savings over caisson construction given the karst topography for the project location. The re-sequencing analysis and schedule reduction for this section utilizing the analysis based off 36" caissons converted to minipile foundations. With the use of a combination minipile and caisson foundation system, two separate foundation contractors can work on the project simultaneously. Generally, the minipile contractor will be working in the convention center while the majority of the caissons (over 36") are located under the hotel tower.

Ivany Block Foundation Walls:

In using Ivany Block for the retaining walls instead of cast-in-place concrete it reduces and nearly eliminates the need for formwork. Ivany block is specifically manufactured with rebar notches in the block, allowing for fast rebar installation, see figure 17 Ivany Block Detail below.

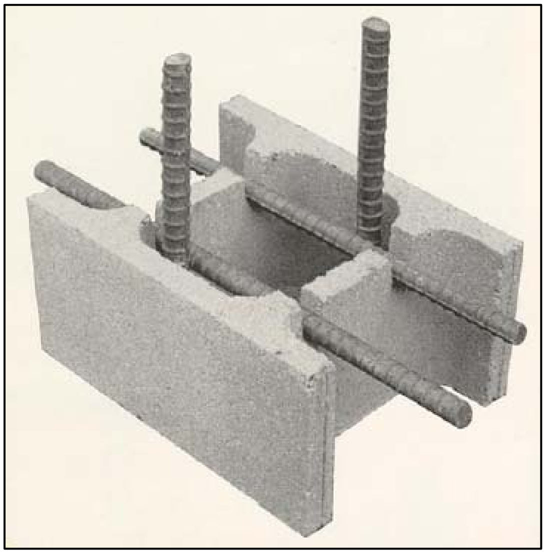


Figure 17 Ivany Block Detail

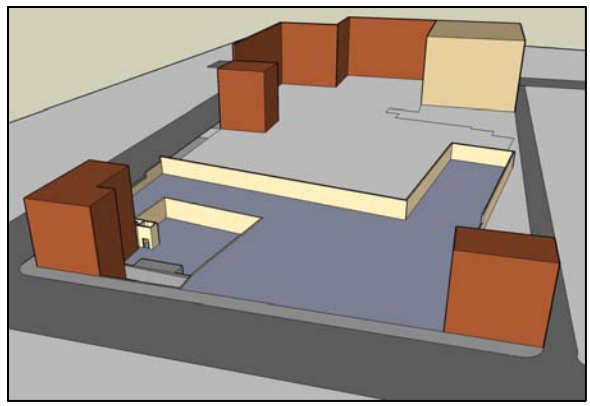
The proposed Ivany block can be used as a cantilever retaining wall which allows for the wall to be backfilled to the full height before the floor diaphragm is installed. A cantilever retaining wall allows for the backfill process to occur before or while the floor installation is in progress. Backfilling while the floor is being constructed saves time and space on a construction project by allowing the tasks to occur simultaneously and then the construction processes required behind the wall can be completed sooner with the backfill of the wall occurring sooner. Additionally space is saved onsite by not having to stock pile spoils to later backfill a wall. See the 'Structural Re-design' section of the report for more information on the design of the Ivany block retaining wall.

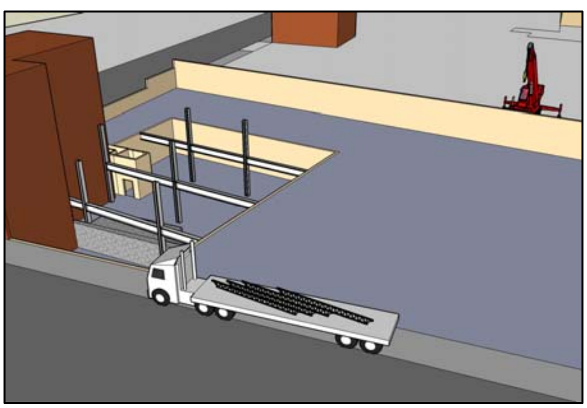
Steel Superstructure:

The alternative steel structure proposed for the museum level and convention entry level eliminates the need for the museum level slab on grade to be complete to proceed with construction of the superstructure. The steel columns, beams and joists can be erected before the issues in the museum level are resolved. By breaking the link in these tasks significant savings can be achieved in the schedule.

The following images outline the sequence to erect the proposed steel structure:

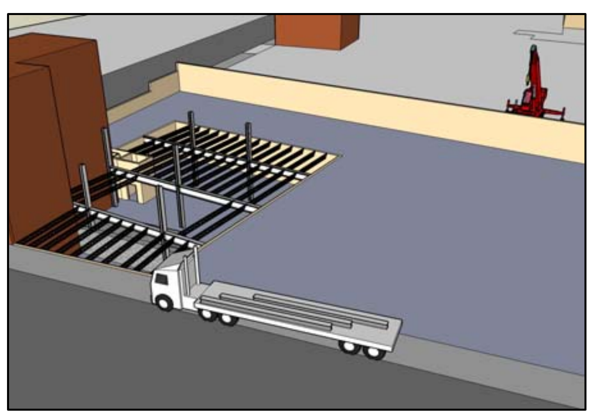
1. Prior to steel erection – no concrete slabs on grade have been placed. The Ivany retaining walls are in place to accommodate the steel members to frame into.

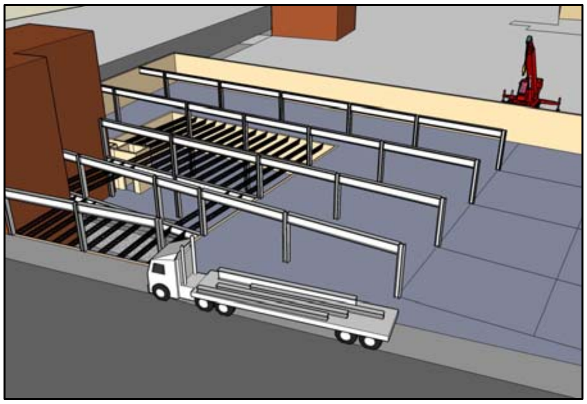




2. The steel columns and beams are erected in the museum level.

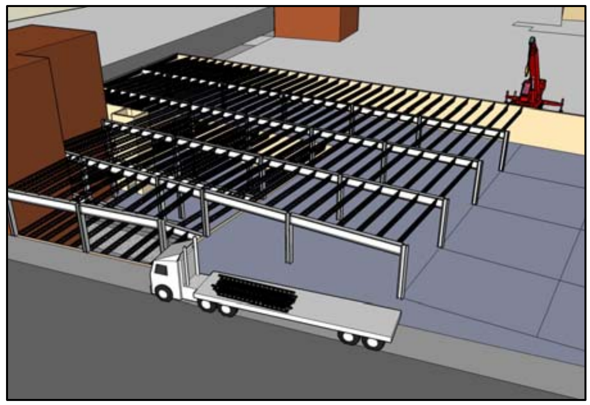
3. The composite joists are erected in the museum level.

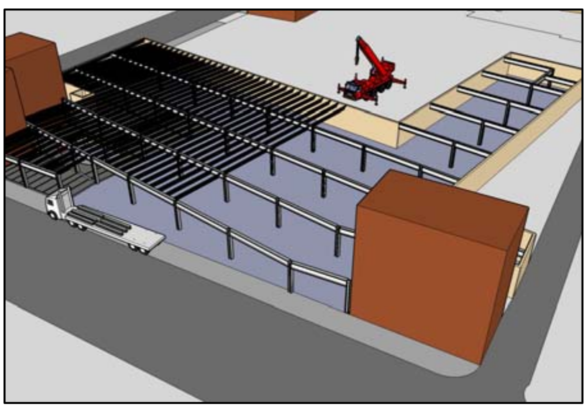




4. The columns and beams are erected for half of the convention entry level.

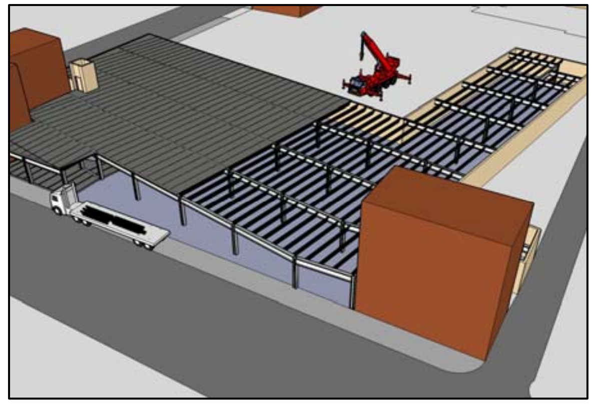
5. The composite joists are erected for half of the convention entry level.





6. The columns and beams for the second half of the convention entry level are erected. The decking over the museum level is placed.

7. The composite joists are erected for the second half of the convention entry. The metal decking is placed over the first half on the convention entry.



8. The remainder of the decking is placed over the convention entry.

Note: An additional key to the schedule reduction is the ability to erect the convention center steel sooner. The crane used to erect the steel is too massive to sit on top of a slab on grade, thus an area of slab needed to be left out where the convention center and hotel join to create a path for the crane to erect and leave the site. The slab on grade that is left out which is used as a crane path prevents any elevated structural cast in place concrete floors to be placed above it for that area in the hotel. See figure 18 Steel Erection below to view the crane erecting the convention center steel and the slab on grade that is left out as a crane path. Also see the sequencing pictures and schedule below for further illustration of the portion of slab on grade that is left out to accommodate the crane path and the schedule impact.

Figure 18 Steel Erection

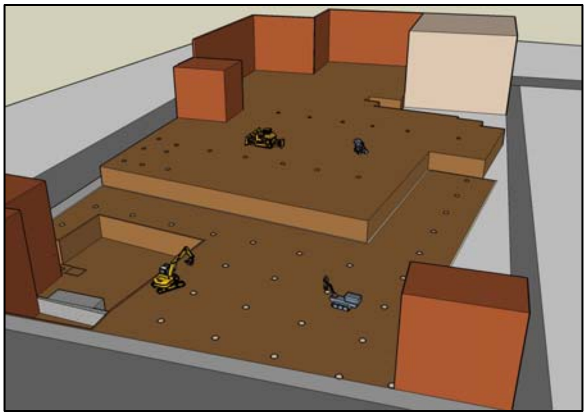
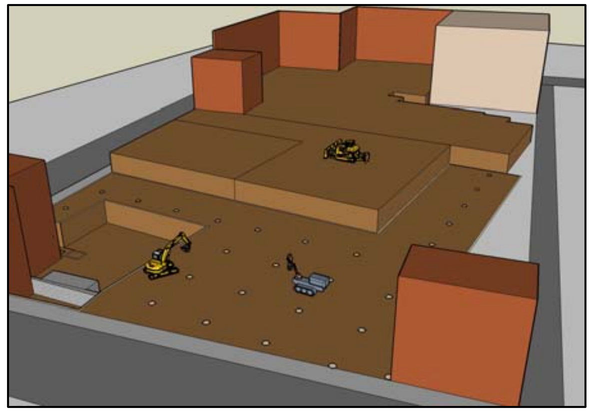
Conclusion

The construction elements and sequence utilized for the actual construction of LCCC yielded a schedule of 193 days finishing on 12/12/07, from the start of excavation to the concrete structure of Ballroom "A" level. In implementing the steel superstructure, Ivany block retaining walls, and combination minipile and caisson foundation system the schedule would be 169 days finishing on 11/8/07, to complete the same portion of the project. Over a month could be saved by implementing the construction means and methods detailed above.

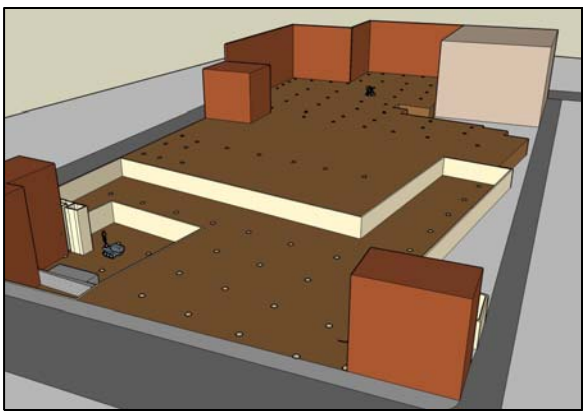
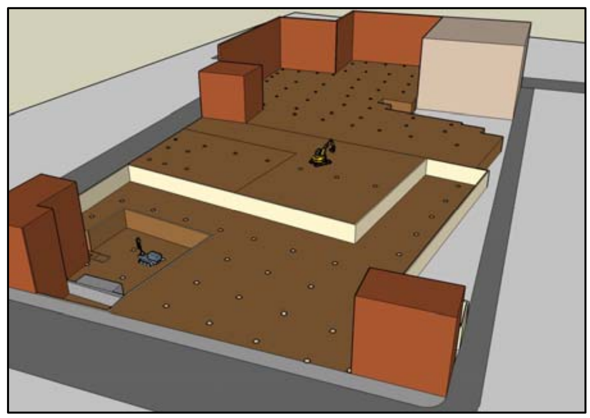
See the 'Resequencing Schedule' on the following page for detailed sequencing information of the utilized sequence and that of the proposed sequence implementing the above mentioned changes.

Attached are photo renderings taken from a 3D model to help illustrate the construction sequencing and schedule savings in implementing the proposed changes. The proposed sequence is on the left, while the utilized sequence is on the right. The dates listed under the photos correspond to the following schedule to illustrate key points in the construction of the proposed sequence and to visualize how far behind the utilized sequencing would be.

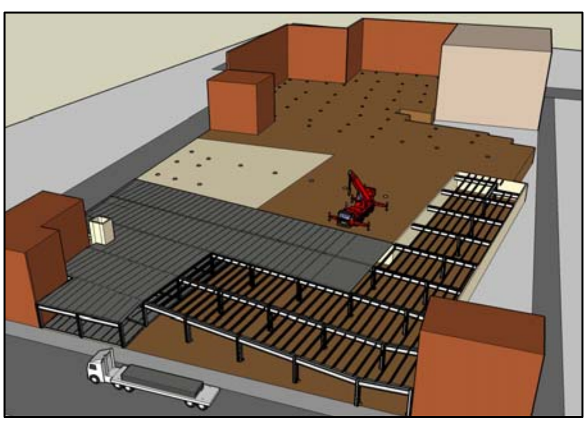
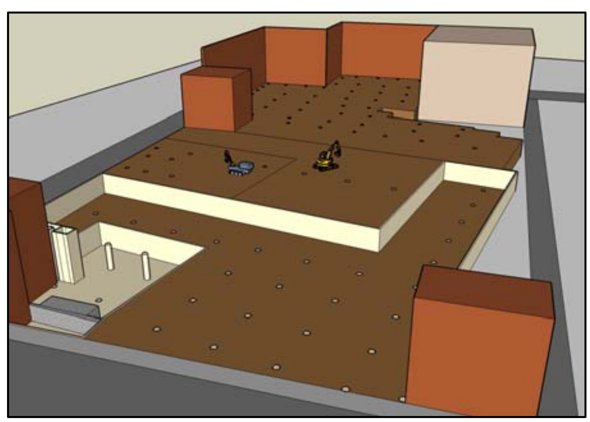
Proposed | Utilized

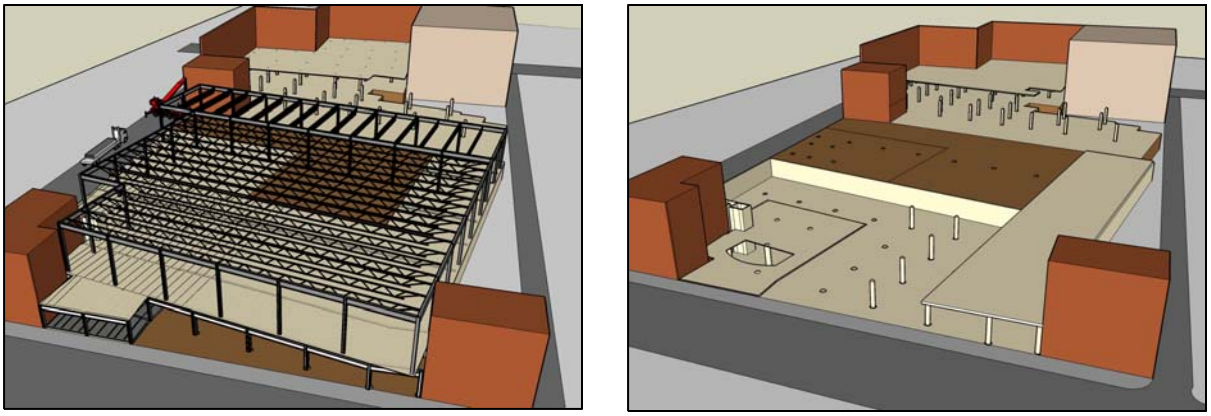
May 14, 2007

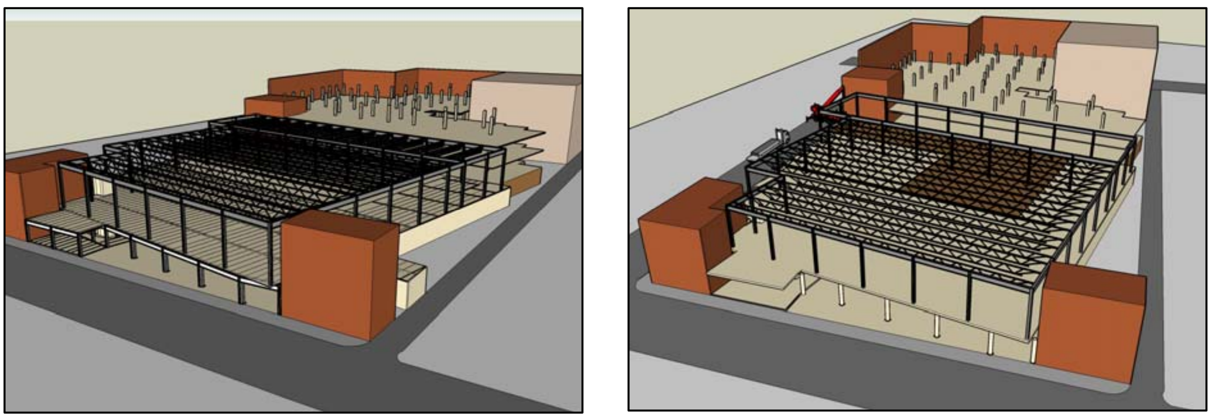
June 22, 2007

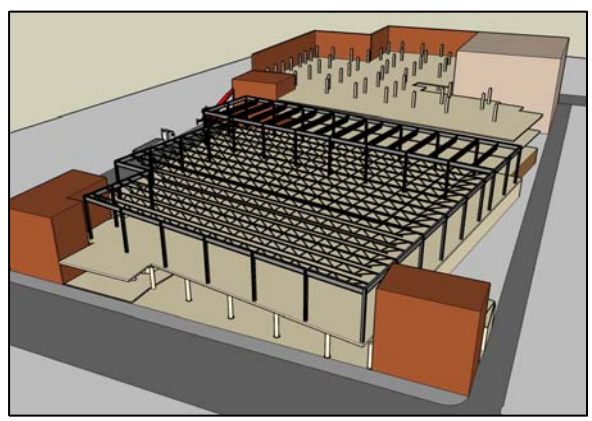
July 24, 2007



September 21, 2007



November 8, 2007



December 12, 2007

Proposed Re-sequencing Schedule

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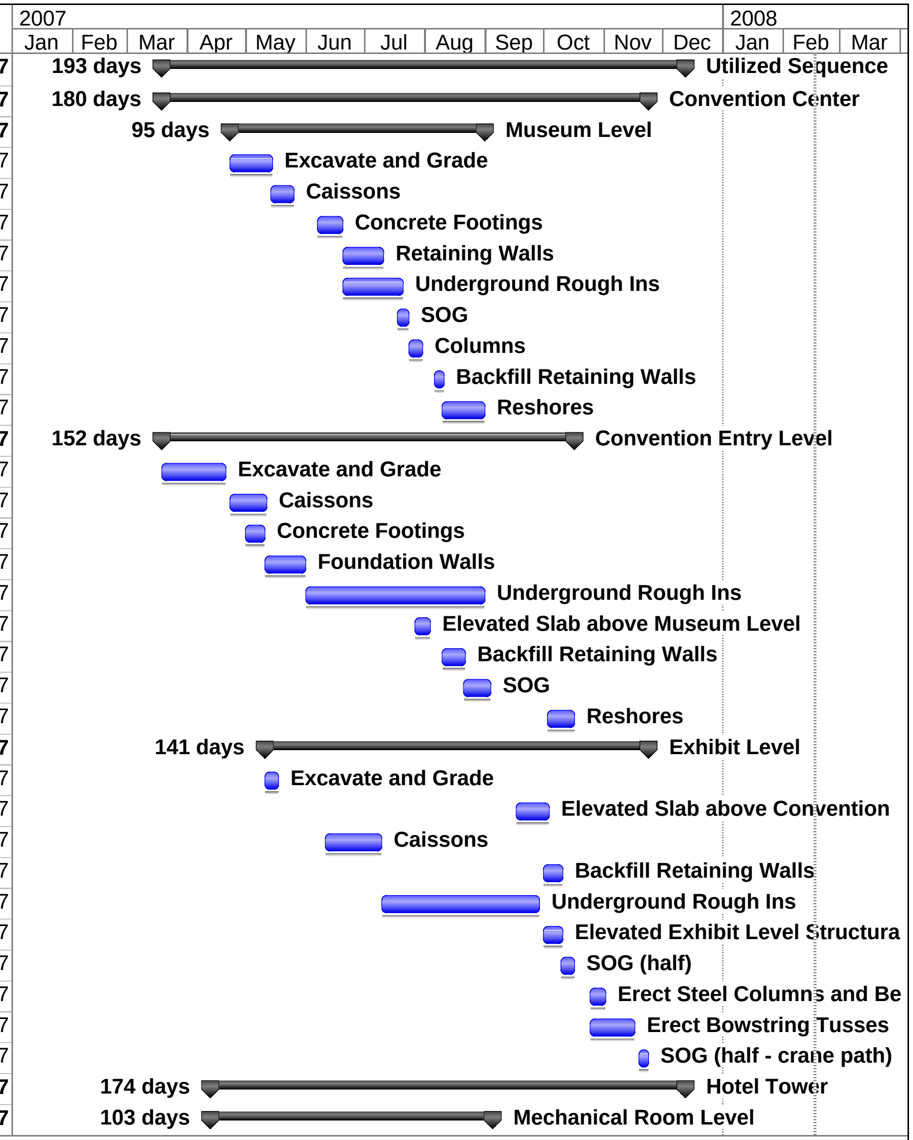
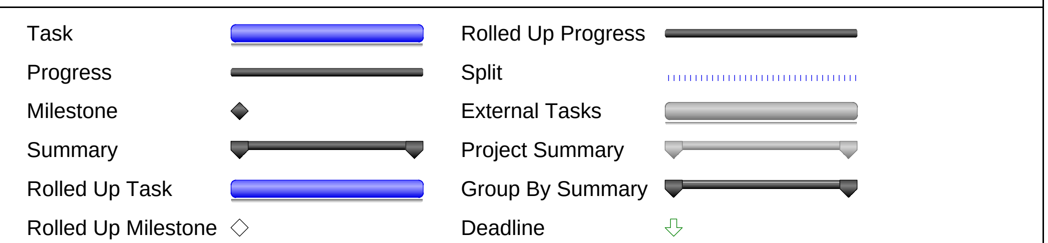
ID	Task Name	Duration	Start	Finish
1	**Utilized Sequence**	**193 days**	**Mon 3/19/07**	**Wed 12/12/07**
2	**Convention Center**	**180 days**	**Mon 3/19/07**	**Fri 11/23/07**
3	**Museum Level**	**95 days**	**Mon 4/23/07**	**Fri 8/31/07**
4	Excavate and Grade	16 days	Mon 4/23/07	Mon 5/14/07
5	Caissons	10 days	Mon 5/14/07	Fri 5/25/07
6	Concrete Footings	9 days	Thu 6/7/07	Tue 6/19/07
7	Retaining Walls	15 days	Wed 6/20/07	Tue 7/10/07
8	Underground Rough Ins	23 days	Wed 6/20/07	Fri 7/20/07
9	SOG	4 days	Wed 7/18/07	Mon 7/23/07
10	Columns	5 days	Tue 7/24/07	Mon 7/30/07
11	Backfill Retaining Walls	5 days	Mon 8/6/07	Fri 8/10/07
12	Reshores	16 days	Fri 8/10/07	Fri 8/31/07
13	**Convention Entry Level**	**152 days**	**Mon 3/19/07**	**Tue 10/16/07**
14	Excavate and Grade	25 days	Mon 3/19/07	Fri 4/20/07
15	Caissons	15 days	Mon 4/23/07	Fri 5/11/07
16	Concrete Footings	8 days	Tue 5/1/07	Thu 5/10/07
17	Foundation Walls	15 days	Fri 5/11/07	Thu 5/31/07
18	Underground Rough Ins	66 days	Fri 6/1/07	Fri 8/31/07
19	Elevated Slab above Museum Level	6 days	Fri 7/27/07	Fri 8/3/07
20	Backfill Retaining Walls	8 days	Fri 8/10/07	Tue 8/21/07
21	SOG	10 days	Tue 8/21/07	Mon 9/3/07
22	Reshores	10 days	Wed 10/3/07	Tue 10/16/07
23	**Exhibit Level**	**141 days**	**Fri 5/11/07**	**Fri 11/23/07**
24	Excavate and Grade	5 days	Fri 5/11/07	Thu 5/17/07
25	Elevated Slab above Convention Entry	13 days	Mon 9/17/07	Wed 10/3/07
26	Caissons	21 days	Mon 6/11/07	Mon 7/9/07
27	Backfill Retaining Walls	8 days	Mon 10/1/07	Wed 10/10/07
28	Underground Rough Ins	59 days	Tue 7/10/07	Fri 9/28/07
29	Elevated Exhibit Level Structural Slab	8 days	Mon 10/1/07	Wed 10/10/07
30	SOG (half)	5 days	Wed 10/10/07	Tue 10/16/07
31	Erect Steel Columns and Beams	6 days	Thu 10/25/07	Thu 11/1/07
32	Erect Bowstring Tusses	17 days	Thu 10/25/07	Fri 11/16/07
33	SOG (half - crane path)	5 days	Mon 11/19/07	Fri 11/23/07
34	**Hotel Tower**	**174 days**	**Fri 4/13/07**	**Wed 12/12/07**
35	**Mechanical Room Level**	**103 days**	**Fri 4/13/07**	**Tue 9/4/07**



