THE BENNER PIKE SHOPS

THESIS REPORT

Prepared for

Architectural Engineering Department
Construction Management
Penn State University

By

Inyoung Hwang

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BENNER PIKE SHOPS

Project Overview

- Location: State College, PA
- Size: 10,900 SF
- Estimated Cost: $15,200,000
- Schedule: Jan, 2005– Jan, 2006
- Delivery Method: General Contractor
- Function Type: Multi-Store Shops

Project Team

- Owner: Jules Patt (Developer)
- Architect: Kasun Architect
- General Contractor: Leonard S. Fiore
- Civil Engineers: Keller Engineers, Inc.
- Structural Engineers: Fando, White, & Associate
- Fire Protection: D.C. Goodman & Sons, Inc
- Geotechnical Engineers: CMT Laboratories Inc.

Architectural Features

The mall is divided into two sections: the new shell building containing two large stores (Bed Bath & Beyond, ROSS Dress for Less), and combination of smaller shops (14 in quantity).

The building itself is concaved in toward the parking space of the mall – better view of the stores and form a space within space.

The exterior entrance doors are uniform throughout the shops.

Structural

- Wall footings - 6" with 1' of thickness (4" rod reinforcing)
- Slab on Grade - 4" of thickness (one layer of 6" x 6" #8 WWF)
- Column footings – 10"x10" in a grid formation (40' apart from each other)
- Steel joists - W16 x 26 typical welded to continuous plate
- Metal roof deck - 1-1/2" deep, No. 22 gage, wide rib, type B
- Roof load capacity – 35 psf of snow load

Electrical/Lighting

<u>Power Distribution</u>:
- 120/208, three phase, four wires
- 120/208 and 277/480 volts panelboards
- 480 volts circuit breaker (64,000 amperes)

<u>Lighting</u>:
- General Electric and Sylvania
- Incandescent with 125 volts, fluorescent, mercury vapor HID, metal halide HID, high pressure sodium HID

Mechanical

<u>HVAC System</u>:
- Air Handling Units located on the rooftop of each shop (# of AHUs ranges from 2–9)
- Each store is served separately

<u>Fire Protection</u>:
- Wet pipe sprinkler system (majority)
- Semi exposed heads for maximum expose

THE PENNSYLVANIA STATE UNIVERSITY

INYOUNG HWANG

CONSTRUCTION MANAGEMENT

Leonard S.Fiore, Inc. GENERAL CONTRACTOR

Executive Summary

The following thesis analysis is performed to examine the Benner Pike Shops project in depth. Based on the research of the project, several construction problems were identified within the project. Of those issues, three were chosen to be studied as depth analyses. Each analysis was introduced with its situation and possible solutions were drawn from them.

First analysis is focused on the research purpose. It discusses in detail about the Benner Pike Shops' close out planning with comparison from other construction companies' planning. It is concluded with the better way for the general contractor of the project to wrap up the project more efficiently. Second analysis deals with structural issues on the exterior wall of the building. Rear side of the exterior system is replaced with tilt-up construction from concrete masonry units. Redesigned system shortens the duration of the process significantly, which will eventually cut down the cost of the project. Last analysis concentrates on mechanical system. The rooftop air handling units of two large shops are reconfigured with diminished quantity of the air handling units. Existing duct system was applied to the redesigned HVAC system to serve the space equally as before.

Overall, duration and cost of the project were reduced retaining the same quality as it was. As mentioned in the first analysis, it is important to plan the project beforehand so the actual project can move on smoothly. During the construction, communication plays a huge role in performing the job correctly. Second and third analyses conclude that there are many ways to cut down the cost of the project. It is learned that the schedule of the project impacts the cost directly.

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Existing Conditions and Building Summary

Local Conditions

The site is located in the general commercial zone which covers large radius of area around. There was not any type of structure or building present prior to this project at the location; which means no demolition was required. The condition of the soil in that area was composed of 90% or greater of limestone. Although the excavation had to take more time and consideration than usual, there was no need for any de-watering the soil because of its dry condition. Those stones plus any left over stones from the construction were the only materials that were recycled. Since the shops are located in the mall area where no tight neighboring buildings exist, the project had no conflicts on congestion problems such as, access road during construction, material staging area, or damaging adjacent buildings. Since the region is rural, there is enough space for mall constructions. Typically, site congestion is not a problem around the area.

Client Information

The sole purpose of the project started by the client is to lease spaces to tenants. For this project, the tenants focused on this project were different shops because of the location and building type. Joules Patt, the president of Keystone Hospitality Group, is a developer, in which the company concentrates their work on real estate primarily. Since the project is a local job, the company hired LSF Contractor who has done numerous projects around the town and knows well about this region. For the fastest possible lease schedule, construction took place focusing on finishing each shop separately after the basic building structure as a whole. This way, the owner could lease out the finished shops while construction takes place on the other incomplete shops. By finishing the shops on the edge of the mall, the owner minimized the risk factors for safety of customers. Overall, the client was pleased with the schedule and construction cost, especially for the early finish of the project. The client is going to keep the building after

the completion and sell spaces for shops in the mall for rent. Since Keystone Group is a quite large developing company in the region, there is less chance for the GC to have any payment risk.

General Building Statistics

Building Name: Benner Pike Shops

Location and Site: 311 Benner Pike
State College, PA 16801

Building Occupant Name: Ross Dress for Less, Bed Bath & Beyond, Fashion Bug, Dress Barn, Mattress Warehouse, Burlington Shoes

Occupancy or Function Types: Combination of different types of shops

Size (Total Sq. Ft.): 10,900 Sq. Ft. of Total Building Area
(22,500 Sq. Ft. Allowable Area)

Number of Stories above Grade: One Story (Heights Vary Throughout)

Primary Project Team:

- Owner: Jules Patt (Developer)
- Architect: Kasun Architect — Holidaysburg, PA
- General Contractor: Leonard S. Fiore — Altoona