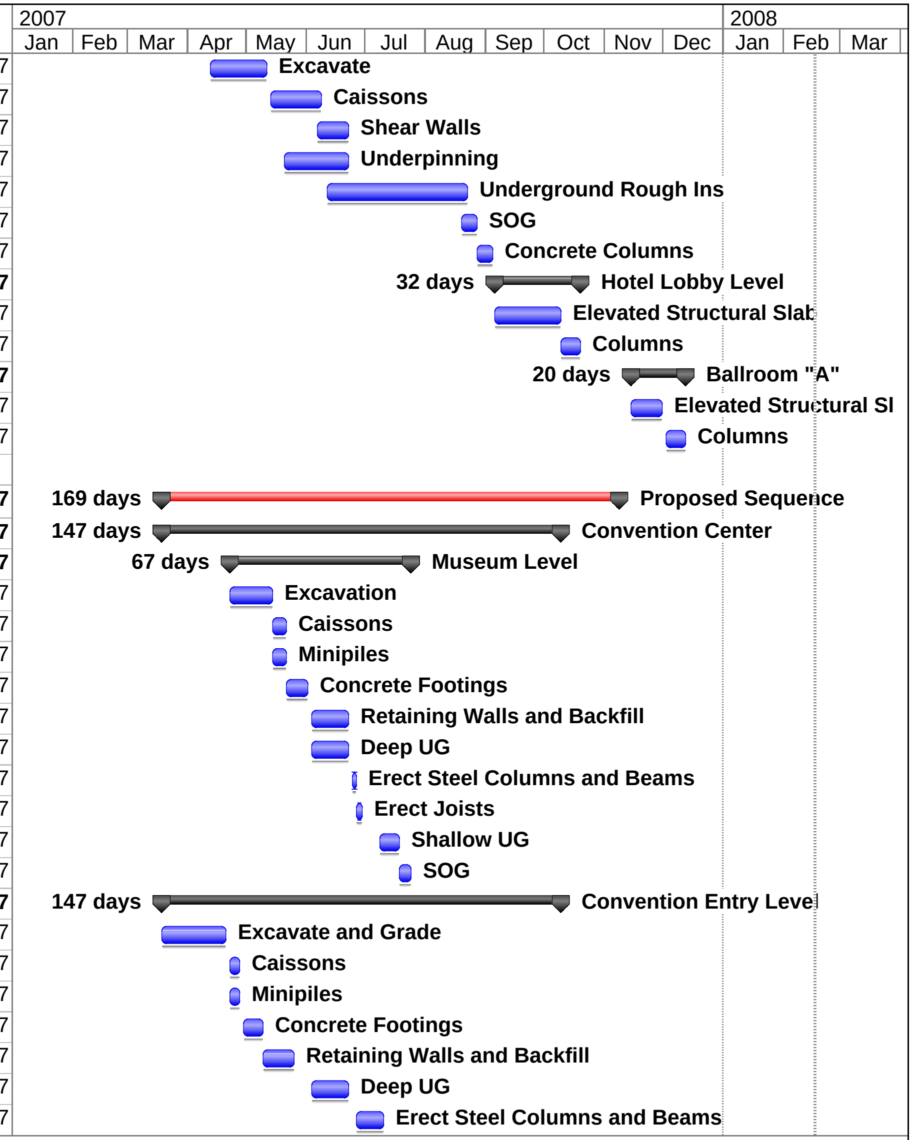
Marriott Hotel at Penn Square and Lancaster County Convention Center

Lancaster, PA

Resequencing Schedule



ID	Task Name	Duration	Start	Finish
36	Excavate	21 days	Fri 4/13/07	Fri 5/11/07
37	Caissons	20 days	Mon 5/14/07	Fri 6/8/07
38	Shear Walls	12 days	Thu 6/7/07	Fri 6/22/07
39	Underpinning	25 days	Mon 5/21/07	Fri 6/22/07
40	Underground Rough Ins	52 days	Tue 6/12/07	Wed 8/22/07
41	SOG	6 days	Mon 8/20/07	Mon 8/27/07
42	Concrete Columns	6 days	Tue 8/28/07	Tue 9/4/07
43	**Hotel Lobby Level**	**32 days**	**Thu 9/6/07**	**Fri 10/19/07**
44	Elevated Structural Slab	24 days	Thu 9/6/07	Tue 10/9/07
45	Columns	8 days	Wed 10/10/07	Fri 10/19/07
46	**Ballroom "A"**	**20 days**	**Thu 11/15/07**	**Wed 12/12/07**
47	Elevated Structural Slab	12 days	Thu 11/15/07	Fri 11/30/07
48	Columns	8 days	Mon 12/3/07	Wed 12/12/07
49				
50	**Proposed Sequence**	**169 days**	**Mon 3/19/07**	**Thu 11/8/07**
51	**Convention Center**	**147 days**	**Mon 3/19/07**	**Tue 10/9/07**
52	**Museum Level**	**67 days**	**Mon 4/23/07**	**Tue 7/24/07**
53	Excavation	16 days	Mon 4/23/07	Mon 5/14/07
54	Caissons	5 days	Tue 5/15/07	Mon 5/21/07
55	Minipiles	5 days	Tue 5/15/07	Mon 5/21/07
56	Concrete Footings	9 days	Tue 5/22/07	Fri 6/1/07
57	Retaining Walls and Backfill	15 days	Mon 6/4/07	Fri 6/22/07
58	Deep UG	15 days	Mon 6/4/07	Fri 6/22/07
59	Erect Steel Columns and Beams	2 days	Mon 6/25/07	Tue 6/26/07
60	Erect Joists	3 days	Wed 6/27/07	Fri 6/29/07
61	Shallow UG	8 days	Mon 7/9/07	Wed 7/18/07
62	SOG	4 days	Thu 7/19/07	Tue 7/24/07
63	**Convention Entry Level**	**147 days**	**Mon 3/19/07**	**Tue 10/9/07**
64	Excavate and Grade	25 days	Mon 3/19/07	Fri 4/20/07
65	Caissons	5 days	Mon 4/23/07	Fri 4/27/07
66	Minipiles	5 days	Mon 4/23/07	Fri 4/27/07
67	Concrete Footings	8 days	Mon 4/30/07	Wed 5/9/07
68	Retaining Walls and Backfill	12 days	Thu 5/10/07	Fri 5/25/07
69	Deep UG	15 days	Mon 6/4/07	Fri 6/22/07
70	Erect Steel Columns and Beams	10 days	Wed 6/27/07	Tue 7/10/07



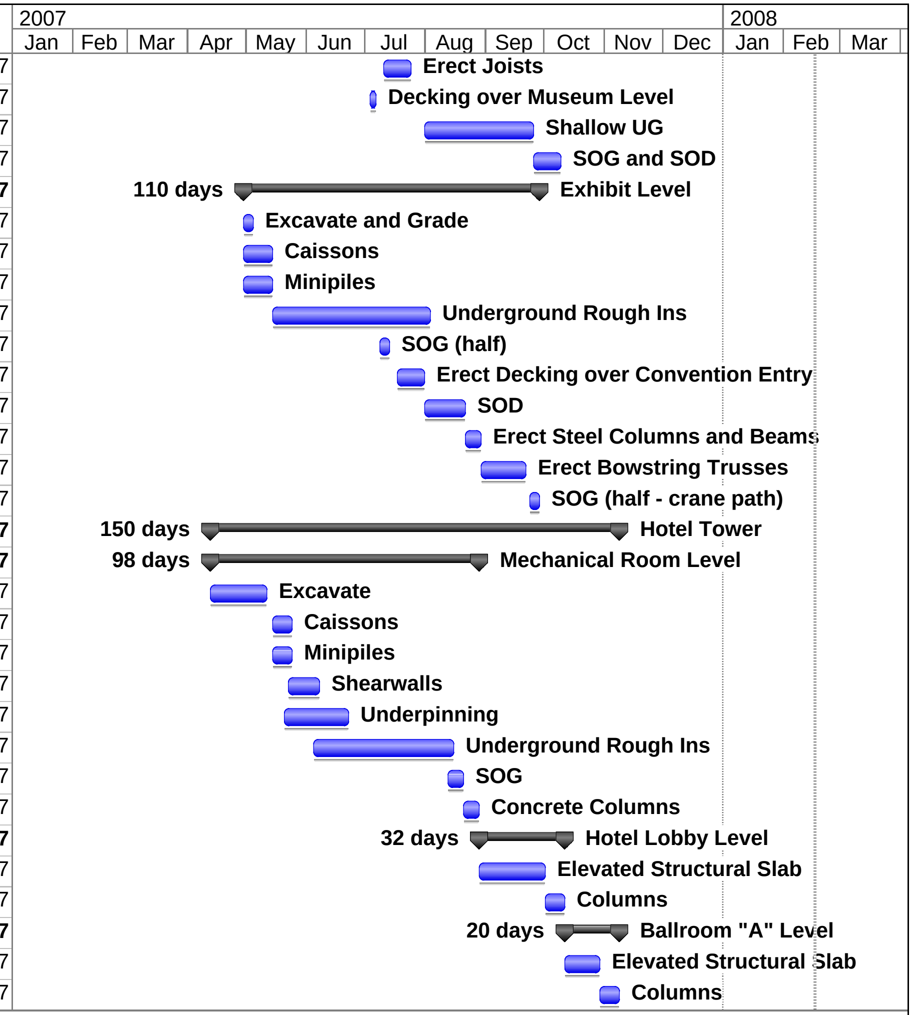
Marriott Hotel at Penn Square and Lancaster County Convention Center

Lancaster, PA

Resequencing Schedule

Task	Rolled Up Progress
Progress	Split
Milestone	External Tasks
Summary	Project Summary
Rolled Up Task	Group By Summary
Rolled Up Milestone	Deadline

ID	Task Name	Duration	Start	Finish
71	Erect Joists	10 days	Wed 7/11/07	Tue 7/24/07
72	Decking over Museum Level	3 days	Wed 7/4/07	Fri 7/6/07
73	Shallow UG	40 days	Wed 8/1/07	Tue 9/25/07
74	SOG and SOD	10 days	Wed 9/26/07	Tue 10/9/07
75	**Exhibit Level**	**110 days**	**Mon 4/30/07**	**Fri 9/28/07**
76	Excavate and Grade	5 days	Mon 4/30/07	Fri 5/4/07
77	Caissons	11 days	Mon 4/30/07	Mon 5/14/07
78	Minipiles	11 days	Mon 4/30/07	Mon 5/14/07
79	Underground Rough Ins	59 days	Tue 5/15/07	Fri 8/3/07
80	SOG (half)	5 days	Mon 7/9/07	Fri 7/13/07
81	Erect Decking over Convention Entry	10 days	Wed 7/18/07	Tue 7/31/07
82	SOD	15 days	Wed 8/1/07	Tue 8/21/07
83	Erect Steel Columns and Beams	6 days	Wed 8/22/07	Wed 8/29/07
84	Erect Bowstring Trusses	17 days	Thu 8/30/07	Fri 9/21/07
85	SOG (half - crane path)	5 days	Mon 9/24/07	Fri 9/28/07
86	**Hotel Tower**	**150 days**	**Fri 4/13/07**	**Thu 11/8/07**
87	**Mechanical Room Level**	**98 days**	**Fri 4/13/07**	**Tue 8/28/07**
88	Excavate	21 days	Fri 4/13/07	Fri 5/11/07
89	Caissons	8 days	Tue 5/15/07	Thu 5/24/07
90	Minipiles	8 days	Tue 5/15/07	Thu 5/24/07
91	Shearwalls	12 days	Wed 5/23/07	Thu 6/7/07
92	Underpinning	25 days	Mon 5/21/07	Fri 6/22/07
93	Underground Rough Ins	52 days	Tue 6/5/07	Wed 8/15/07
94	SOG	6 days	Mon 8/13/07	Mon 8/20/07
95	Concrete Columns	6 days	Tue 8/21/07	Tue 8/28/07
96	**Hotel Lobby Level**	**32 days**	**Wed 8/29/07**	**Thu 10/11/07**
97	Elevated Structural Slab	24 days	Wed 8/29/07	Mon 10/1/07
98	Columns	8 days	Tue 10/2/07	Thu 10/11/07
99	**Ballroom "A" Level**	**20 days**	**Fri 10/12/07**	**Thu 11/8/07**
100	Elevated Structural Slab	12 days	Fri 10/12/07	Mon 10/29/07
101	Columns	8 days	Tue 10/30/07	Thu 11/8/07



Marriott Hotel at Penn Square and
Lancaster County Convention Center
Lancaster, PA

Resequencing Schedule

Task		Rolled Up Progress	
Progress		Split	
Milestone	◆	External Tasks	
Summary		Project Summary	
Rolled Up Task		Group By Summary	
Rolled Up Milestone	◇	Deadline	⇩

Conclusions

This thesis report analyzes the redesign and implementation of; a structural steel joist floor system over a C.I.P. concrete system, Ivany block for a cantilever retaining wall over a C.I.P. concrete pinned retaining wall, the redesign of the groundwater lift station system from a duplex 120 GPM to a triplex 1020 GPM system, the use of laser scanning technology to document the existing Watt & Shand façade over traditional surveying techniques, the implementation of a combination minipile and caisson foundation system over a strictly caisson system, and the resequencing of construction activities for the proposed alternatives.

The redesigned structural system for the convention entry and elevated exhibit level floors offers significant schedule savings over the current cast-in-place concrete structure, though the steel system costs an additional $102,361. Additionally, the steel structural system eliminates the need for forming, shoring, and reshoring creating a cleaner more efficient work space – and the main reason for the redesign, it eliminates the requirement of having the museum level slab-on-grade complete (allowing time the plumbing redesign to occur). The redesigned retaining walls utilizing Ivany Block system offer schedule and a cost savings of $289,125 over the cast-in-place foundation wall system.

The mechanical redesign took place due to an underwater spring discovered during the excavation in the museum level. The additional water flows created by the discovery required the redesign of the existing groundwater lift station system to be resized to account for the additional water. Initially the groundwater lift station utilized a duplex 120 GPM system, whereas the redesigned system uses a triplex system capable of 1020 GPM, along with larger under slab and behind footing drains as well. The redesigned system provides a safer, more redundant system that also reduces the risk of hydrostatic forces creating uplift on the museum level slab with the increased system capabilities. To increase the system to meet the required flows brought about by the underwater spring the new triplex system with increased drains costs an additional $74,050 for just the plumbing considerations (excludes increased electrical capacity, and increased excavation).

The researched new technology of laser scanning has been evaluated towards its use to scan the existing Watt & Shand façade to locate it precisely and quickly. While to implement the use of laser scanning for the façade would cost $27,500 initially, ($27,000 over the costs of traditional surveying techniques employed on the project) it would have saved contractors $40,000 (for a total new savings of $13,000) and designers 3 months from redesign work due to the limited data provided on the existing facades location and conflicts that arose in construction.

A minipile foundation system was also researched towards its advantages for the Lancaster County Convention Center Project given its location in karst topography. The resulting research concluded that when (2) 8" 300K minipiles are used to replace the 36" diameter caissons for the project it results in an additional cost of $382,020. Though a higher first cost the resulting combination foundation system can be installed much faster then the caisson system alone; given two separate crews working simultaneously and that (2) 8" minipiles can be installed faster then a single 36" caisson given the karst topography for the project.

Lastly, a construction analysis was completed on the implementation of the above redesigned systems. The resequenced construction activities including all the proposed redesigns above provide a total of 5 weeks of schedule savings for the project. The additional $256,306 to implement all the proposed changes can be justified through the schedule savings: calculating 67% occupancy for the hotel (200/300 rooms) for 5 weeks at $200/night would generate $1.4 million worth of revenue for the project. Along with the additional revenue stream, the owners would also save on construction loans, consultants fee, construction managers fee, lawyers fees, etc… by finishing the project early – easily justifying the additional costs.

It is recommended to implement all of the proposed changes outlined in this report as to provide a higher quality building to the owners while saving five weeks to the construction schedule which offsets the additional costs increase of 0.15% to the project. See Figure 19 Summary Table below for a summary of the proposed changes and results in this report.

Summary Table		
Item	**Cost**	**Schedule**
Structural Redesign		
C.I.P. Concrete to Steel Joists	$102,361	
C.I.P. Concrete to Block Retaining Walls	-$289,125	
Plumbing (Groundwater Lift Station) Redesign		
Duplex 120GPM to Triplex 1020 GPM Capacity	$74,050	
Research		
Laser Scanning Technology	-$13,000	
Minipile and Caisson Foundation System	$382,020	
CM Study		
Resequencing	-	- 5 Weeks
Total	**$256,306**	**- 5 Weeks**
Additional Cost of $256,306 Saves 5 Weeks		

Figure 19 Summary Table

References

Building Background

1. www.coopercarry.com 14 Oct. 2007

2. www.co.lancaster.pa.us/lancastercity/cwp/view.asp?a=869&q=551148 14 Oct. 2007

3. www.lccca.com 14 Oct. 2007

Minipile Research

4. http://www.skylinesteel.com/products/pipe/micro_piles.aspx 15 Nov. 2007

5. http://www.delminsociety.net/motm/images/images_feb2007/PA_karst_map_lga.gif 2 Mar. 2008

6. "Karst" Def. 1. http://dictionary.reference.com/browse/karst 15 Jan. 2008

7. Traylor, A.W. Cadden P.E., D.A. Bruce MASCE. "High Capacity Micropiles In Karst: Challenges and Opportunities." February 2, 2008. <www.geosystemsbruce.com/v20/biblio/z166_2002_highCapacityPiles Karst.pdf>

8. D.A. Bruce, A.W. Cadden, P.J. Sabatini. "Practical Advice for Foundation Design – Micropiles for Structural Support." GSP 131 Contemporary Issues in Foundation Engineering February 2, 2008. <www.geosystemsbruce.com/v20/biblio/202%20Practical%20Advice%20for%20Fdn%20Design.pdf>

9. "Quantapoint – Technology and Services for Zero-Defect Projects." February 2, 2008. <www.quantapoint.com>

Laser Scan Survey Research

10. Stephen Booth. "Measured Building Surveys." The Building Conservation Directory. 2002. *Cathedral Communications*. February 12, 2008. <www.buildingconservation.com/articles/measuredbsurveys/measuredbsurveys.htm>

11. www.gsa.gov/Portal/gsa/ep/ 2 Feb. 2008.

Plumbing Breadth

12. Alfred McClymont, PE, "Report of Hydrogeological Study: Proposed Marriott Hotel and Convention Center – Penn Square Center". McClymont & Rak Geotechnical Engineers LLC. April 12, 2007.
13. City of Lancaster Department of Engineering, "Sanitary Sewer Pump Station Design Manual". May 2001.
14. McQuiston, Parker and Spitler. Heating, Ventilating, and Air Conditioning Analysis and Design. 6th Ed. John Wiley & Sons, Inc.
15. Goldis, Alon. "Lecture 5: Pump Design" Department of Chemical Engineering. Technion. 2005.
16. http://flexpvc.com/WaterFlowBasedOnPipeSize.shtml. 22 March 2008.

Structural Breadth

17. 1st Ed. CJ Series Standard Specifications for Composite Joists; Weight table and bridging tables code of standard practice by SJI (Steel Joist Institute).
18. American Institute of Steel Construction Inc. Steel Construction Manual. 13th Ed. 2005.
19. "Ivany Block: An innovation in concrete masonry." G. R. Ivany and Associates 1990. 20 Jan. 2008 < http://ivanyblock.com/index.html>.

Appendices Index

Appendix A – Minipile Analysis and Design Calculations

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Caisson Cost Analysis

	Diameter	Quantity	Length (ft.)	$/LF	$
Museum Level					
	36"	20	30	$141	$84,600
	42"	7	30	$141	$29,610
				Subtotal	$114,210
Convention Entry					
	36"	58	30	$141	$245,340
	42"	11	30	$141	$46,530
	54"	1	30	$283	$8,490
	60"	1	30	$283	$8,490
	66"	1	30	$283	$8,490
				Subtotal	$317,340
Exhibit Level					
	36"	48	30	$141	$203,040
	42"	23	30	$141	$97,290
	54"	8	30	$283	$67,920
	60"	4	30	$283	$33,960
	66"	12	30	$283	$101,880
	72"	6	30	$495	$89,100
	84"	2	30	$495	$29,700
	90"	2	30	$495	$29,700
				Subtotal	$652,590
				Total	**$1,084,140**

Minipile and Caisson Cost Analysis
36" and 42" caissons converted to minipiles

	Diameter	Quantity	Length (ft.)	$/LF	$
Museum Level					
	36"	20	30	$141	$84,600
	42"	7	30	$141	$29,610
				Caisson Subtotal	**$114,210**
	8"	61	30	$125	$228,750
				Minipile/Caisson Subtotal	**$228,750**
Convention Entry					
	36"	58	30	$141	$245,340
	42"	11	30	$141	$46,530
	54"	1	30	$283	$8,490
	60"	1	30	$283	$8,490
	66"	1	30	$283	$8,490
				Caisson Subtotal	**$317,340**
	8"	149	30	$125	$558,750
	54"	1	30	$283	$8,490
	60"	1	30	$283	$8,490
	66"	1	30	$283	$8,490
				Minipile/Caisson Subtotal	**$584,220**
Exhibit Level					
	36"	48	30	$141	$203,040
	42"	23	30	$141	$97,290
	54"	8	30	$283	$67,920
	60"	4	30	$283	$33,960
	66"	12	30	$283	$101,880
	72"	6	30	$495	$89,100
	84"	2	30	$495	$29,700
	90"	2	30	$495	$29,700
				Caisson Subtotal	**$652,590**
	8"	165	30	$125	$618,750
	54"	8	30	$283	$67,920
	60"	4	30	$283	$33,960
	66"	12	30	$283	$101,880
	72"	6	30	$495	$89,100
	84"	2	30	$495	$29,700
	90"	2	30	$495	$29,700
				Minipile/Caisson Subtotal	**$971,010**
				Caisson Total	**$1,084,140**
				Minipile/Caisson Total	**$1,783,980**
				Minipile Subtotal	$1,406,250
				Caisson Subtotal	$377,730

Minipile and Caisson Cost Analysis

36" caissons converted to minipiles

	Diameter	Quantity	Length (ft.)	$/LF	$
Museum Level					
	36"	20	30	$141	$84,600
	42"	7	30	$141	$29,610
			Caisson Subtotal		**$114,210**
	8"	40	30	$125	$150,000
	42"	7	30	$141	$29,610
			Minipile/Caisson Subtotal		**$179,610**
Convention Entry	36"	58	30	$141	$245,340
	42"	11	30	$141	$46,530
	54"	1	30	$283	$8,490
	60"	1	30	$283	$8,490
	66"	1	30	$283	$8,490
			Caisson Subtotal		**$317,340**
	8"	108	30	$125	$405,000
	42"	11	30	$141	$46,530
	54"	1	30	$283	$8,490
	60"	1	30	$283	$8,490
	66"	1	30	$283	$8,490
			Minipile/Caisson Subtotal		**$477,000**
Exhibit Level	36"	48	30	$141	$203,040
	42"	23	30	$141	$97,290
	54"	8	30	$283	$67,920
	60"	4	30	$283	$33,960
	66"	12	30	$283	$101,880
	72"	6	30	$495	$89,100
	84"	2	30	$495	$29,700
	90"	2	30	$495	$29,700
			Caisson Subtotal		**$652,590**
	8"	96	30	$125	$360,000
	42"	23	30	$141	$97,290
	54"	8	30	$283	$67,920
	60"	4	30	$283	$33,960
	66"	12	30	$283	$101,880
	72"	6	30	$495	$89,100
	84"	2	30	$495	$29,700
	90"	2	30	$495	$29,700
			Minipile/Caisson Subtotal		**$809,550**
			Caisson Total		**$1,084,140**
			Minipile/Caisson Total		**$1,466,160**
			Minipile Subtotal		$915,000
			Caisson Subtotal		$551,160

Minipile and Caisson Cost Analysis Summary

Description	Cost	Cost Difference
All caissons (existing system)	$1,084,140	-
36" caissons converted to minipiles	$1,466,160	$382,020
36" and 42" caissons converted to minipiles	$1,783,980	$699,840

The allowable compression load for the cased (free) length of a minipile is given as:[8]

$$P_{c-allowable} = \left[\frac{f'_{c-grout}}{FS_{grout}} \times A_{grout} + \frac{F_{y-steel}}{FS_{grout}} \left(A_{bar} + A_{ca\sin g} \right) \right] \times \frac{F_a}{\dfrac{F_{y-steel}}{FS_{y-steel}}}$$

where,

f'_c = uniaxial compressive strength of grout

FS_g = factor of safety on grout

A_g = cross sectional area of grout

$F_{y\text{-steel}}$ = minimum steel yield stress

$FS_{y\text{-steel}}$ = factor of safety on grout

A_{bar} = cross sectional area of bar

A_{casing} = cross sectional area of casing

F_a = allowable axial stress

Minipile Foundation Design

Design Input

1) Grout Strength
   $f'c$ = 3 ksi

2) Grout Factor Safety
   FS_g = 3

3) Cross Sectional Area of Grout
   A_g = 38.48 in^2

4) Steel Yield Strength
   $F_{y\text{-}steel}$ = 60 ksi

5) Steel Factor of Safety
   $FS_{y\text{-}steel}$ = 0.47

6) Bar Diameter
   A_b = 1.25 in^2

7) Cross Sectional Area of Casing
   A_{casing} = 11.82 in^2

Design Output

1) Allowable Axial Stress
   F_a = 128 ksi

2) Axial Compression
   $P_{c\text{-}allowable}$ = 300 k

Appendix B.1 - RAM Retaining Wall report printouts

Cantilever Retaining Wall Design

The following is the cantilever retaining wall design utilizing a single layer of rebar to resist soil pressure and a 25 lb/ft^2 construction load behind the wall.

RAM Retaining Wall

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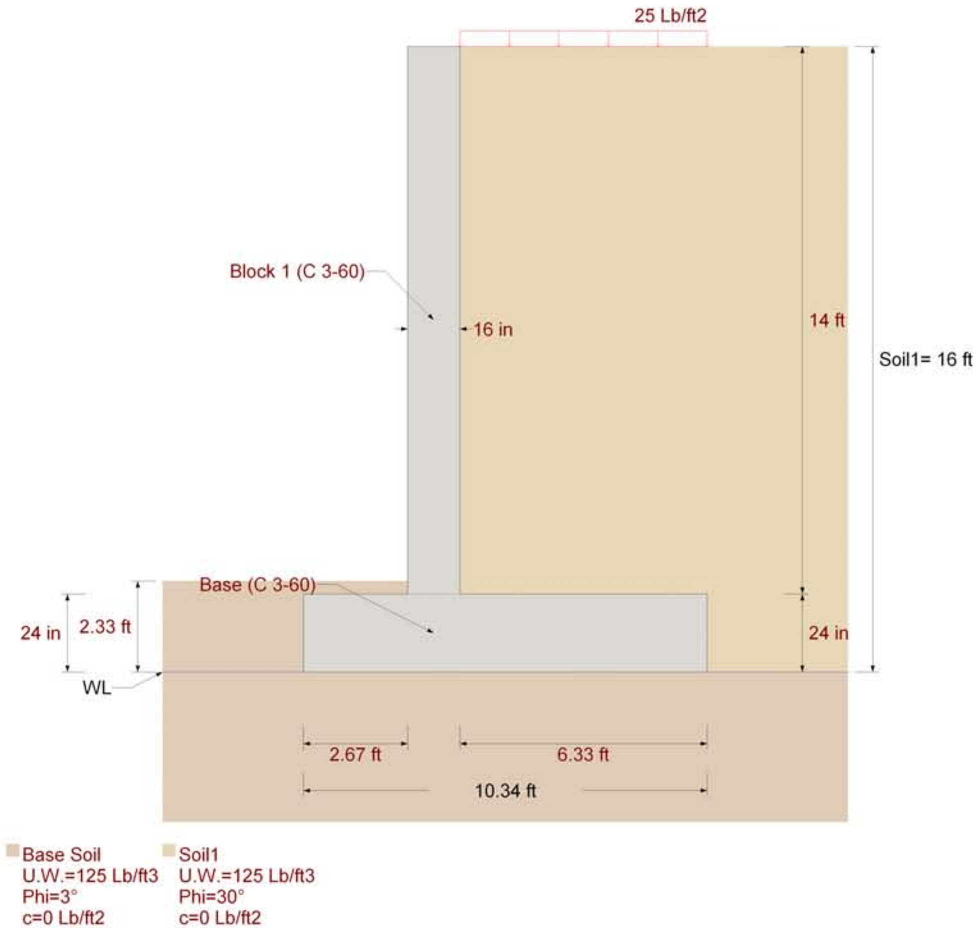
Units system: English
Current Date:3/24/2008 3:02 PM



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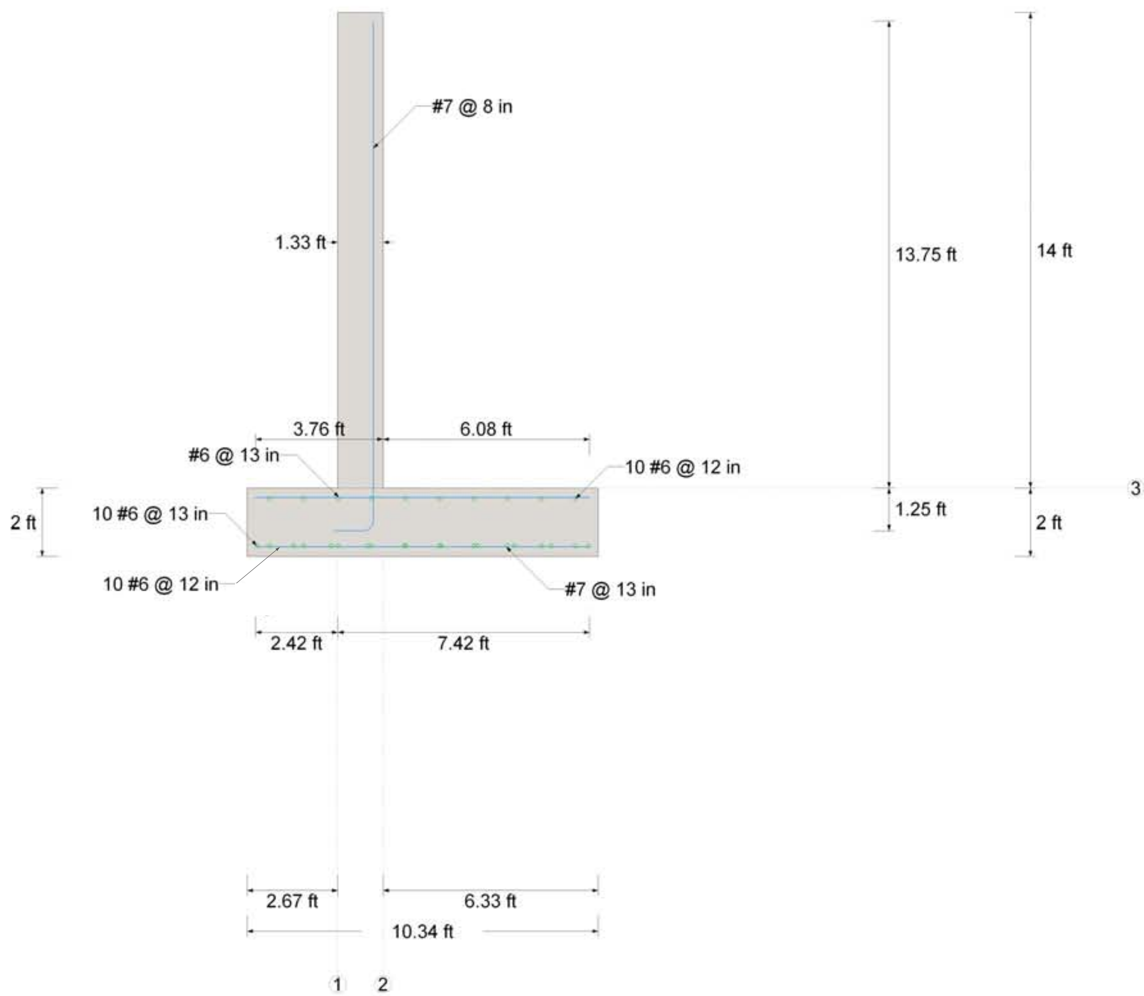


RAM Retaining Wall

File name: E:\Structural Breadth\Cantilever\Trevors Retaining Wall (1).rtw
Units system: English
Current Date: 3/24/2008 3:03 PM

Design Results

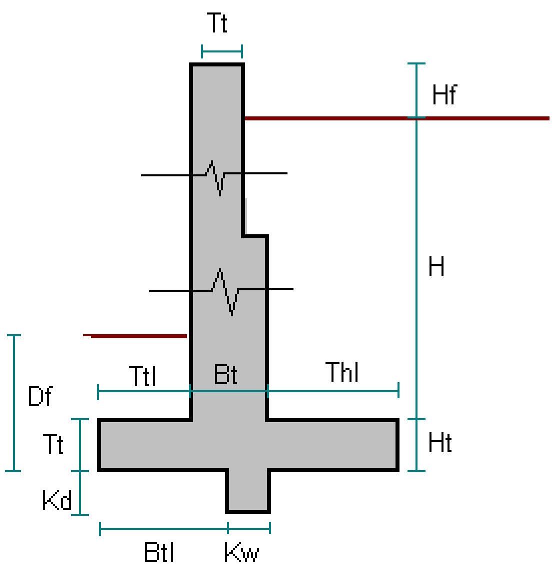
Retaining wall

GENERAL INFORMATION:

Design Code : ACI 318-05

Geometry

Wall type : Cantilever



Retained height H	:	14.00 [ft]	Wall height above retained soil Hf	:	0.00 [ft]
Base depth Df	:	2.33 [ft]	Use key	:	No
Top toe length Ttl	:	2.67 [ft]	Toe thickness Tt	:	2.00 [ft]
Bottom toe length Btl	:	2.00 [ft]			
Top heel length Thl	:	6.33 [ft]	Heel thickness Ht	:	2.00 [ft]
Base material	:	C 3-60			

Stem thickness at base Bt	:	16.00 [in]
Stem blocks number	:	1

Block	Thickness [in]	Height [ft]	Material
1	16.00	14.00	C 3-60

Materials

Description	:	C 3-60
Concrete, f'c	:	3.00 [Kip/in2]
Steel, fy	:	60.00 [Kip/in2]
Elasticity modulus	:	3122.02 [Kip/in2]
Unit weight	:	0.14 [Kip/ft3]

Soil

Modulus of subgrade reaction	:	115.74 [Lb/in3]
Backfill slope	:	0.00 [°]

Description	U.W. [Kip/ft3]	Saturated U.W. [Kip/ft3]	phi [°]	c [Kip/ft2]	Friction wall/soil	Ko
Base Soil	0.13	0.14	3.00	0.00	26.57	--
Soil1	0.13	--	30.00	0.00	0.00	0.00

Loads:

Backfill surcharge	:	0.03 [Kip/ft2]

Load conditions included in the design:

Service Load Combinations:
S1 = DL+LL+H

Strength Design Load Combinations:
R1 = 1.4DL+1.7LL+1.7H

Steel reinforcement bars:

Stem free cover	:	3.00 [in]
Base free cover	:	3.00 [in]
Maximum Rho/Rho balanced ratio	:	0.75
Minimum spacing between longitudinal bars	:	1.00 [in]
Round longitudinal bar lengths to	:	1.00 [in]
Estimated distance to mechanical center	:	0.50 [in]

Longitudinal reinforcement

Element	Size	Spacing [in]	Pos	Axis	Dist1 [ft]	Dist2 [ft]	Hook1	Hook2
Toe	#7	13.00	Int.	1	-2.42	7.41	No	No
Heel	#6	13.00	Ext.	2	-3.75	6.08	No	No
Stem	#7	8.00	Int.	3	-1.25	13.75	Yes	No

Development and splice lengths

Element	Diameter	Ld [in]	Ldh [in]	L. Splice [in]	L. total [ft]
Toe	#7	48.00	14.00	63.00	9.83
Heel	#6	43.00	12.00	56.00	9.83
Stem	#7	48.00	14.00	63.00	16.00

Horizontal reinforcement

Element	Diameter	Nr	@ [in]	Position
Base	#6	10	12.00	Ext.
Base	#6	10	12.00	Int.
Base	#6	13	13.00	Int.

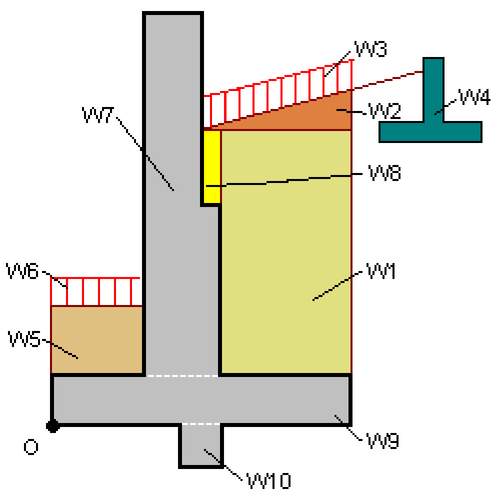
Assumptions

Active pressures calculation method	:	Rankine
Use resistant soil pressures for overturning	:	No
Calculation method for lateral soil pressures	:	Boussinesq
Calculation method for soil bearing pressures	:	Hansen
Use vertical component of soil pressures for overturning	:	No
Use vertical component of soil pressures for sliding	:	No
Use vertical component of soil pressures for bearing	:	No
Frost depth	:	0.00 [ft]
Undermining depth	:	0.00 [ft]

RESULTS:

Status : OK

Calculation of resisting forces



Description	Force [Kip]	Distance [ft]	Moment [Kip*ft]
Weight of soil over heel (W1)	11.08	7.17	79.41
Surcharge over heel (W3)	0.16	7.17	1.13
Weight of soil over toe (W5)	0.11	1.34	0.15
Stem weight (W7)	2.69	3.34	8.97
Base weight (W9)	2.97	5.17	15.37
Total	17.01		105.02
Toe horizontal soil pressure against sliding (Pp)	0.38	0.78	0.29
Toe horizontal soil pressure against overturning (Pp)	0.38	0.78	0.29

Calculation of destabilizing forces

Description	Force [Kip]	Distance [ft]	Moment [Kip*ft]
Heel horizontal soil pressure (Pah)	5.47	5.40	29.51

Global stability

Allowable safety factor for overturning	:	1.50
Allowable safety factor for sliding	:	1.50
Minimum additional safety factor for soil pressures	:	1.00

Load case	qmax [Kip/ft2]	qa [Kip/ft2]	Soil Pres. SF	RM [Kip*ft]	OTM [Kip*ft]	Overt. SF	Res F [Kip]	Slid F [Kip]	Slid. SF	Defl [in]
S1	2.32	6.00	2.58	105.32	29.51	3.57	8.88	5.47	1.62	0.31

Bending and Shear per element

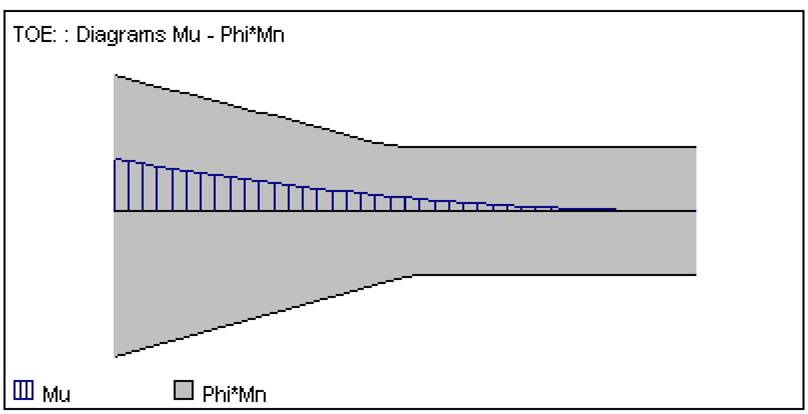
Element: Toe

Station Nr.	Dist	d [in]	Mu [Kip*ft] neg	Mu pos	ϕ*Mn [Kip*ft] neg	ϕ*Mn pos	Asreq [in2] ext	Asreq int	Asprov [in2] ext	Asprov int	sb [in] ext	sb int	Mu/(ϕ*Mn)
1	0%	20.50	0.00	11.73	-32.74	30.56	0.00	0.13	0.36	0.34	13.00	13.00	0.38
2	10%	20.50	0.00	9.56	-29.19	27.23	0.00	0.10	0.32	0.30	13.00	13.00	0.35
3	20%	20.50	0.00	7.60	-25.62	23.90	0.00	0.08	0.28	0.26	13.00	13.00	0.32
4	30%	20.50	0.00	5.85	-22.03	20.55	0.00	0.06	0.24	0.22	13.00	13.00	0.28
5	40%	20.50	0.00	4.33	-18.43	17.19	0.00	0.05	0.20	0.19	13.00	13.00	0.25
6	50%	20.50	0.00	3.02	-14.82	14.46	0.00	0.00	0.16	0.15	13.00	13.00	0.21
7	60%	20.50	0.00	1.95	-14.46	14.46	0.00	0.00	0.12	0.11	13.00	13.00	0.13
8	70%	20.50	0.00	1.10	-14.46	14.46	0.00	0.00	0.08	0.08	13.00	13.00	0.08
9	80%	20.50	0.00	0.49	-14.46	14.46	0.00	0.00	0.04	0.04	13.00	13.00	0.03
10	90%	20.50	0.00	0.12	-14.46	14.46	0.00	0.00	0.00	0.00	13.00	13.00	0.01
11	100%	20.50	0.00	0.00	-14.46	14.46	0.00	0.00	0.00	0.00	--	--	0.00
C	0%	20.50	0.00	11.73	-32.74	30.56	0.00	0.13	0.36	0.34	13.00	13.00	0.38

Maximum allowed spacing between bars	:	18.00 [in]

Base transverse reinforcement:

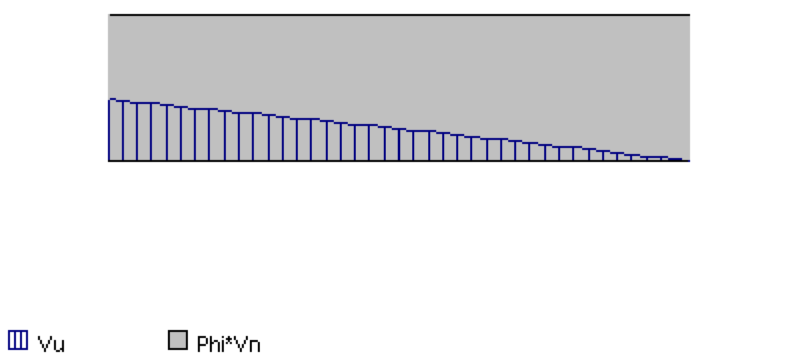
Top reinforcement	:	0.44 [in2]
Bottom reinforcement	:	0.44 [in2]
Minimum shrinkage and temperature reinforcement	:	0.58 [in2]



Station Nr.	Dist	Vu [Kip]	Vc [Kip]	ϕ*Vn [Kip]	Vu/(ϕ*Vn)
1	0%	8.52	26.95	20.21	0.42
2	10%	7.74	26.95	20.21	0.38
3	20%	6.95	26.95	20.21	0.34
4	30%	6.13	26.95	20.21	0.30
5	40%	5.30	26.95	20.21	0.26
6	50%	4.46	26.95	20.21	0.22

7	60%	3.60	26.95	20.21	0.18
8	70%	2.72	26.95	20.21	0.13
9	80%	1.83	26.95	20.21	0.09
10	90%	0.92	26.95	20.21	0.05
11	100%	0.00	26.95	20.21	0.00
C	0%	8.52	26.95	20.21	0.42

TOE: : Diagrams Vu - Phi*Vn

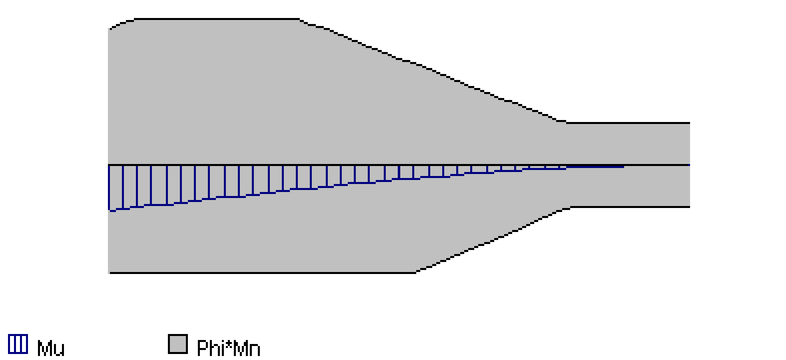


Element: Heel

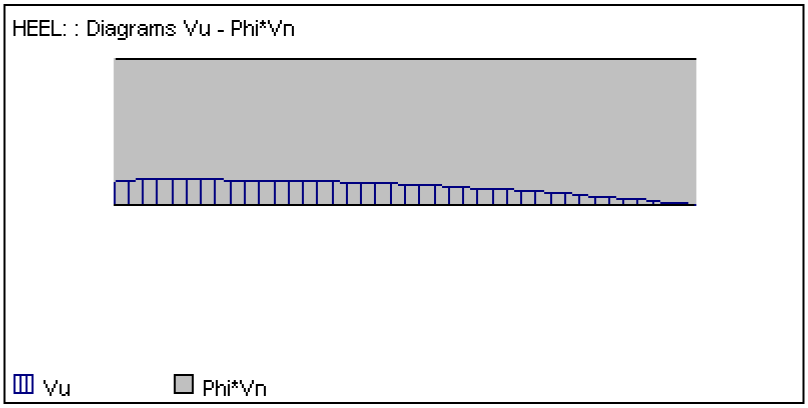
Station		**d**	**Mu** [Kip*ft]		**ϕ*Mn** [Kip*ft]		**Asreq** [in2]		**Asprov** [in2]		**sb** [in]		**Mu/(ϕ*Mn)**
Nr.	Dist	[in]	neg	pos	neg	pos	ext	int	ext	int	ext	int	
1	0%	20.50	-15.62	0.00	-36.97	46.97	0.17	0.00	0.41	0.52	13.00	13.00	0.42
2	10%	20.50	-13.41	0.00	-36.97	49.89	0.15	0.00	0.41	0.55	13.00	13.00	0.36
3	20%	20.50	-11.20	0.00	-36.97	49.89	0.12	0.00	0.41	0.55	13.00	13.00	0.30
4	30%	20.50	-9.04	0.00	-36.97	49.89	0.10	0.00	0.41	0.55	13.00	13.00	0.24
5	40%	20.50	-6.98	0.00	-36.97	44.46	0.08	0.00	0.41	0.49	13.00	13.00	0.19
6	50%	20.50	-5.08	0.00	-36.97	36.68	0.05	0.00	0.41	0.40	13.00	13.00	0.14
7	60%	20.50	-3.40	0.00	-30.91	28.84	0.04	0.00	0.34	0.32	13.00	13.00	0.11
8	70%	20.50	-2.00	0.00	-22.43	20.93	0.02	0.00	0.24	0.23	13.00	13.00	0.09
9	80%	20.50	-0.93	0.00	-14.46	14.46	0.00	0.00	0.15	0.14	13.00	13.00	0.06
10	90%	20.50	-0.24	0.00	-14.46	14.46	0.00	0.00	0.06	0.05	13.00	13.00	0.02
11	100%	20.50	0.00	0.00	-14.46	14.46	0.00	0.00	0.00	0.00	--	--	0.00
C	0%	20.50	-15.62	0.00	-36.97	46.97	0.17	0.00	0.41	0.52	13.00	13.00	0.42

Maximum allowed spacing between bars : 18.00 [in]

HEEL: : Diagrams Mu - Phi*Mn



Station Nr.	Dist	Vu [Kip]	Vc [Kip]	ϕ*Vn [Kip]	Vu/(ϕ*Vn)
1	0%	3.44	26.95	20.21	0.17
2	10%	3.50	26.95	20.21	0.17
3	20%	3.47	26.95	20.21	0.17
4	30%	3.35	26.95	20.21	0.17
5	40%	3.14	26.95	20.21	0.16
6	50%	2.84	26.95	20.21	0.14
7	60%	2.45	26.95	20.21	0.12
8	70%	1.97	26.95	20.21	0.10
9	80%	1.40	26.95	20.21	0.07
10	90%	0.75	26.95	20.21	0.04
11	100%	0.00	26.95	20.21	0.00
C	12%	3.50	26.95	20.21	0.17



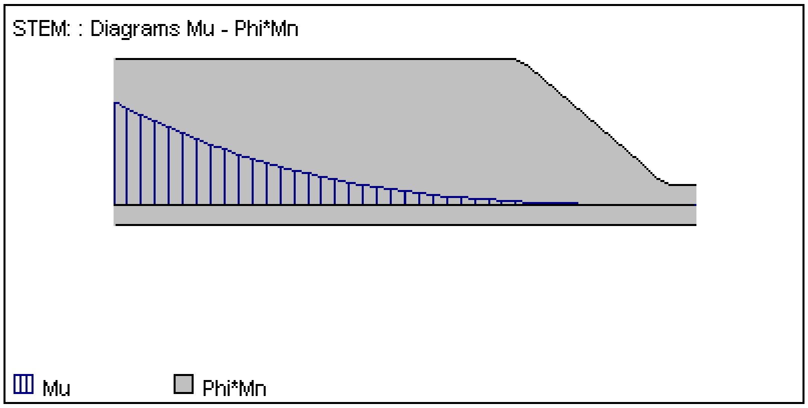
Element: Stem (Block 1)

Station Nr.	Dist	d [in]	Mu [Kip*ft] neg	Mu [Kip*ft] pos	ϕ*Mn [Kip*ft] neg	ϕ*Mn [Kip*ft] pos	Asreq [in2] ext	Asreq [in2] int	Asprov [in2] ext	Asprov [in2] int	sb [in] ext	sb [in] int	Mu/(ϕ*Mn)
1	0%	12.50	0.00	33.78	-6.43	47.30	0.00	0.63	0.00	0.90	--	8.00	0.71
2	10%	12.50	0.00	24.75	-6.43	47.30	0.00	0.45	0.00	0.90	--	8.00	0.52
3	20%	12.50	0.00	17.49	-6.43	47.30	0.00	0.32	0.00	0.90	--	8.00	0.37
4	30%	12.50	0.00	11.80	-6.43	47.30	0.00	0.21	0.00	0.90	--	8.00	0.25
5	40%	12.50	0.00	7.50	-6.43	47.30	0.00	0.13	0.00	0.90	--	8.00	0.16
6	50%	12.50	0.00	4.40	-6.43	47.30	0.00	0.08	0.00	0.90	--	8.00	0.09
7	60%	12.50	0.00	2.30	-6.43	47.30	0.00	0.04	0.00	0.90	--	8.00	0.05
8	70%	12.50	0.00	1.00	-6.43	46.23	0.00	0.02	0.00	0.88	--	8.00	0.02
9	80%	12.50	0.00	0.32	-6.43	31.02	0.00	0.01	0.00	0.57	--	8.00	0.01
10	90%	12.50	0.00	0.05	-6.43	14.35	0.00	0.00	0.00	0.26	--	8.00	0.00
11	100%	12.50	0.00	0.00	-6.43	6.43	0.00	0.00	0.00	0.00	--	8.00	0.00
C	0%	12.50	0.00	33.78	-6.43	47.30	0.00	0.63	0.00	0.90	--	8.00	0.71

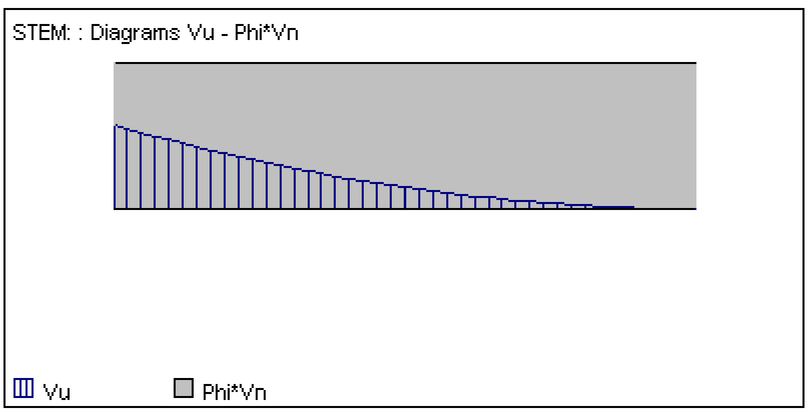
Maximum allowed spacing between bars : 18.00 [in]

Stem transverse reinforcement:

Exterior reinforcement : 0.00 [in2]
Interior reinforcement : 0.00 [in2]
Minimum shrinkage and temperature reinforcement : 0.38 [in2]



Station Nr.	Dist	Vu [Kip]	Vc [Kip]	ϕ*Vn [Kip]	Vu/(ϕ*Vn)
1	0%	7.14	16.43	12.32	0.58
2	10%	5.80	16.43	12.32	0.47
3	20%	4.60	16.43	12.32	0.37
4	30%	3.54	16.43	12.32	0.29
5	40%	2.62	16.43	12.32	0.21
6	50%	1.83	16.43	12.32	0.15
7	60%	1.19	16.43	12.32	0.10
8	70%	0.69	16.43	12.32	0.06
9	80%	0.32	16.43	12.32	0.03
10	90%	0.09	16.43	12.32	0.01
11	100%	0.00	16.43	12.32	0.00
C	0%	7.14	16.43	12.32	0.58



Notes

* The soil beneath the wall is considered elastic and homogeneous. A linear variation of pressures is adopted.

* The required reinforcement for bending takes into account the minimum reinforcement ratio given by Code.

* For bending and shear design, the critical section is adopted at the support faces and axial forces are not considered.

* Shear reinforcement is not considered.

* Values shown in red are not in compliance with a provision of the code

* Ld,Ldh = Development length of each bar. If the bar ends with a hook, it considers the Ldh length.

*qprom = Mean compression pressure on soil.

*qmax = Maximum compression pressure on soil.

* SF = Safety factor, RM = Resisting moment, OTM = Overturning moment.

* ResF = Resisting force, SlidF = Sliding force, Defl = Deflection.

* sb = Free distance between bars.

* If the section at which member flexural strength is being calculated is within the development length of a group of bars, the bars will contribute to the bending capacity an amount proportional to their actual length / their full development length.

* Asprov is the provided reinforcement, considering the reduction due to the development length as described previously.

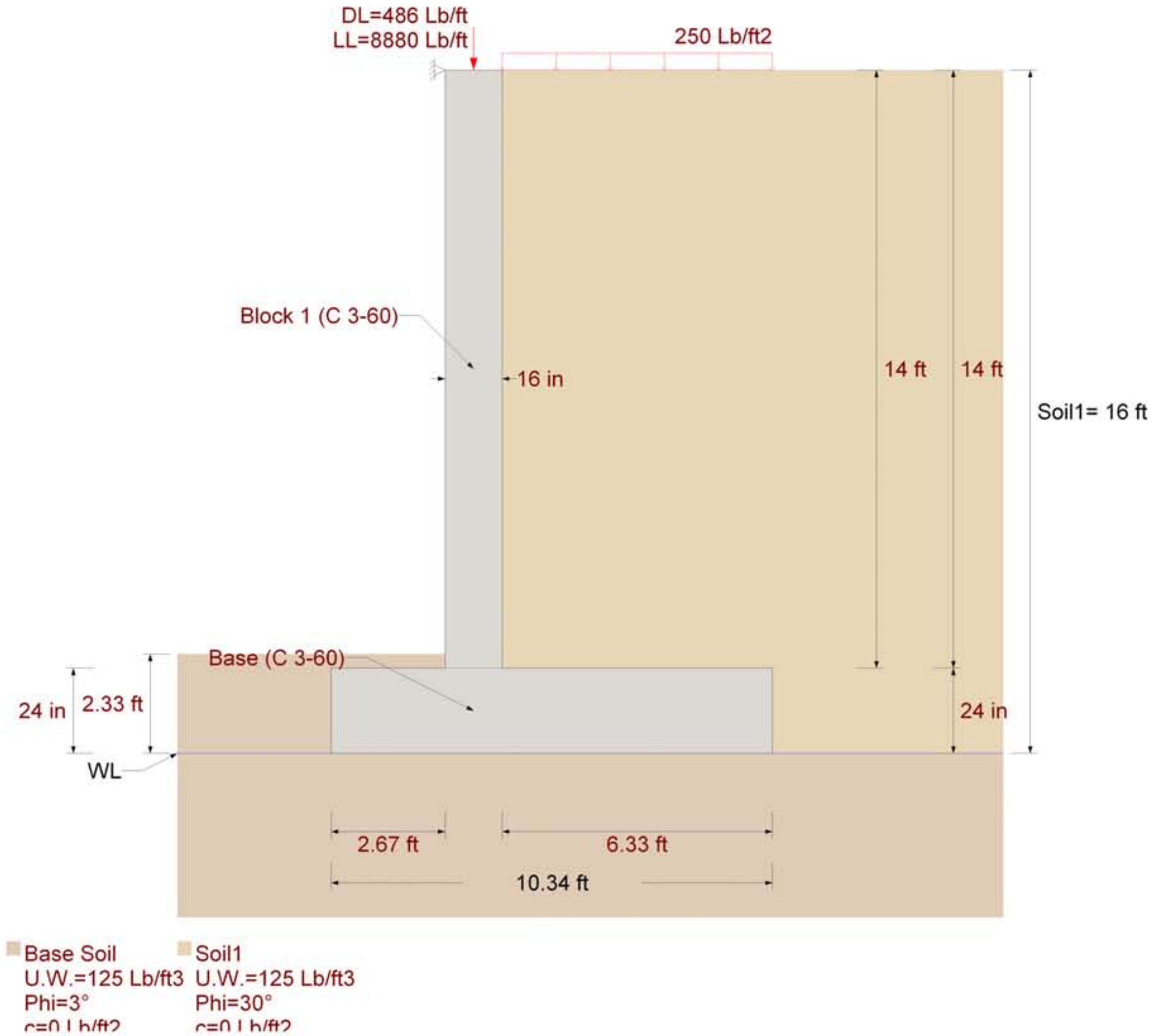
Appendix B.2 - RAM Retaining Wall report printouts

Pinned Retaining Wall Design

The following is the pinned retaining wall design utilizing two layers of rebar to resist the soil pressure, the joist load, and the 250 lb/ft^2 live load behind the wall.

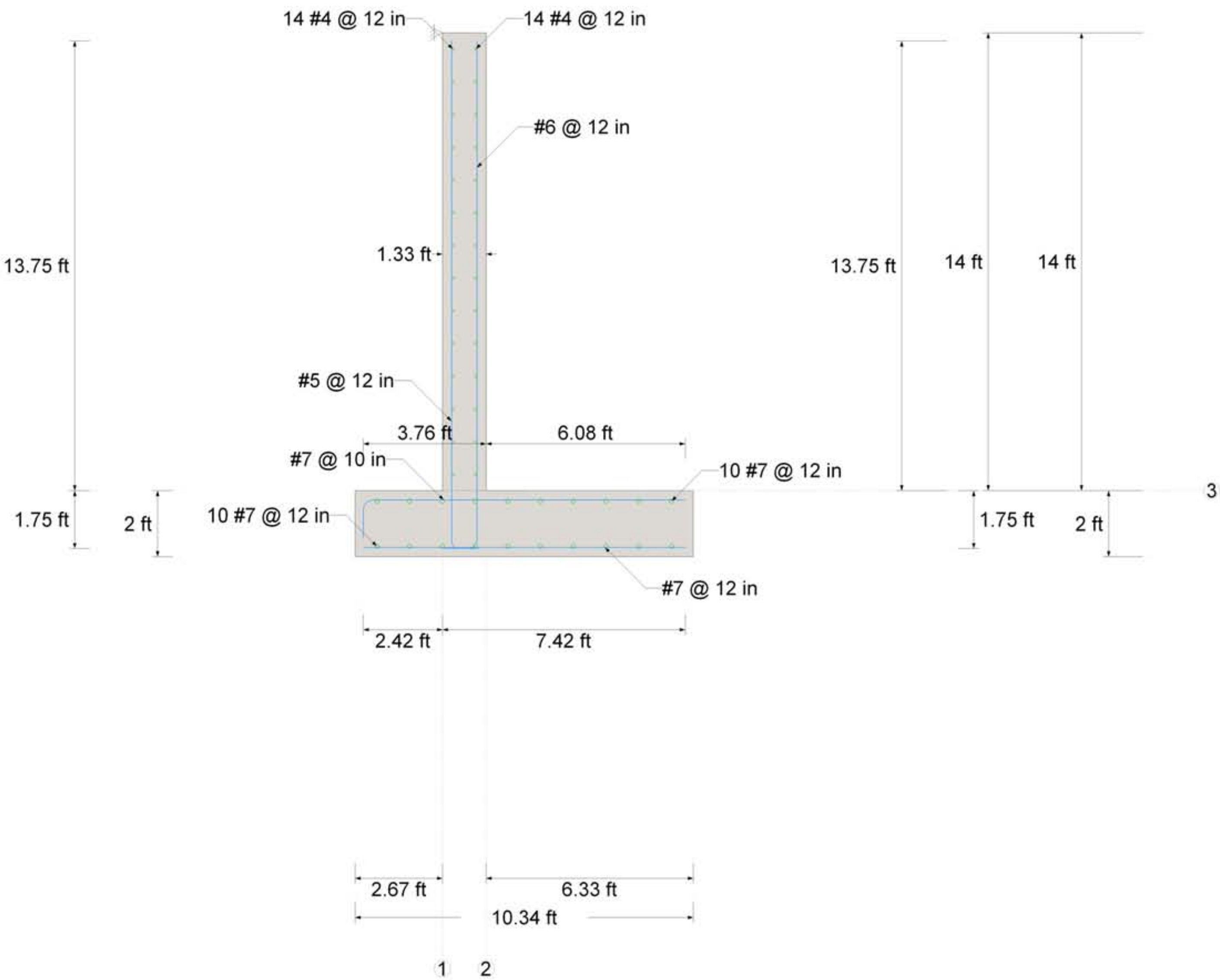
RAM Retaining Wall

File name:E:\Final Report\Structural Breadth\Pinned\Trevors Retaining Wall (2).rtw
Units system: English
Current Date:3/24/2008 3:07 PM



RAM Retaining Wall

File name:E:\Structural Breadth\Pinned\Trevors Retaining Wall (2).rtw
Units system: English
Current Date:3/24/2008 2:47 PM



RAM Retaining Wall

File name: E:\Structural Breadth\Pinned\Trevors Retaining Wall (2).rtw
Units system: English
Current Date: 3/24/2008 2:42 PM

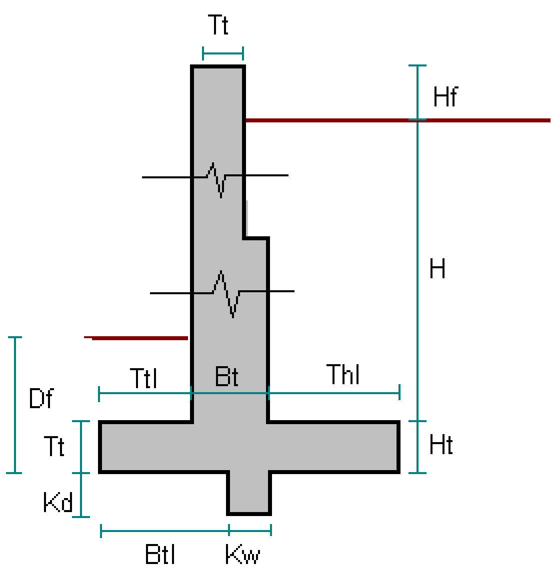
Design Results

Retaining wall

GENERAL INFORMATION:

Design Code : ACI 318-05

Geometry
Wall type : Restrained



Retained height H	:	14.00 [ft]	Wall height above retained soil Hf	:	0.00 [ft]
Base depth Df	:	2.33 [ft]	Use key	:	No
Top toe length Ttl	:	2.67 [ft]	Toe thickness Tt	:	2.00 [ft]
Bottom toe length Btl	:	2.00 [ft]			
Top heel length Thl	:	6.33 [ft]	Heel thickness Ht	:	2.00 [ft]
Base material	:	C 3-60			

Stem thickness at base Bt : 16.00 [in]
Stem blocks number : 1

Block	Thickness [in]	Height [ft]	Material
1	16.00	14.00	C 3-60

Materials

Description	:	C 3-60
Concrete, f'c	:	3.00 [Kip/in2]
Steel, fy	:	60.00 [Kip/in2]
Elasticity modulus	:	3122.02 [Kip/in2]
Unit weight	:	0.14 [Kip/ft3]

Soil

Modulus of subgrade reaction : 115.74 [Lb/in3]
Backfill slope : 0.00 [°]

Description	U.W. [Kip/ft3]	Saturated U.W. [Kip/ft3]	phi [°]	c [Kip/ft2]	Friction wall/soil	Ko
Base Soil	0.13	0.14	3.00	0.00	26.57	--
Soil1	0.13	--	30.00	0.00	0.00	0.00

Loads:

Backfill surcharge : 0.25 [Kip/ft2]
Stem axial load (DL) : 0.49 [Kip]
Stem axial load (LL) : 8.88 [Kip]

Load conditions included in the design:

Service Load Combinations:
S1 = DL+LL+H

Strength Design Load Combinations:
R1 = 1.2DL+1.6LL

Steel reinforcement bars:

Stem free cover : 3.00 [in]
Base free cover : 3.00 [in]
Maximum Rho/Rho balanced ratio : 0.75
Minimum spacing between longitudinal bars : 1.00 [in]
Round longitudinal bar lengths to : 1.00 [in]
Estimated distance to mechanical center : 0.50 [in]

Longitudinal reinforcement

Element	Size	Spacing [in]	Pos	Axis	Dist1 [ft]	Dist2 [ft]	Hook1	Hook2
Toe	#7	12.00	Int.	1	-2.42	7.41	No	No
Heel	#7	10.00	Ext.	2	-3.75	6.08	Yes	No
Stem	#5	12.00	Ext.	3	-1.75	13.75	Yes	No
Stem	#6	12.00	Int.	3	-1.75	13.75	Yes	No

Development and splice lengths

Element	Diameter	Ld [in]	Ldh [in]	L. Splice [in]	L. total [ft]
Toe	#7	48.00	14.00	63.00	9.83
Heel	#7	63.00	14.00	81.00	10.83
Stem	#5	28.00	10.00	36.00	16.25
Stem	#6	33.00	12.00	43.00	16.42

Horizontal reinforcement

Element	Diameter	Nr	@ [in]	Position
Base	#7	10	12.00	Ext.
Base	#7	10	12.00	Int.
Stem	#4	14	12.00	Ext.
Stem	#4	14	12.00	Int.

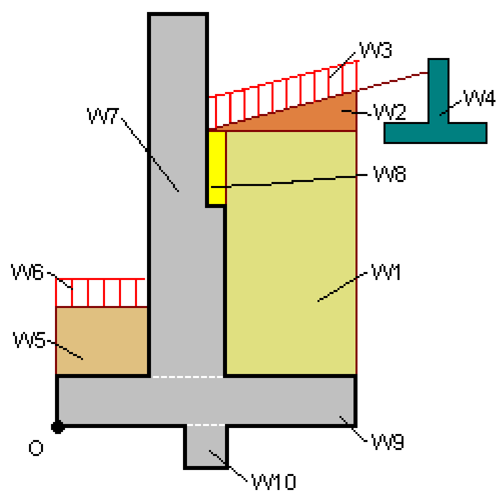
Assumptions

Active pressures calculation method	:	Rankine
Calculation method for lateral soil pressures	:	Boussinesq
Calculation method for soil bearing pressures	:	Hansen
Frost depth	:	0.00 [ft]
Undermining depth	:	0.00 [ft]

RESULTS:

Status : OK

Calculation of resisting forces



Description	Force [Kip]	Distance [ft]	Moment [Kip*ft]
Weight of soil over heel (W1)	11.08	7.17	79.41
Surcharge over heel (W3)	1.58	7.17	11.34
Weight of soil over toe (W5)	0.11	1.34	0.15
Stem weight (W7)	2.69	3.34	8.97
Base weight (W9)	2.97	5.17	15.37
Stem axial load (DL)	0.49	3.34	1.62
Stem axial load (LL)	8.88	3.34	29.63
Total	19.21		117.84

Calculation of destabilizing forces

Description	Force [Kip]	Distance [ft]	Moment [Kip*ft]
Heel horizontal soil pressure (Pah)	6.67	5.87	39.11

Global stability

Allowable safety factor for overturning : 1.50
Allowable safety factor for sliding : 1.50
Minimum additional safety factor for soil pressures : 1.00

Load case	qmax [Kip/ft2]	qa [Kip/ft2]	Soil Pres. SF	RM [Kip*ft]	OTM [Kip*ft]	Overt. SF	Res F [Kip]	Slid F [Kip]	Slid. SF	Defl [in]
S1	2.69	6.00	2.23	-	-	N.A.	-	-	N.A.	-

Bending and Shear per element

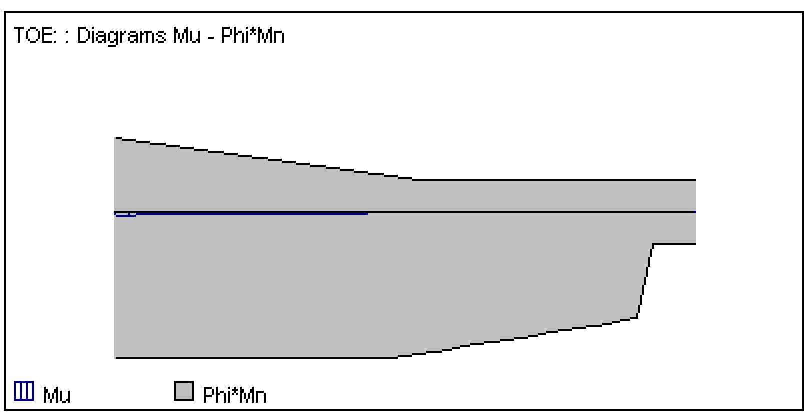
Element: Toe

Station Nr.	Dist	d [in]	Mu [Kip*ft] neg	Mu pos	ϕ*Mn [Kip*ft] neg	ϕ*Mn pos	Asreq [in2] ext	Asreq int	Asprov [in2] ext	Asprov int	sb [in] ext	sb int	Mu/(ϕ*Mn)
1	0%	20.50	-1.41	0.00	-64.34	33.06	0.02	0.00	0.72	0.36	10.00	12.00	0.02
2	10%	20.50	-1.14	0.00	-64.34	29.47	0.01	0.00	0.72	0.32	10.00	12.00	0.02
3	20%	20.50	-0.90	0.00	-64.34	25.86	0.01	0.00	0.72	0.28	10.00	12.00	0.01
4	30%	20.50	-0.69	0.00	-64.34	22.25	0.01	0.00	0.72	0.24	10.00	12.00	0.01
5	40%	20.50	-0.51	0.00	-64.34	18.61	0.01	0.00	0.72	0.20	10.00	12.00	0.01
6	50%	20.50	-0.35	0.00	-63.82	14.97	0.00	0.00	0.71	0.16	10.00	12.00	0.01
7	60%	20.50	-0.23	0.00	-59.66	14.46	0.00	0.00	0.67	0.12	10.00	12.00	0.00
8	70%	20.50	-0.13	0.00	-55.48	14.46	0.00	0.00	0.62	0.08	10.00	12.00	0.00
9	80%	20.50	-0.06	0.00	-51.27	14.46	0.00	0.00	0.57	0.04	10.00	12.00	0.00
10	90%	20.50	-0.01	0.00	-47.05	14.46	0.00	0.00	0.52	0.00	10.00	12.00	0.00
11	100%	20.50	0.00	0.00	-14.46	14.46	0.00	0.00	0.00	0.00	--	--	0.00
C	0%	20.50	-1.41	0.00	-64.34	33.06	0.02	0.00	0.72	0.36	10.00	12.00	0.02

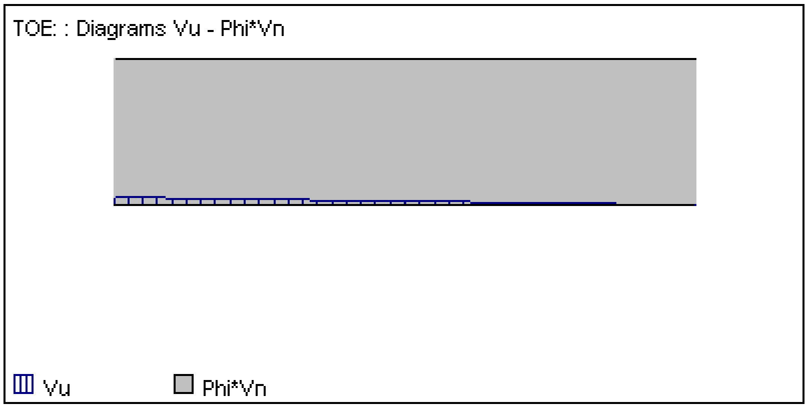
Maximum allowed spacing between bars : 18.00 [in]

Base transverse reinforcement:

Top reinforcement : 0.60 [in2]
Bottom reinforcement : 0.60 [in2]
Minimum shrinkage and temperature reinforcement : 0.58 [in2]



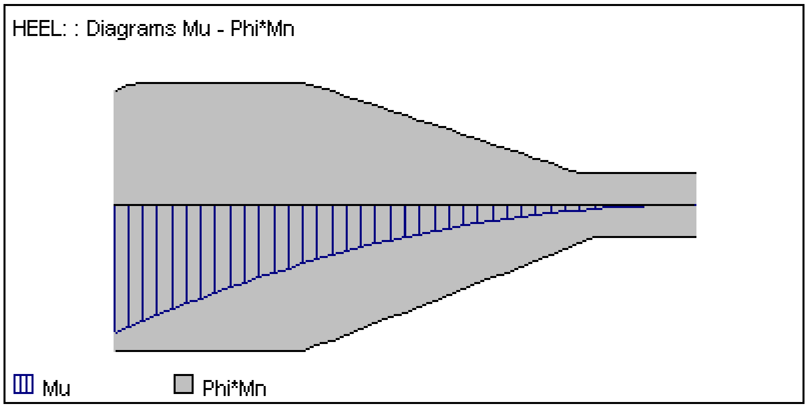
Station		Vu	Vc	ϕ*Vn	Vu/(ϕ*Vn)
Nr.	Dist	[Kip]	[Kip]	[Kip]	
1	0%	1.05	26.95	20.21	0.05
2	10%	0.95	26.95	20.21	0.05
3	20%	0.84	26.95	20.21	0.04
4	30%	0.74	26.95	20.21	0.04
5	40%	0.63	26.95	20.21	0.03
6	50%	0.53	26.95	20.21	0.03
7	60%	0.42	26.95	20.21	0.02
8	70%	0.32	26.95	20.21	0.02
9	80%	0.21	26.95	20.21	0.01
10	90%	0.11	26.95	20.21	0.01
11	100%	0.00	26.95	20.21	0.00
C	0%	1.05	26.95	20.21	0.05



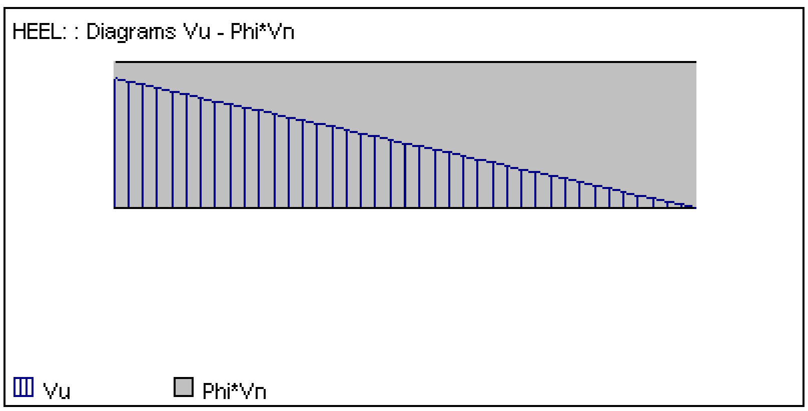
Element: Heel

Station		d	Mu [Kip*ft]		ϕ*Mn [Kip*ft]		Asreq [in2]		Asprov [in2]		sb [in]		Mu/(ϕ*Mn)
Nr.	Dist	[in]	neg	pos	neg	pos	ext	int	ext	int	ext	int	
1	0%	20.50	-57.01	0.00	-64.34	50.77	0.64	0.00	0.72	0.56	10.00	12.00	0.89
2	10%	20.50	-46.18	0.00	-64.34	53.93	0.51	0.00	0.72	0.60	10.00	12.00	0.72
3	20%	20.50	-36.48	0.00	-64.34	53.93	0.40	0.00	0.72	0.60	10.00	12.00	0.57
4	30%	20.50	-27.93	0.00	-64.34	53.93	0.31	0.00	0.72	0.60	10.00	12.00	0.43
5	40%	20.50	-20.52	0.00	-57.38	48.07	0.22	0.00	0.64	0.53	10.00	12.00	0.36
6	50%	20.50	-14.25	0.00	-47.41	39.68	0.16	0.00	0.53	0.44	10.00	12.00	0.30
7	60%	20.50	-9.12	0.00	-37.32	31.20	0.10	0.00	0.41	0.34	10.00	12.00	0.24
8	70%	20.50	-5.13	0.00	-27.12	22.65	0.06	0.00	0.30	0.25	10.00	12.00	0.19
9	80%	20.50	-2.28	0.00	-16.80	14.46	0.02	0.00	0.18	0.15	10.00	12.00	0.14
10	90%	20.50	-0.57	0.00	-14.46	14.46	0.00	0.00	0.07	0.06	10.00	12.00	0.04
11	100%	20.50	0.00	0.00	-14.46	14.46	0.00	0.00	0.00	0.00	--	--	0.00
C	0%	20.50	-57.01	0.00	-64.34	50.77	0.64	0.00	0.72	0.56	10.00	12.00	0.89

Maximum allowed spacing between bars : 18.00 [in]



Station Nr.	Dist	Vu [Kip]	Vc [Kip]	ϕ*Vn [Kip]	Vu/(ϕ*Vn)
1	0%	18.01	26.95	20.21	0.89
2	10%	16.21	26.95	20.21	0.80
3	20%	14.41	26.95	20.21	0.71
4	30%	12.61	26.95	20.21	0.62
5	40%	10.81	26.95	20.21	0.53
6	50%	9.01	26.95	20.21	0.45
7	60%	7.20	26.95	20.21	0.36
8	70%	5.40	26.95	20.21	0.27
9	80%	3.60	26.95	20.21	0.18
10	90%	1.80	26.95	20.21	0.09
11	100%	0.00	26.95	20.21	0.00
C	0%	18.01	26.95	20.21	0.89



Element: Stem (Block 1)

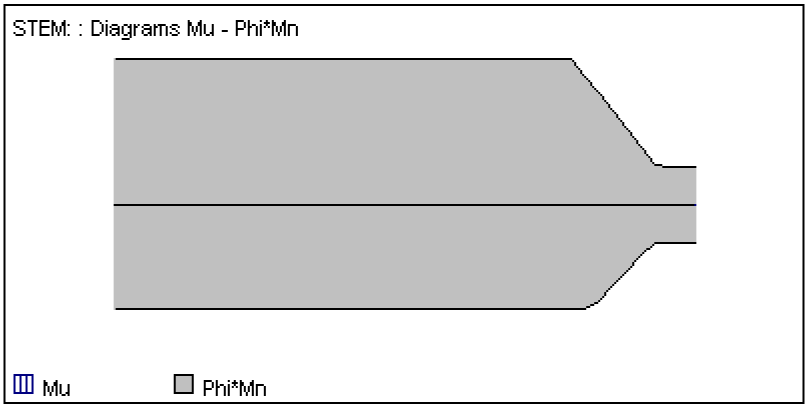
Station Nr.	Dist	d [in]	Mu [Kip*ft] neg	Mu [Kip*ft] pos	ϕ*Mn [Kip*ft] neg	ϕ*Mn [Kip*ft] pos	Asreq [in2] ext	Asreq [in2] int	Asprov [in2] ext	Asprov [in2] int	sb [in] ext	sb [in] int	Mu/(ϕ*Mn)
1	0%	12.50	0.00	0.00	-17.28	24.14	0.00	0.00	0.31	0.44	12.00	12.00	0.00
2	10%	12.50	0.00	0.00	-17.28	24.14	0.00	0.00	0.31	0.44	12.00	12.00	0.00
3	20%	12.50	0.00	0.00	-17.28	24.14	0.00	0.00	0.31	0.44	12.00	12.00	0.00
4	30%	12.50	0.00	0.00	-17.28	24.14	0.00	0.00	0.31	0.44	12.00	12.00	0.00
5	40%	12.50	0.00	0.00	-17.28	24.14	0.00	0.00	0.31	0.44	12.00	12.00	0.00
6	50%	12.50	0.00	0.00	-17.28	24.14	0.00	0.00	0.31	0.44	12.00	12.00	0.00
7	60%	12.50	0.00	0.00	-17.28	24.14	0.00	0.00	0.31	0.44	12.00	12.00	0.00

8	70%	12.50	0.00	0.00	-17.28	24.14	0.00	0.00	0.31	0.44	12.00	12.00	0.00
9	80%	12.50	0.00	0.00	-17.28	22.49	0.00	0.00	0.31	0.41	12.00	12.00	0.00
10	90%	12.50	0.00	0.00	-8.81	10.34	0.00	0.00	0.16	0.18	12.00	12.00	0.00
11	100%	12.50	0.00	0.00	-6.43	6.43	0.00	0.00	0.00	0.00	12.00	12.00	0.00
C	0%	12.50	0.00	0.00	-17.28	24.14	0.00	0.00	0.31	0.44	12.00	12.00	0.00

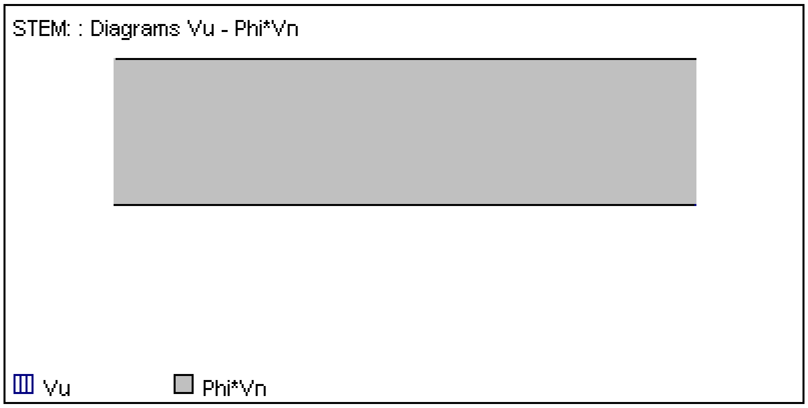
Maximum allowed spacing between bars : 18.00 [in]

Stem transverse reinforcement:

Exterior reinforcement : 0.20 [in2]
Interior reinforcement : 0.20 [in2]
Minimum shrinkage and temperature reinforcement : 0.38 [in2]



Station Nr.	Dist	**Vu** [Kip]	**Vc** [Kip]	**ϕ*Vn** [Kip]	**Vu/(ϕ*Vn)**
1	0%	0.00	16.43	12.32	0.00
2	10%	0.00	16.43	12.32	0.00
3	20%	0.00	16.43	12.32	0.00
4	30%	0.00	16.43	12.32	0.00
5	40%	0.00	16.43	12.32	0.00
6	50%	0.00	16.43	12.32	0.00
7	60%	0.00	16.43	12.32	0.00
8	70%	0.00	16.43	12.32	0.00
9	80%	0.00	16.43	12.32	0.00
10	90%	0.00	16.43	12.32	0.00
11	100%	0.00	16.43	12.32	0.00
C	0%	0.00	16.43	12.32	0.00



Notes

* The soil beneath the wall is considered elastic and homogeneous. A linear variation of pressures is adopted.

* The required reinforcement for bending takes into account the minimum reinforcement ratio given by Code.

* For bending and shear design, the critical section is adopted at the support faces and axial forces are not considered.

* Shear reinforcement is not considered.

* Values shown in red are not in compliance with a provision of the code

* Ld,Ldh = Development length of each bar. If the bar ends with a hook, it considers the Ldh length.

*qprom = Mean compression pressure on soil.

*qmax = Maximum compression pressure on soil.

* SF = Safety factor, RM = Resisting moment, OTM = Overturning moment.

* ResF = Resisting force, SlidF = Sliding force, Defl = Deflection.

* sb = Free distance between bars.

* If the section at which member flexural strength is being calculated is within the development length of a group of bars, the bars will contribute to the bending capacity an amount proportional to their actual length / their full development length.

* Asprov is the provided reinforcement, considering the reduction due to the development length as described previously.

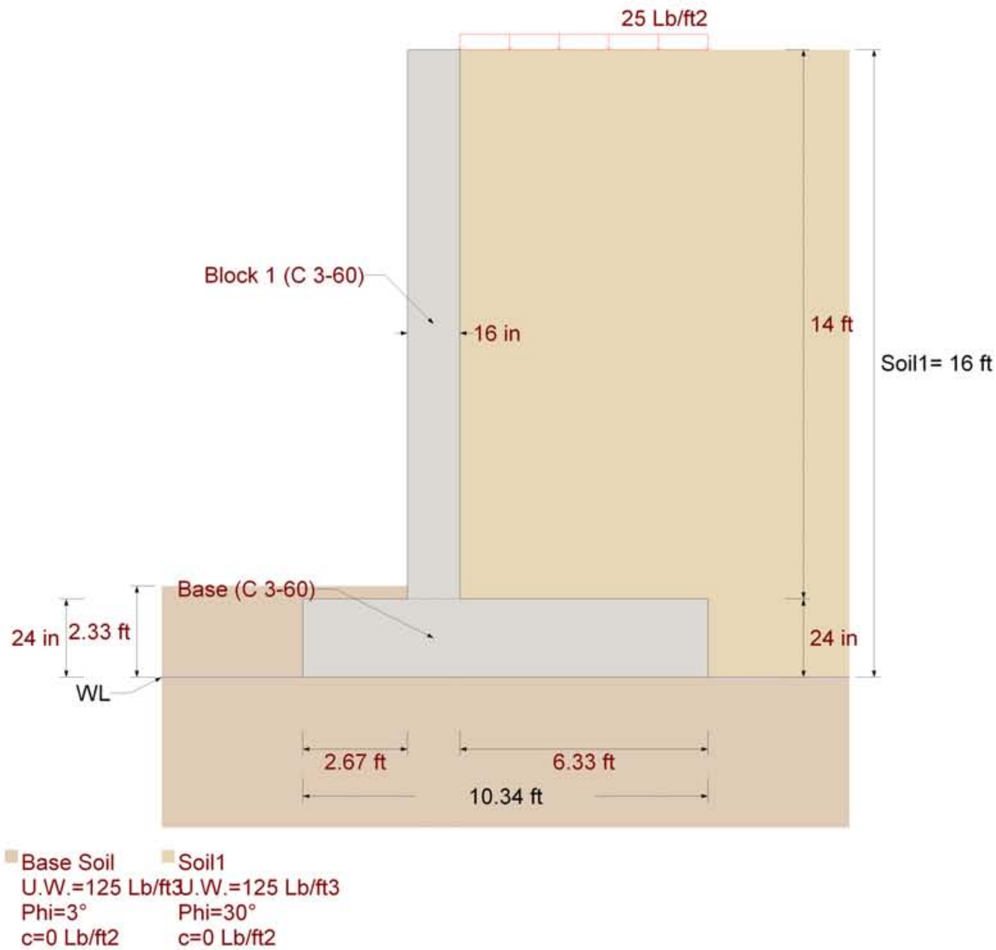
Appendix B.3 - RAM Retaining Wall report printouts

Cantilever Retaining Wall Scenario

The following is the cantilever retaining wall design utilizing the same rebar configuration as the pinned retaining wall design which is the controlling condition for the wall, to confirm the wall is acceptable during the construction process. The design utilizes checks the cantilevered wall to resist the soil pressure and a 25 lb/ft^2 construction load behind the wall.

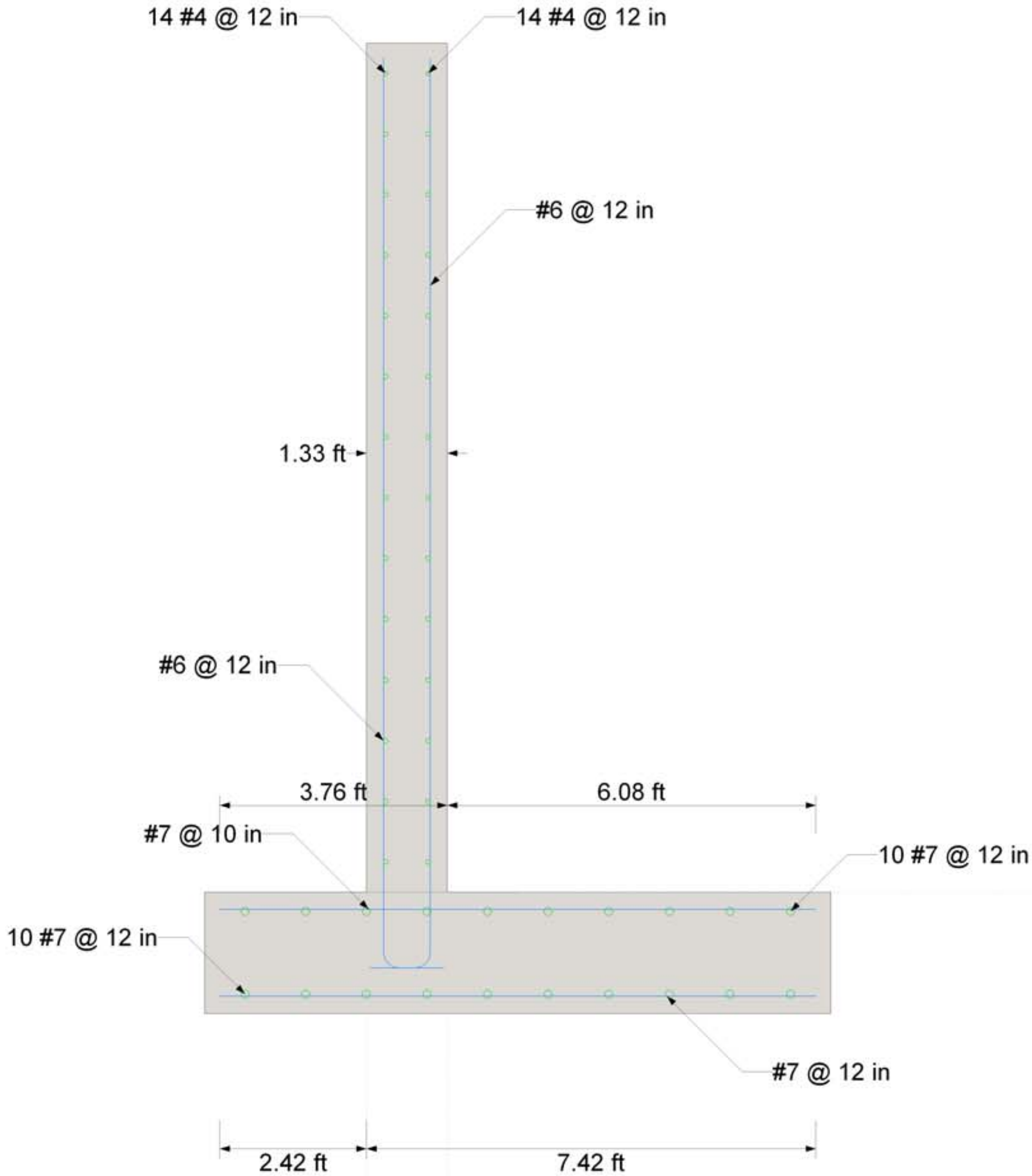
RAM Retaining Wall

File name: E:\Final Report\Structural Breadth\Cantilever\Trevors Retaining Wall (1).rtw
Units system: English
Current Date: 3/24/2008 2:50 PM



RAM Retaining Wall

File name:C:\Documents and Settings\ner116\Desktop\Trevors Retaining Wall (1.1).rtw
Units system: English
Current Date:2/25/2008 3:39 PM



RAM Retaining Wall
File name: C:\Documents and Settings\ner116\Desktop\Trevors Retaining Wall (1.1).rtw
Units system: English
Current Date: 2/25/2008 3:41 PM

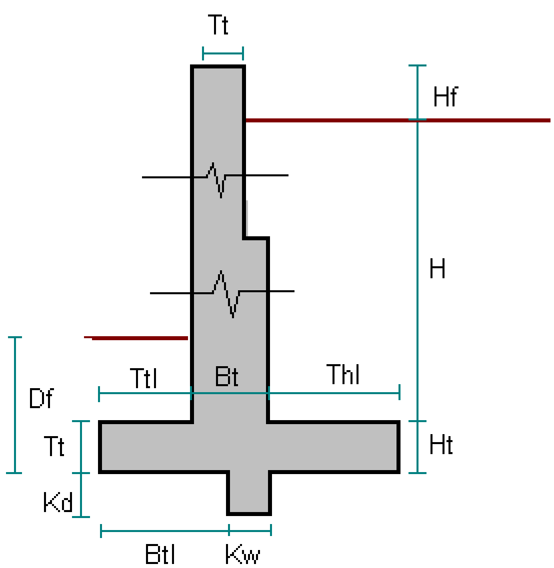
Design Results

Retaining wall

GENERAL INFORMATION:

Design Code : ACI 318-05

Geometry
Wall type : Cantilever



Retained height H	:	14.00 [ft]	Wall height above retained soil Hf	:	0.00 [ft]
Base depth Df	:	2.33 [ft]	Use key	:	No
Top toe length Ttl	:	2.67 [ft]	Toe thickness Tt	:	2.00 [ft]
Bottom toe length Btl	:	2.00 [ft]			
Top heel length Thl	:	6.33 [ft]	Heel thickness Ht	:	2.00 [ft]
Base material	:	C 3-60			

Stem thickness at base Bt : 16.00 [in]
Stem blocks number : 1

Block	Thickness [in]	Height [ft]	Material
1	16.00	14.00	C 3-60

Materials

Description	:	C 3-60
Concrete, f'c	:	3.00 [Kip/in2]
Steel, fy	:	60.00 [Kip/in2]
Elasticity modulus	:	3122.02 [Kip/in2]
Unit weight	:	0.14 [Kip/ft3]

Soil

Modulus of subgrade reaction	:	115.74 [Lb/in3]
Backfill slope	:	0.00 [°]

Description	U.W. [Kip/ft3]	Saturated U.W. [Kip/ft3]	phi [°]	c [Kip/ft2]	Friction wall/soil	Ko
Base Soil	0.13	0.14	3.00	0.00	26.57	--
Soil1	0.13	--	30.00	0.00	0.00	0.00

Loads:

Backfill surcharge	:	0.03 [Kip/ft2]

Load conditions included in the design:

Service Load Combinations:
S1 = DL+LL+H

Strength Design Load Combinations:
R1 = 1.2DL + 1.6LL

Steel reinforcement bars:

Stem free cover	:	3.00 [in]
Base free cover	:	3.00 [in]
Maximum Rho/Rho balanced ratio	:	0.75
Minimum spacing between longitudinal bars	:	1.00 [in]
Round longitudinal bar lengths to	:	1.00 [in]
Estimated distance to mechanical center	:	0.50 [in]

Longitudinal reinforcement

Element	Size	Spacing [in]	Pos	Axis	Dist1 [ft]	Dist2 [ft]	Hook1	Hook2
Toe	#7	12.00	Int.	1	-2.42	7.41	No	No
Heel	#7	10.00	Ext.	2	-3.75	6.08	No	No
Stem	#6	12.00	Int.	3	-1.25	13.75	Yes	No
Stem	#6	12.00	Ext.	3	-1.25	13.75	Yes	No

Development and splice lengths

Element	Diameter	Ld [in]	Ldh [in]	L. Splice [in]	L. total [ft]
Toe	#7	48.00	14.00	63.00	9.83
Heel	#7	63.00	14.00	81.00	9.83
Stem	#6	33.00	12.00	43.00	15.92
Stem	#6	33.00	12.00	43.00	15.92

Horizontal reinforcement

Element	Diameter	Nr	@ [in]	Position
Base	#7	10	12.00	Ext.
Base	#7	10	12.00	Int.
Stem	#4	14	12.00	Int.
Stem	#4	14	12.00	Ext.

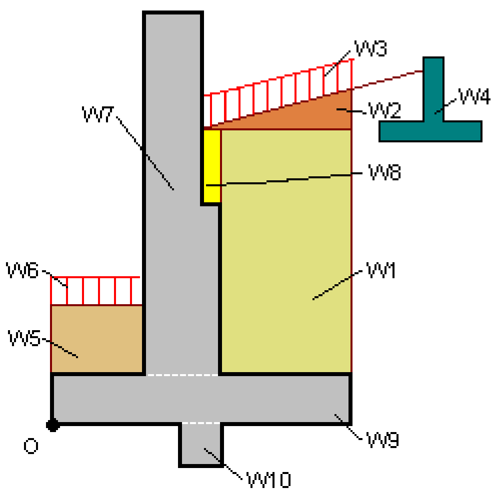
Assumptions

Active pressures calculation method	:	Rankine
Use resistant soil pressures for overturning	:	No
Calculation method for lateral soil pressures	:	Boussinesq
Calculation method for soil bearing pressures	:	Hansen
Use vertical component of soil pressures for overturning	:	No
Use vertical component of soil pressures for sliding	:	No
Use vertical component of soil pressures for bearing	:	No
Frost depth	:	0.00 [ft]
Undermining depth	:	0.00 [ft]

RESULTS:

Status : OK

Calculation of resisting forces



Description	Force [Kip]	Distance [ft]	Moment [Kip*ft]
Weight of soil over heel (W1)	11.08	7.17	79.41
Surcharge over heel (W3)	0.16	7.17	1.13
Weight of soil over toe (W5)	0.11	1.34	0.15
Stem weight (W7)	2.69	3.34	8.97
Base weight (W9)	2.97	5.17	15.37
Total	17.01		105.02
Toe horizontal soil pressure against sliding (Pp)	0.38	0.78	0.29
Toe horizontal soil pressure against overturning (Pp)	0.38	0.78	0.29

Calculation of destabilizing forces

Description	Force [Kip]	Distance [ft]	Moment [Kip*ft]
Heel horizontal soil pressure (Pah)	5.47	5.40	29.51

Global stability

Allowable safety factor for overturning : 1.50
Allowable safety factor for sliding : 1.50
Minimum additional safety factor for soil pressures : 1.00

Load case	qmax [Kip/ft2]	qa [Kip/ft2]	Soil Pres. SF	RM [Kip*ft]	OTM [Kip*ft]	Overt. SF	Res F [Kip]	Slid F [Kip]	Slid. SF	Defl [in]
S1	2.32	6.00	2.58	105.32	29.51	3.57	8.88	5.47	1.62	0.31

Bending and Shear per element

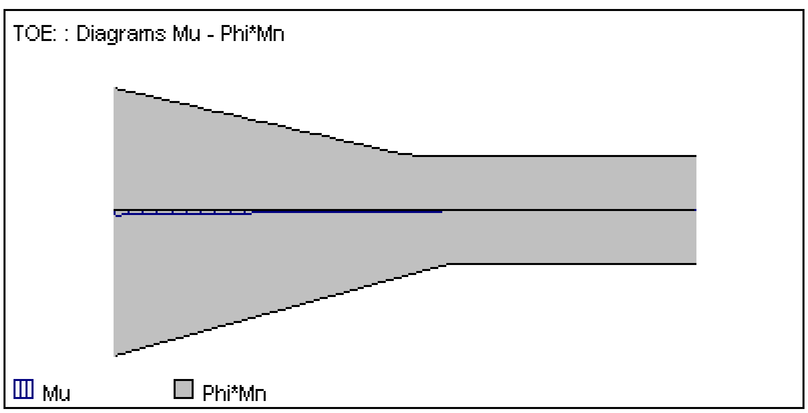
Element: Toe

Station Nr.	Dist	d [in]	Mu [Kip*ft] neg	Mu pos	ϕ*Mn [Kip*ft] neg	ϕ*Mn pos	Asreq [in2] ext	Asreq int	Asprov [in2] ext	Asprov int	sb [in] ext	sb int	Mu/(ϕ*Mn)
1	0%	20.50	-1.41	0.00	-39.53	33.06	0.02	0.00	0.44	0.36	10.00	12.00	0.04
2	10%	20.50	-1.14	0.00	-35.25	29.47	0.01	0.00	0.39	0.32	10.00	12.00	0.03
3	20%	20.50	-0.90	0.00	-30.95	25.86	0.01	0.00	0.34	0.28	10.00	12.00	0.03
4	30%	20.50	-0.69	0.00	-26.63	22.25	0.01	0.00	0.29	0.24	10.00	12.00	0.03
5	40%	20.50	-0.51	0.00	-22.29	18.61	0.01	0.00	0.24	0.20	10.00	12.00	0.02
6	50%	20.50	-0.35	0.00	-17.93	14.97	0.00	0.00	0.20	0.16	10.00	12.00	0.02
7	60%	20.50	-0.23	0.00	-14.46	14.46	0.00	0.00	0.15	0.12	10.00	12.00	0.02
8	70%	20.50	-0.13	0.00	-14.46	14.46	0.00	0.00	0.10	0.08	10.00	12.00	0.01
9	80%	20.50	-0.06	0.00	-14.46	14.46	0.00	0.00	0.05	0.04	10.00	12.00	0.00
10	90%	20.50	-0.01	0.00	-14.46	14.46	0.00	0.00	0.00	0.00	10.00	12.00	0.00
11	100%	20.50	0.00	0.00	-14.46	14.46	0.00	0.00	0.00	0.00	--	--	0.00
C	0%	20.50	-1.41	0.00	-39.53	33.06	0.02	0.00	0.44	0.36	10.00	12.00	0.04

Maximum allowed spacing between bars : 18.00 [in]

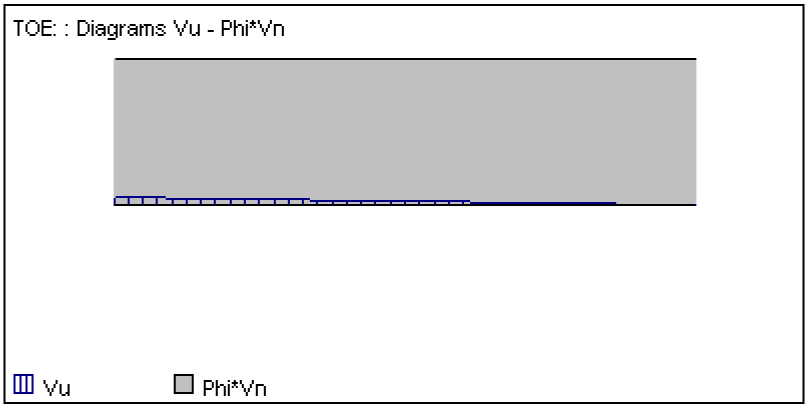
Base transverse reinforcement:

Top reinforcement : 0.60 [in2]
Bottom reinforcement : 0.60 [in2]
Minimum shrinkage and temperature reinforcement : 0.58 [in2]



Station Nr.	Dist	Vu [Kip]	Vc [Kip]	ϕ*Vn [Kip]	Vu/(ϕ*Vn)
1	0%	1.05	26.95	20.21	0.05
2	10%	0.95	26.95	20.21	0.05
3	20%	0.84	26.95	20.21	0.04
4	30%	0.74	26.95	20.21	0.04
5	40%	0.63	26.95	20.21	0.03
6	50%	0.53	26.95	20.21	0.03

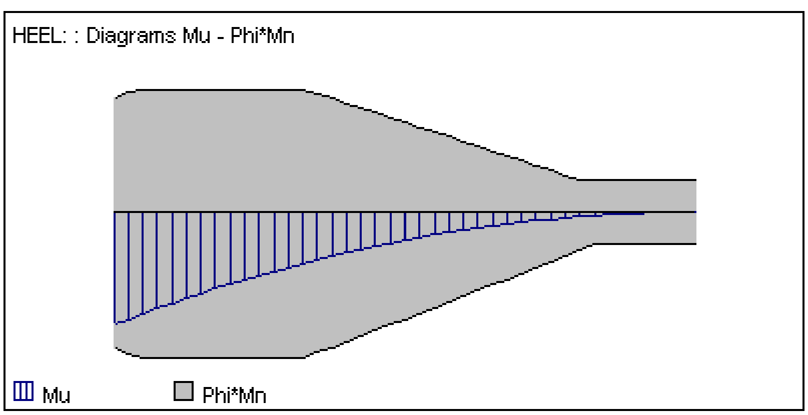
7	60%	0.42	26.95	20.21	0.02
8	70%	0.32	26.95	20.21	0.02
9	80%	0.21	26.95	20.21	0.01
10	90%	0.11	26.95	20.21	0.01
11	100%	0.00	26.95	20.21	0.00
C	0%	1.05	26.95	20.21	0.05



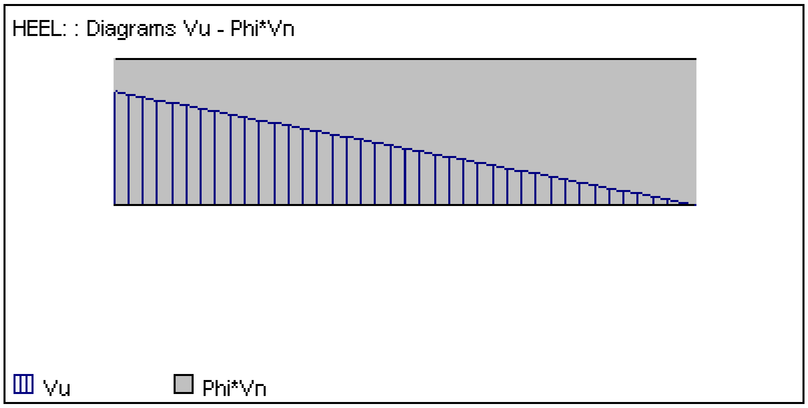
Element: Heel

Station		**d**	**Mu** [Kip*ft]		**ϕ*Mn** [Kip*ft]		**Asreq** [in2]		**Asprov** [in2]		**sb** [in]		**Mu/(ϕ*Mn)**
Nr.	Dist	[in]	neg	pos	neg	pos	ext	int	ext	int	ext	int	
1	0%	20.50	-49.79	0.00	-60.59	50.77	0.55	0.00	0.68	0.56	10.00	12.00	0.82
2	10%	20.50	-40.33	0.00	-64.34	53.93	0.45	0.00	0.72	0.60	10.00	12.00	0.63
3	20%	20.50	-31.87	0.00	-64.34	53.93	0.35	0.00	0.72	0.60	10.00	12.00	0.50
4	30%	20.50	-24.40	0.00	-64.34	53.93	0.27	0.00	0.72	0.60	10.00	12.00	0.38
5	40%	20.50	-17.93	0.00	-57.38	48.07	0.20	0.00	0.64	0.53	10.00	12.00	0.31
6	50%	20.50	-12.45	0.00	-47.41	39.68	0.14	0.00	0.53	0.44	10.00	12.00	0.26
7	60%	20.50	-7.97	0.00	-37.32	31.20	0.09	0.00	0.41	0.34	10.00	12.00	0.21
8	70%	20.50	-4.48	0.00	-27.12	22.65	0.05	0.00	0.30	0.25	10.00	12.00	0.17
9	80%	20.50	-1.99	0.00	-16.80	14.46	0.02	0.00	0.18	0.15	10.00	12.00	0.12
10	90%	20.50	-0.50	0.00	-14.46	14.46	0.00	0.00	0.07	0.06	10.00	12.00	0.03
11	100%	20.50	0.00	0.00	-14.46	14.46	0.00	0.00	0.00	0.00	--	--	0.00
C	0%	20.50	-49.79	0.00	-60.59	50.77	0.55	0.00	0.68	0.56	10.00	12.00	0.82

Maximum allowed spacing between bars : 18.00 [in]



Station Nr.	Dist	Vu [Kip]	Vc [Kip]	ϕ*Vn [Kip]	Vu/(ϕ*Vn)
1	0%	15.73	26.95	20.21	0.78
2	10%	14.16	26.95	20.21	0.70
3	20%	12.59	26.95	20.21	0.62
4	30%	11.01	26.95	20.21	0.54
5	40%	9.44	26.95	20.21	0.47
6	50%	7.87	26.95	20.21	0.39
7	60%	6.29	26.95	20.21	0.31
8	70%	4.72	26.95	20.21	0.23
9	80%	3.15	26.95	20.21	0.16
10	90%	1.57	26.95	20.21	0.08
11	100%	0.00	26.95	20.21	0.00
C	0%	15.73	26.95	20.21	0.78



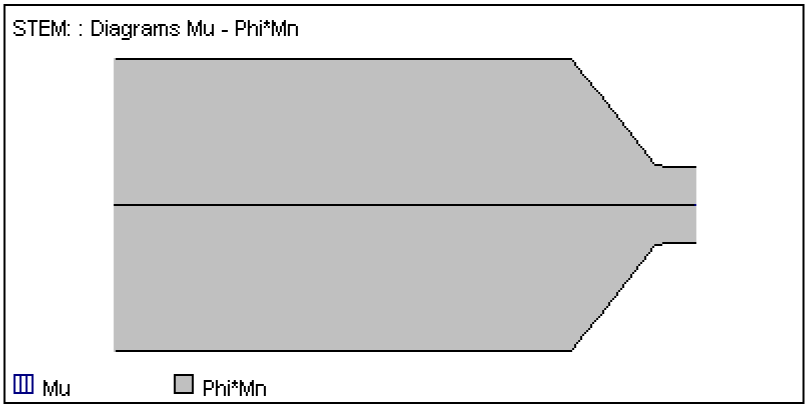
Element: Stem (Block 1)

Station Nr.	Dist	d [in]	Mu [Kip*ft] neg	Mu pos	ϕ*Mn [Kip*ft] neg	ϕ*Mn pos	Asreq [in2] ext	Asreq int	Asprov [in2] ext	Asprov int	sb [in] ext	sb int	Mu/(ϕ*Mn)
1	0%	12.50	0.00	0.00	-24.14	24.14	0.00	0.00	0.44	0.44	12.00	12.00	0.00
2	10%	12.50	0.00	0.00	-24.14	24.14	0.00	0.00	0.44	0.44	12.00	12.00	0.00
3	20%	12.50	0.00	0.00	-24.14	24.14	0.00	0.00	0.44	0.44	12.00	12.00	0.00
4	30%	12.50	0.00	0.00	-24.14	24.14	0.00	0.00	0.44	0.44	12.00	12.00	0.00
5	40%	12.50	0.00	0.00	-24.14	24.14	0.00	0.00	0.44	0.44	12.00	12.00	0.00
6	50%	12.50	0.00	0.00	-24.14	24.14	0.00	0.00	0.44	0.44	12.00	12.00	0.00
7	60%	12.50	0.00	0.00	-24.14	24.14	0.00	0.00	0.44	0.44	12.00	12.00	0.00
8	70%	12.50	0.00	0.00	-24.14	24.14	0.00	0.00	0.44	0.44	12.00	12.00	0.00
9	80%	12.50	0.00	0.00	-22.49	22.49	0.00	0.00	0.41	0.41	12.00	12.00	0.00
10	90%	12.50	0.00	0.00	-10.34	10.34	0.00	0.00	0.18	0.18	12.00	12.00	0.00
11	100%	12.50	0.00	0.00	-6.43	6.43	0.00	0.00	0.00	0.00	12.00	12.00	0.00
C	0%	12.50	0.00	0.00	-24.14	24.14	0.00	0.00	0.44	0.44	12.00	12.00	0.00

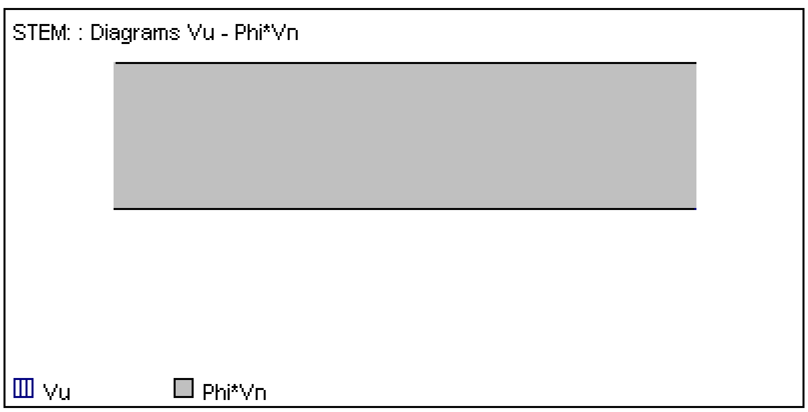
Maximum allowed spacing between bars : 18.00 [in]

Stem transverse reinforcement:

Exterior reinforcement : 0.20 [in2]
Interior reinforcement : 0.20 [in2]
Minimum shrinkage and temperature reinforcement : 0.38 [in2]



Station Nr.	Dist	Vu [Kip]	Vc [Kip]	ϕ*Vn [Kip]	Vu/(ϕ*Vn)
1	0%	0.00	16.43	12.32	0.00
2	10%	0.00	16.43	12.32	0.00
3	20%	0.00	16.43	12.32	0.00
4	30%	0.00	16.43	12.32	0.00
5	40%	0.00	16.43	12.32	0.00
6	50%	0.00	16.43	12.32	0.00
7	60%	0.00	16.43	12.32	0.00
8	70%	0.00	16.43	12.32	0.00
9	80%	0.00	16.43	12.32	0.00
10	90%	0.00	16.43	12.32	0.00
11	100%	0.00	16.43	12.32	0.00
C	0%	0.00	16.43	12.32	0.00



Notes

* The soil beneath the wall is considered elastic and homogeneous. A linear variation of pressures is adopted.

* The required reinforcement for bending takes into account the minimum reinforcement ratio given by Code.

* For bending and shear design, the critical section is adopted at the support faces and axial forces are not considered.

* Shear reinforcement is not considered.

* Values shown in red are not in compliance with a provision of the code

* Ld,Ldh = Development length of each bar. If the bar ends with a hook, it considers the Ldh length.

*qprom = Mean compression pressure on soil.

*qmax = Maximum compression pressure on soil.

* SF = Safety factor, RM = Resisting moment, OTM = Overturning moment.

* ResF = Resisting force, SlidF = Sliding force, Defl = Deflection.

* sb = Free distance between bars.

* If the section at which member flexural strength is being calculated is within the development length of a group of bars, the bars will contribute to the bending capacity an amount proportional to their actual length / their full development length.

* Asprov is the provided reinforcement, considering the reduction due to the development length as described previously.

Appendix C – Joist Tables for Exhibit Level Floor System

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Marriott Hotel and Lancaster County Convention Center

Floor System Redesign
Composite Joist Input Information

Design by: Trevor J. Sullivan
Date: 2/14/08

Joist Geometry:

1)	Depth	18	in
2)	Span	40	ft
3)	Adjacent Member Spacing (left)	4	ft
4)	Adjacent Member Spacing (right)	4	ft

Concrete and Deck:

1)	Type of Floor Deck		
2)	Depth of Floor Deck	3	in
3)	Slab Thickness Above Deck	2.5	in
4)	Concrete Unit Weight	145	pcf
5)	Concrete Compressive Strength	4	ksi

Nominal Loads:

1)	Non-Composite Construction Dead Load			
	a)	Concrete	50	psf
	b)	Joist and Bridging (Estimated)	5	psf
	c)	Deck	2	psf
	d)	**Total**	**57**	psf
			228	plf
2)	Construction Live Load			
	a)	During Concrete Placement	25	psf
			100	plf
3)	Composite Dead Load			
	a)	Fixed Partitions	0	psf
	b)	Mechanical	5	psf
	c)	Electrical	5	psf
	d)	Fireproofing	2	psf
	e)	Floor Covering and Ceiling	10	psf
	f)	Miscellaneous Dead Loads	5	psf
	g)	**Total**	**27**	psf
			108	plf
4)	Composite Live Load			
	a)	Live Load (Reduced as Applicable)	350	psf
	b)	Moveable Partitions	20	psf
	c)	**Total**	**370**	psf
			1480	plf
5)	Total Factored Non-Composite Dead Load, 1.2 x (1d)		**68.4**	psf
			273.6	plf

6)	Total Factored Composite Dead Load, 1.2 x (3g)	**32.4**	psf
		129.6	plf
7)	Total Factored Composite Design Load, 1.6 x (4c)	**592**	psf
		2368	plf
8)	Total Factored Composite Design Load (5) + (6) + (7)	**692.8**	psf
	(Concentrated Dead Load Not Included)	**2771.2**	plf
Additional Concentrated Dead Load, P, at Top Chord		0	kips
	Distance from Left	0	ft
Total Factored Composite Dead Load		**0**	kips

Camber and Deflection (Unfactored Load):

1)	Loads to Camber For		
	a) Percent of Non-Composite DL, (1d) x 100%	**57**	psf
	b) Percent of Composite DL, (3g) x 50%	**13.5**	psf
	c) Percent of Composite LL, (4c) x 20%	**74**	psf
2)	Maximum Allowable Live Load Deflection, Span/360	**1.33**	in
3)	Maximum Deflection, Span/240	**2.00**	in

Marriott Hotel and Lancaster County Convention Center

Floor System Redesign
Composite Joist Load and Moment Calculations

Design by: Trevor J. Sullivan
Date: 2/14/08

1) Calculate Factored Loads

a) Uniformly Distributed Loads

w_f = **2771.2** plf

b) Concentrated Loads

P_f = **0** lbs

2) Calculate Maximum Moment and Location

R_A = **55,424** lbs

L_0 = **20.0** ft

M_f = **554,240** ft-lbs

3) Calculate Maximum End Reaction

R_A = **55,424** lbs

R_B = **55,424** lbs

4) Calculate Equivalent Uniform Load

w_{eM} = **2771** plf

5) Calculate Equivalent Load from End Reaction

w_{eR} = **2771.2** plf

6) Determine Equivalent Load

w_e = **2771** plf

7) Select Composite Joist and Bridging from Weight and Bridging Tables

Marriott Hotel and Lancaster County Convention Center

Floor System Redesign
Composite Joist Selection and Deflection

Design by: Trevor J. Sullivan
Date: 2/29/08

Joist Specification: 18CJ 2771/2368/130

Height of Deck Ribs
h_r = 3 in

Thickness of Concrete
t_c = 2.5 in

Joist Spacing
J_c = 4 ft

1) Self Weight of Joist
Wt_{joist} = 54 plf

2) Allowable Composite Live Load
w_{360} = 1509 plf

3) Number of Shear Studs/Diameter
N-ds = 80-3/4"

4) Composite Moment of Inertia
I_{eff} = 2250 in^4

5) Type of Bridging Required
(1) L2.5x.0187H

6) Non-Composite Moment of Inertia
$I_{n-c,\ eff}$ = 698

Deflection and Camber:

1) Deflection Prior to Composite Action

Δ = **0.6274** in or L / 765

A) Design Length 39.67 ft
B) E_s (psi) 2.9E+07 psi

2) Deflection Due to Composite Dead Load

Δ = **0.0922** in or L / 5206

4) Deflection Due to Live Load

Δ = **1.2968** in or L / 370

5) Total Deflection

Δ = **2.0164** in or L / 238

6) Camber

Joist Camber = **0.933** in

Marriott Hotel and Lancaster County Convention Center

Floor System Redesign
Girder Analysis/Design

Design by: Trevor Sullivan
Date: 2/29/08

Girder Specifications

1) Span 20 ft
2) Tributary Width 40 ft
2) Allowable Live Load Deflection
Δ_{LL} = Span/360 = 0.67 in
3) Allowable Total Load Deflection
Δ_{TL} = Span/240 = 1.00 in
4) Uniform Live Load
w_{LL} = 350 psf
5) Uniform Dead Load
w_{DL} = 75 psf
6) Uniform Total Load
w_{TL} = 425 psf

Design Criteria

1) Minimum Moment of Inertia
A) Live Load Requirement
$I \geq$ 2607 in^4
B) Total Load Requirement
$I \geq$ 2110 in^4
2) Required Bending Moment Capacity
A) M = 1300 ft*k
3) Required Shear Capacity
A) V = 260 k

Girder Selection

1) Girder Designation **W18x158**
A) I_X = 3060 in^4
B) M_u = 1340 ft*k
C) V_u = 479 k

Column Design

1) Compressive Load

	P	=	**392**	k

Column Selection

1)	Column Designation		**W14x53**	
A)	P_u	=	401	k
B)	KL	=	14	ft

Marriott Hotel and Lancaster County Convention Center

Floor System Redesign
Composite Joist Vibration Analysis (SJI Method)

Design by: Trevor J. Sullivan
Date: 2/14/08

Determine Effective Area for Vibration

1) Equivalent Number of Fully Effective Joists

   N = 4.125019

2) Flexural Stiffness Perpendicular to Joists (Slab Only)

   A) Modulus of Elasticity of Concrete
   E_c = 3605 ksi
   B) Slab Thickness
   t = 4 in
   C) Flexural Stiffness
   D_x = 19227

3) Flexural Stiffness Parallel to Joists (Composite Section)

   A) Modulus of Elasticity of Steel
   E_s = 29000 ksi
   B) Moment of Inertia of the Composite Section
   I_t = 2250 in^4
   C) Joist Spacing
   b = 48 in
   D) Flexural Stiffness
   D_y = 1359375

4) Stiffness Ratio
   ε = 0.345

5) Effective Floor Half Width
   x_o = 14.63 ft

6) Combined Flexural Stiffness

   I_{equ} = 9281 in^4

7) Uniformly Distributed Load per Unit Length

   w = 54.33333 lbs/in

8) Natural Joist Frequency
   f_n = 0.668 Hz

Marriott Hotel and Lancaster County Convention Center

Floor System Redesign
Composite Joist Vibration Analysis (SJI Method)

Design by: Trevor J. Sullivan
Date: 2/20/08

Determine Vibration Effects Due to Impact

1) Impact Caused by Object

A) First Maximum Amplitude
A_o = **0.000281** in

B) Force of Rectangular Impulse
F = 794 lbs

C) Duration of Impulse
t_d = 0.01 s

D) Time to Occurrence of Maximum Amplitude
t_o = **0.748** s

E) Human Response Factor
R = **0.63** 4% Critical Damping
0.60 10% Critical Damping

2) Impact Caused by Heel Drop

A) First Maximum Amplitude
A_o = **0.000536** in

B) Force of Rectangular Impulse
F = 606 lbs

C) Duration of Impulse
t_d = 0.05 s

D) Time to Occurrence of Maximum Amplitude
t_o = **0.099** s

E) Human Response Factor
R = **0.75** 4% Critical Damping
0.71 10% Critical Damping

Appendix D – Joist Tables for Convention Entry Floor System

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Marriott Hotel and Lancaster County Convention Center

Floor System Redesign
Composite Joist Input Information

Design by: Trevor J. Sullivan
Date: 2/14/08

Joist Geometry:

1)	Depth	24	in
2)	Span	40	ft
3)	Adjacent Member Spacing (left)	4	ft
4)	Adjacent Member Spacing (right)	4	ft

Concrete and Deck:

1)	Type of Floor Deck		
2)	Depth of Floor Deck	3	in
3)	Slab Thickness Above Deck	2.5	in
4)	Concrete Unit Weight	145	pcf
5)	Concrete Compressive Strength	4	ksi

Nominal Loads:

1)	Non-Composite Construction Dead Load			
	a)	Concrete	50	psf
	b)	Joist and Bridging (Estimated)	5	psf
	c)	Deck	2	psf
	d)	**Total**	57	psf
			228	plf
2)	Construction Live Load			
	a)	During Concrete Placement	25	psf
			100	plf
3)	Composite Dead Load			
	a)	Fixed Partitions	0	psf
	b)	Mechanical	5	psf
	c)	Electrical	5	psf
	d)	Fireproofing	2	psf
	e)	Floor Covering and Ceiling	10	psf
	f)	Miscellaneous Dead Loads	5	psf
	g)	**Total**	27	psf
			108	plf
4)	Composite Live Load			
	a)	Live Load (Reduced as Applicable)	100	psf
	b)	Moveable Partitions	20	psf
	c)	**Total**	120	psf
			480	plf
5)	Total Factored Non-Composite Dead Load, 1.2 x (1d)		68.4	psf
			273.6	plf

6)	Total Factored Composite Dead Load, 1.2 x (3g)	32.4	psf
		129.6	plf
7)	Total Factored Composite Design Load, 1.6 x (4c)	192	psf
		768	plf
8)	Total Factored Composite Design Load (5) + (6) + (7)	292.8	psf
	(Concentrated Dead Load Not Included)	1171.2	plf
Additional Concentrated Dead Load, P, at Top Chord		0	kips
	Distance from Left	0	ft
Total Factored Composite Dead Load		0	kips

Camber and Deflection (Unfactored Load):

1)	Loads to Camber For		
	a) Percent of Non-Composite DL, (1d) x 100%	57	psf
	b) Percent of Composite DL, (3g) x 50%	13.5	psf
	c) Percent of Composite LL, (4c) x 20%	24	psf
2)	Maximum Allowable Live Load Deflection, Span/360	1.33	in
3)	Maximum Deflection, Span/240	2.00	in

Marriott Hotel and Lancaster County Convention Center

Floor System Redesign
Composite Joist Load and Moment Calculations

Design by: Trevor J. Sullivan
Date: 2/14/08

1) Calculate Factored Loads

a) Uniformly Distributed Loads

w_f = **1171.2** plf

b) Concentrated Loads

P_f = **0** lbs

2) Calculate Maximum Moment and Location

R_A = **23,424** lbs
L_0 = **20.0** ft

M_f = **234,240** ft-lbs

3) Calculate Maximum End Reaction

R_A = **23,424** lbs
R_B = **23,424** lbs

4) Calculate Equivalent Uniform Load

w_{eM} = **1171** plf

5) Calculate Equivalent Load from End Reaction

w_{eR} = **1171.2** plf

6) Determine Equivalent Load

w_e = **1171** plf

7) Select Composite Joist and Bridging from Weight and Bridging Tables

Marriott Hotel and Lancaster County Convention Center

Floor System Redesign
Composite Joist Selection and Deflection

Design by: Trevor J. Sullivan
Date: 2/29/08

Joist Specification: 18CJ 1171/768/130

Height of Deck Ribs
h_r = 3 in

Thickness of Concrete
t_c = 2.5 in

Joist Spacing
J_c = 4 ft

1) Self Weight of Joist
Wt_{joist} = 20 plf

2) Allowable Composite Live Load
w_{360} = 561 plf

3) Number of Shear Studs/Diameter
N-ds = 42-5/8"

4) Composite Moment of Inertia
I_{eff} = 835 in^4

5) Type of Bridging Required
(1) L1.25x0.109H

6) Non-Composite Moment of Inertia
$I_{n\text{-}c,\ eff}$ = 281

Deflection and Camber:

1) Deflection Prior to Composite Action

Δ = **1.5585** in or L / 308

A) Design Length 39.67 ft
B) E_s (psi) 2.9E+07 psi

2) Deflection Due to Composite Dead Load

Δ = **0.2484** in or L / 1932

4) Deflection Due to Live Load

Δ = **1.1313** in or L / 424

5) Total Deflection

Δ = **2.9383** in or L / 163

6) Camber

Joist Camber = **1.909** in

Marriott Hotel and Lancaster County Convention Center

Floor System Redesign
Girder Analysis/Design

Design by: Trevor Sullivan
Date: 2/29/08

Girder Specifications

1)	Span		20	ft
2)	Tributary Width		40	ft
2)	Allowable Live Load Deflection			
	Δ_{LL} =	Span/360 =	0.67	in
3)	Allowable Total Load Deflection			
	Δ_{TL} =	Span/240 =	1.00	in
4)	Uniform Live Load			
	w_{LL} =	100	psf	
5)	Uniform Dead Load			
	w_{DL} =	75	psf	
6)	Uniform Total Load			
	w_{TL} =	175	psf	

Design Criteria

1)	Minimum Moment of Inertia			
	A)	Live Load Requirement		
		$I \geq$	745	in^4
	B)	Total Load Requirement		
		$I \geq$	869	in^4
2)	Required Bending Moment Capacity			
	A)	M =	500	ft*k
3)	Required Shear Capacity			
	A)	V =	100	k

Girder Selection

1)	Girder Designation			W18x71	
	A)	I_X	=	1170	in^4
	B)	M_u	=	548	ft*k
	C)	V_u	=	274	k

Column Design

1) Compressive Load

	P	=	**592**	k

Column Selection

1) Column Designation **W14x68**

A)	P_u	=	639	k
B)	KL	=	14	ft

Marriott Hotel and Lancaster County Convention Center

Floor System Redesign
Composite Joist Vibration Analysis (SJI Method)

Design by: Trevor J. Sullivan
Date: 2/14/08

Determine Effective Area for Vibration

1) Equivalent Number of Fully Effective Joists

$N =$ 4.455928

2) Flexural Stiffness Perpendicular to Joists (Slab Only)

A) Modulus of Elasticity of Concrete
$E_c =$ 3605 ksi

B) Slab Thickness
$t =$ 4 in

C) Flexural Stiffness
$D_x =$ 19227

3) Flexural Stiffness Parallel to Joists (Composite Section)

A) Modulus of Elasticity of Steel
$E_s =$ 29000 ksi

B) Moment of Inertia of the Composite Section
$I_t =$ 835 in^4

C) Joist Spacing
$b =$ 48 in

D) Flexural Stiffness
$D_y =$ 504479

4) Stiffness Ratio
$\varepsilon =$ 0.442

5) Effective Floor Half Width
$x_o =$ 18.75 ft

6) Combined Flexural Stiffness

$I_{equ} =$ 3721 in^4

7) Uniformly Distributed Load per Unit Length

$w =$ 30.66667 lbs/in

8) Natural Joist Frequency
$f_n =$ 0.542 Hz

Marriott Hotel and Lancaster County Convention Center

Floor System Redesign
Composite Joist Vibration Analysis (SJI Method)

Design by: Trevor J. Sullivan
Date: 2/20/08

Determine Vibration Effects Due to Impact

1) Impact Caused by Object

A) First Maximum Amplitude
A_o = **0.000569** in

B) Force of Rectangular Impulse
F = 794 lbs

C) Duration of Impulse
t_d = 0.01 s

D) Time to Occurrence of Maximum Amplitude
t_o = **0.923** s

E) Human Response Factor
R = **0.72** 4% Critical Damping
0.68 10% Critical Damping

2) Impact Caused by Heel Drop

A) First Maximum Amplitude
A_o = **0.001085** in

B) Force of Rectangular Impulse
F = 606 lbs

C) Duration of Impulse
t_d = 0.05 s

D) Time to Occurrence of Maximum Amplitude
t_o = **0.099** s

E) Human Response Factor
R = **0.85** 4% Critical Damping
0.81 10% Critical Damping

Appendix E – Structural System Estimate

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Marriott Hotel at Penn Square and Lancaster County Convention Center
Structural Concrete Quantity Take Off and Estimate

Slabs and Columns

	Column (Quantity)	Column Height (ft)	Column Rebar Vertical	Column Rebar Ties	Column Formwork (SF)	Elevated Slab (SF)	Elevated Slab Thickness (in)	Elevated Slab Formwork (SF)	Elevated Slab Rebar (E.W.)	PT Tendons (No. @ Length)	PT Tendons (No. @ Length)
Convention Entry	6	14	8 #8	#3 @ 16"	3600	3500	13	3500	#5 @ 12"	-	-
Exhibit Level	28	12	8 #8	#3 @ 16"	7240	30000	13	30000	#6 @ 12"	-	-

Slabs and Columns Totals With Waste Factors

	Column Concrete (CY)	Column Rebar (Tons)	Column Formwork (SF)	Slab Concrete (CY)	Slab Rebar (Tons)	Slab Formwork (SF)
Convention Entry	159	3.98	4140	155	3.65	4025
Exhibit Level	482	10.91	8326	1324	45.06	34500

Marriott Hotel at Penn Square and Lancaster County Convention Center
Structural Concrete Quantity Take Off and Estimate

Columns and Elevated Structural Slabs

	Item	Concrete (CY)	$/CY	Total
033105.35.0411	**Columns**	641	$137.00	$87,817
033105.35.0200	**Elevated Structural Slabs**	1479	$113.00	$167,127

	Item	Placing (CY)	$/CY	Total
033105.70.0800	**Columns**	641	$64.50	$41,345
033105.70.1500	**Elevated Structural Slabs**	1479	$45.25	$66,925

	Item	Finishing (SF)	$/SF	Total
033529.30.0350	**Elevated Structural Slabs**	33500	$0.37	$12,395

	Item	Formwork (SF)	$/CY	Total
031113.25.6650	**Columns**	12466	$8.50	$105,961
031113.35.2150	**Elevated Structural Slabs**	38525	$11.15	$429,554

	Item	Shoring (Each)	$/Each	Total
031505.70.0500	**Elevated Structural Slabs**	930	$15.80	$14,694

	Item	Reshoring (SF)	$/SF	Total
031505.70.1500	**Elevated Structural Slabs**	33500	$1.60	$53,600

	Item	Rebar (Tons)	$/Ton	Total
032110.60.0250	**Columns**	14.89	$2,000.00	$29,780
032110.60.0400	**Elevated Structural Slabs**	48.71	$1,875.00	$91,331

Item	Total
Columns	$264,903
Elevated Structural Slabs	$835,626
Total	**$1,100,528**

Marriott Hotel at Penn Square and Lancaster County Convention Center
Structural Steel Quantity Take Off and Estimate

	Member	Quantity	lb/ft	Length (ft)	Weight (lbs)	Weight (Tons)
Convention Entry Slab						
Columns	W14x68	6	90	26	14040	7.02
Base Plates	3/4"x14"x14"	6	490 (lb/ft^3)	0.085	249.9	0.12
Beams	W18x71	8	71	20	11360	5.68
Composite Joists	24CJ 1171/768/130	16	20	40	12800	6.40

	Member	Quantity	lb/ft	Length (ft)	Weight (lbs)	Weight (Tons)
Exhibit Level Slab						
Columns	W14x53	28	53	14	20776	10.39
Base Plates	3/4"x14"x14"	28	490 (lb/ft^3)	0.085	1166.2	0.58
Beams	W18x158	33	158	20	104280	52.14
Composite Joists	24CJ 2771/2368/130	173	54	40	373680	186.84

Column Total:	17.41
Base Plate Total:	0.71
Beam Total:	57.82
Composite Joists Total:	193.24

Marriott Hotel at Penn Square and Lancaster County Convention Center
Structural Steel Quantity Take Off and Estimate

	Item	Amount (Tons)	Unit Cost ($/Ton)	Total
051223.77.0500	**Column Total:**	**17.41**	**$2,000**	**$34,816**
051223.73.0400	**Base Plate Total:**	**0.71**	**$1,000**	**$708**
051223.76.0500	**Beam Total:**	**57.82**	**$2,200**	**$127,204**
052123.50.7100	**Joist Total:**	**193.24**	**$3,000**	**$579,720**
053113.50.3400	**Metal Decking w/ Slab:**	**38525 SF**	**$10/SF**	**$385,250**
053113.75.1750	**Spray Fire Proofing:**	**38525 SF**	**$2/SF**	**$77,050**
			Total:	**$1,204,748**

Marriott Hotel at Penn Square and Lancaster County Convention Center
Structural System Cost Comparison: Proposed Steel vs. Existing Concrete

Steel System

	Item	Amount (Tons)	Unit Cost ($/Ton)	Total
051223.77.0500	**Column Total:**	**17.41**	**$2,000**	**$34,816**
051223.73.0400	**Base Plate Total:**	**0.71**	**$1,000**	**$708**
051223.76.0500	**Beam Total:**	**57.82**	**$2,200**	**$127,204**
052123.50.7100	**Joist Total:**	**193.24**	**$3,000**	**$579,720**
053113.50.3400	**Metal Decking w/ Slab:**	**38525 SF**	**$10/SF**	**$385,250**
053113.75.1750	**Spray Fire Proofing:**	**38525 SF**	**$2/SF**	**$77,050**
			Total:	**$1,204,748**

Concrete System

	Item	Concrete (CY)	$/CY	Total
033105.35.0411	**Columns**	641	$137.00	$87,817
033105.35.0200	**Elevated Structural Slabs**	1479	$113.00	$167,127
	Item	**Placing (CY)**	**$/CY**	**Total**
033105.70.0800	**Columns**	641	$64.50	$41,345
033105.70.1500	**Elevated Structural Slabs**	1479	$45.25	$66,925
	Item	**Finishing (SF)**	**$/SF**	**Total**
033529.30.0350	**Elevated Structural Slabs**	38525	$0.37	$14,254
	Item	**Formwork (SF)**	**$/CY**	**Total**
031113.25.6650	**Columns**	12466	$8.50	$105,961
031113.35.2150	**Elevated Structural Slabs**	38525	$11.15	$429,554
	Item	**Shoring (Each)**	**$/Each**	**Total**
031505.70.0500	**Elevated Structural Slabs**	930	$15.80	$14,694
	Item	**Reshoring (SF)**	**$/SF**	**Total**
031505.70.1500	**Elevated Structural Slabs**	33500	$1.60	$53,600
	Item	**Rebar (Tons)**	**$/Ton**	**Total**
032110.60.0250	**Columns**	14.89	$2,000.00	$29,780
032110.60.0400	**Elevated Structural Slabs**	48.71	$1,875.00	$91,331
		Total		**$1,102,388**

Steel System Cost an Additional: $102,361

Appendix F – Ground Water Lift Station Plans

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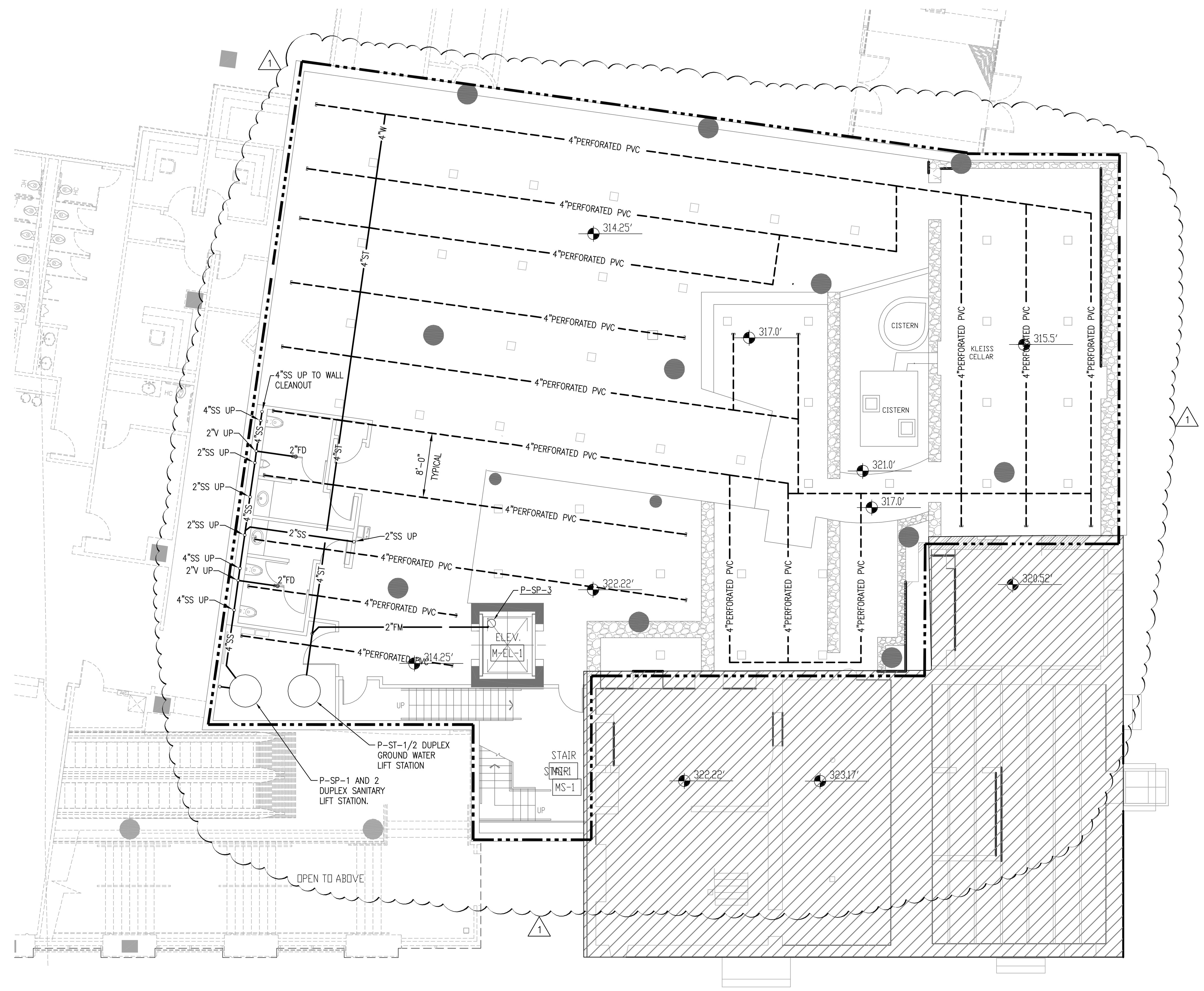


1 P2.0B ENLARGED PLAN - MUSEUM LEVEL UNDERGROUND PART B - PLUMBING
1/8" = 1'-0"

JSE

JORDAN & SKALA ENGINEERS, INC.

5365 OAKBROOK PARKWAY
NORCROSS, GEORGIA 30093
770/447-5547 FAX 770/448-0262
JSE Number - 0410326

COMMONWEALTH OF PENNSYLVANIA REGISTERED PROFESSIONAL G.M. SKALA ENGINEER NO. 36028-E

No	Drawing Issue Description	Date
1	BULLETIN #4	01/29/07

PENN SQUARE CENTER
MARRIOTT HOTEL AND
LANCASTER COUNTY
CONVENTION CENTER

Lancaster, Pennsylvania

PENN SQUARE PARTNERS
LANCASTER COUNTY CONVENTION CENTER AUTHORITY

ENLARGED PLAN MUSEUM LEVEL UNDERGROUND - PART B PLUMBING

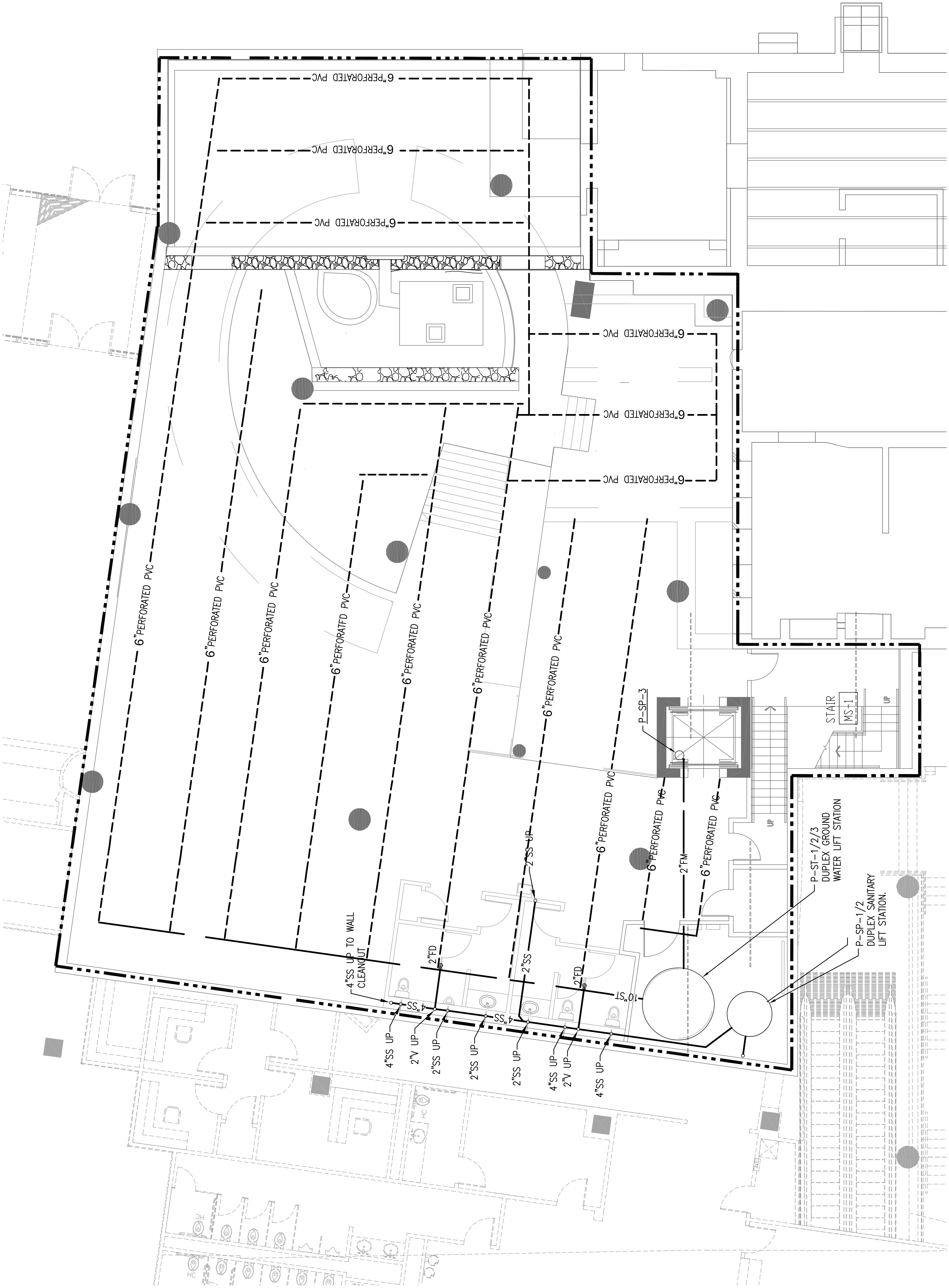
Skala (Principal-in-Charge)	204030 (Project No.)
Haefeli (Project Director)	As Noted (Scale)
Haefeli (Project Manager)	3/21/06 (Date)
Creson (Project Engineer)	

NEW DRAWING ISSUED 1/29/07

File Path

File Plot Date

P2.0B-UG



6"PERFORATED PVC
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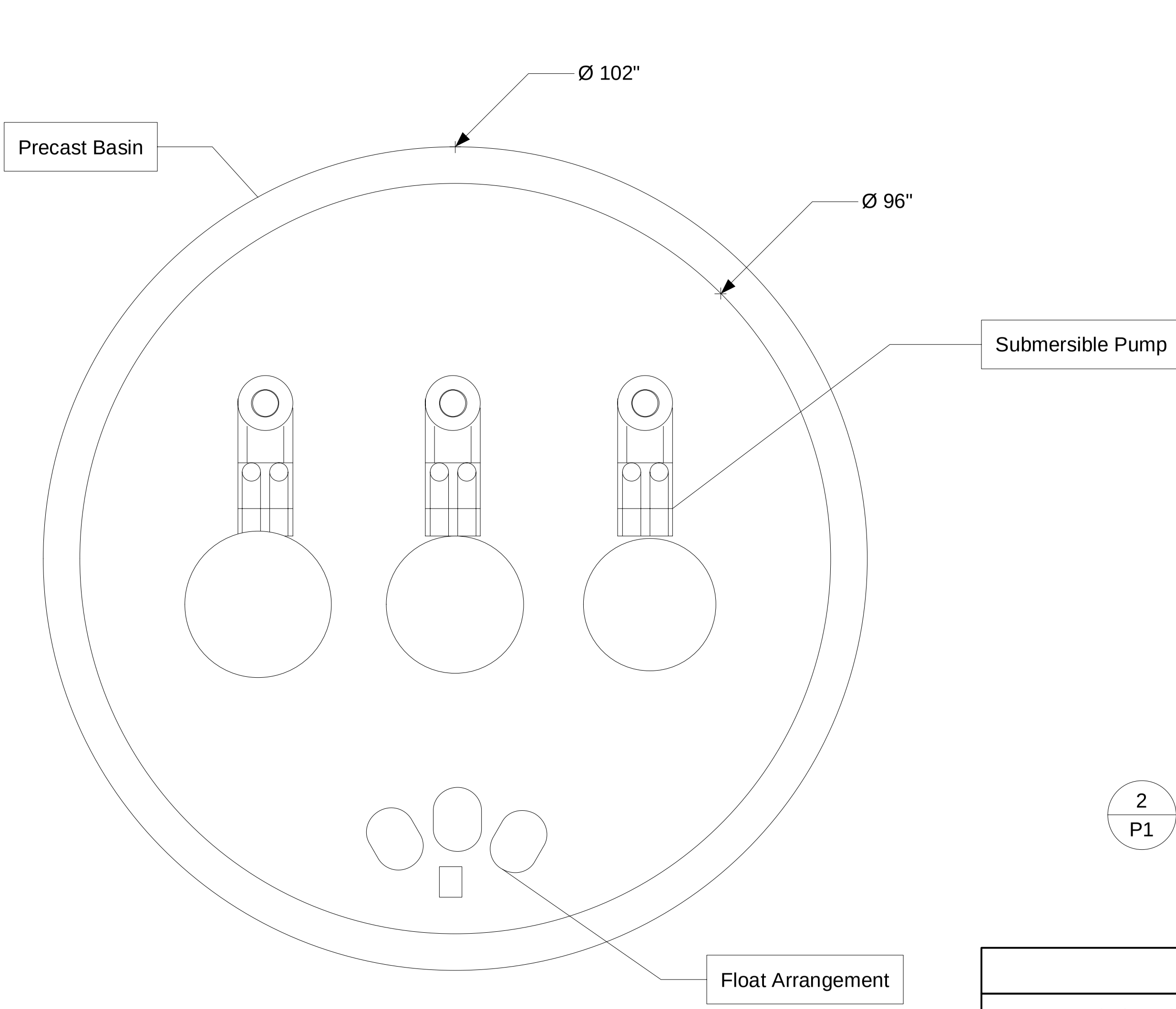
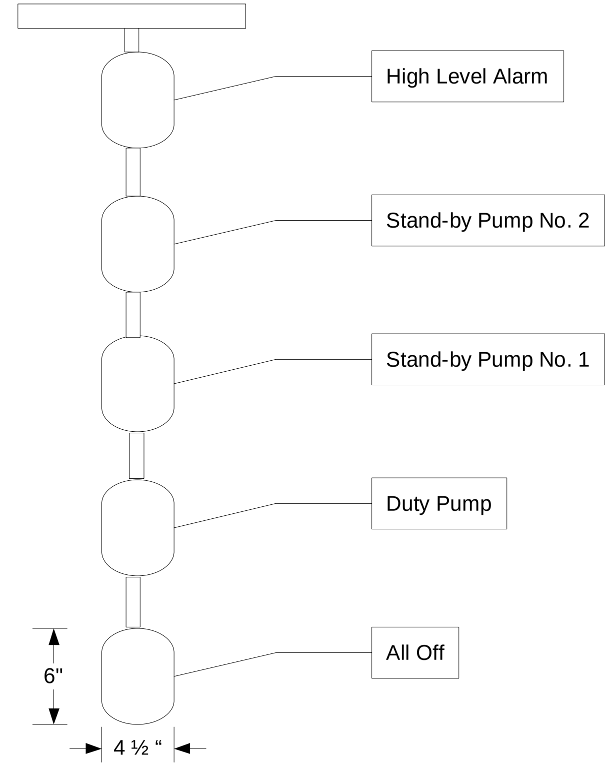
6"PERFORATED PVC
6"PERFORATED PVC
6"PERFORATED PVC
6"PERFORATED PVC
P-SP-3
STAIR
MS-1
UP
UP
2"FM
P-ST-1/2/3
DUPLEX GROUND
WATER LIFT STATION
P-SP-1/2
DUPLEX SANITARY
LIFT STATION.
2"SS UP
4"SS UP TO WALL
CLEANOUT
2"FD
2"SS
2"FD
10"ST
4"SS
4"SS
4"SS UP
2"V UP
2"SS UP
2"SS UP
2"SS UP
4"SS UP
2"V UP
4"SS UP



1 / P1 Triplex Groundwater Lift Station Detail

Plan



2 / P1 Suspended Multiple Float Arrangement

Elevation

Triplex Groundwater Pump System			
Capacity/Head			340 GPM at 92' TDH
Pump	3	Weil 2525	4" discharge with cast iron impeller, cast iron casing
Motor	3	Weil 2525	15 HP, 460 volt, 3 phase, 1750 RPM
Controls	5	S20NO	Suspended mercury float switch level controls
Basin	1	by others	96" I.D. precast concrete basin with access hatch

Triplex Groundwater Pump System Details

Museum Level	Redesign	Marriott Hotel and Lancaster County Convention Center Project	Scale: NTS	APPROVED

Appendix G – Ground Water Lift Station Calculations

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Plumbing Design Equations:

$$H = \frac{V^2}{2g}$$

H - Total head developed (feet)
V - Velocity of impeller (feet/sec)
g - 32.2 feet/sec^2

$$V = \frac{RPM \cdot D}{229}$$

D - Impeller diameter (inch)
V - Velocity (ft/sec)

$$Q = 449 \cdot A \cdot V$$

where
A = area of pipe cross section (ft^2)
V = velocity of flow (ft/sec)
Q = Capacity (GPM=gallons per minute)

$$BHP = \frac{Q \cdot TDH \cdot S.G}{3960 \cdot \text{Pump Efficiency}}$$

$$WHP = \frac{Q \cdot TDH \cdot S.G}{3960}$$

Plumbing Design Charts:

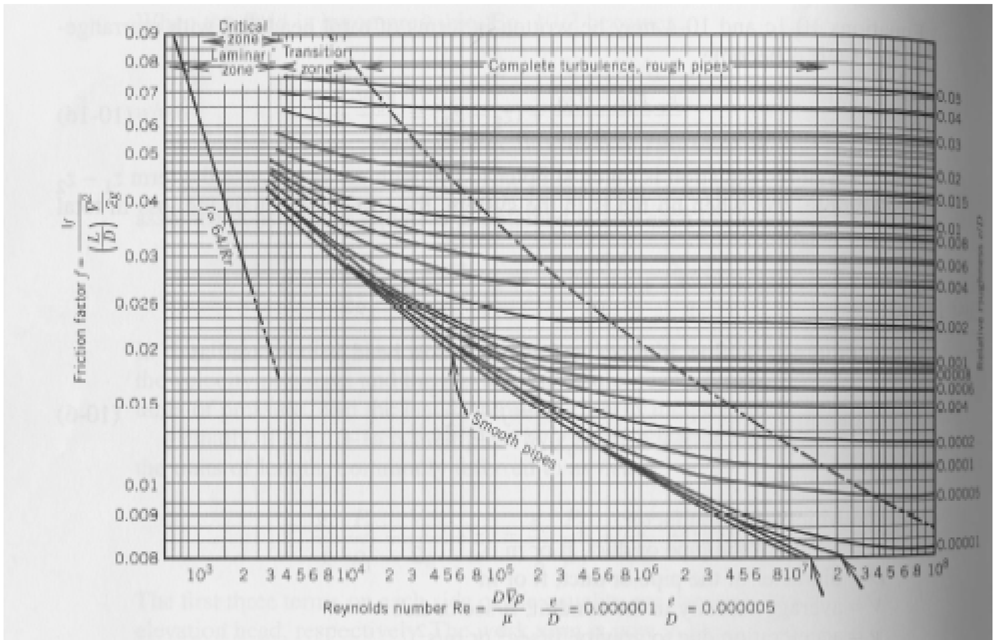
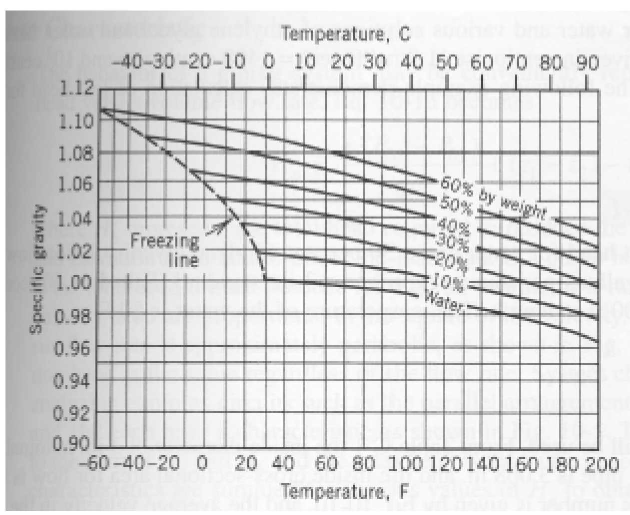
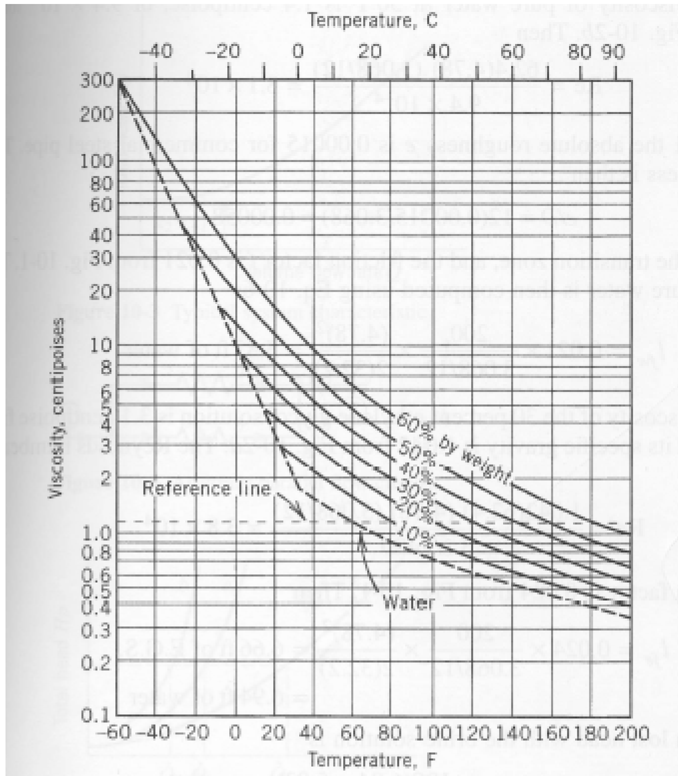


Figure 10-1 Friction factors for pipe flow.





$$l_f = f \frac{L}{D} \frac{\overline{V}^2}{2g} \tag{10-6}$$

where:

f = Moody friction factor
L = length of the pipe or duct, ft or m
D = diameter of the pipe or duct, ft or m
$\overline{V}$ = average velocity in the conduit, ft/sec or m/s
g = acceleration due to gravity, ft/sec^2 or m/s^2

The Reynolds number is defined as

$$\text{Re} = \frac{\rho \overline{V} D}{\mu} = \frac{\overline{V} D}{\nu} \tag{10-10}$$

where:

ρ = mass density of the flowing fluid, lbm/ft^3 or kg/m^3
μ = dynamic viscosity, lbm/(ft-sec) or (N-s)/m^2
ν = kinematic viscosity, ft^2/sec or m^2/s

Groundwater Pump Design

Head Loss Calculation (Friction Loss)

1) Volumetric Flow Rate

Q	=	340	gal/min
A	=	0.2006	ft^2
V	=	226.6	ft/min

2) Reynolds Number

u	=	1.5	gal/min
S.G.		62.4	lb/ft^3
v		9.4x10-4	lbm/(ft-sec)
Re		31337.3	

3) Relative Roughness for the Pipe

e	=	0.00015	
e /D	=	0.00120	

4) Head Loss

f	=	0.031	
L		70	ft
D		0.50540	ft
V		3.78	ft/sec
g		32.2	ft/sec^2
l_{fw}	=	0.95	ft

Total Dynamic Head (TDH)

1) TDH

Static Lift	=	0	ft
Static Height	=	18	ft
Friction Loss	=	0.95	ft
TDH	=	18.95	ft

Sizing the Pump

1)	Total Discharge Head			
	TDH	=	18.95	ft
2)	Gallons per Minute			
	GPM	=	340	gal/min
3)	Impeller Diameter			
	D	=	8	in
4)	Impeller RPM			
	RPM	=	1750	rpm
5)	Impeller Velocity			
	V	=	61.1	ft/sec
6)	Total Head Developed			
	H	=	58.0	ft
7)	Impeller Capacity			
	Q	=	5506.4	gpm
8)	Hydraulic Horsepower			
	WHP	=	8.2	HP_{water}
9)	Pump Efficiency			
	efficiency	=	0.6	(decimal)
10)	Brake Horsepower			
	BHP	=	13.7	HP_{pump}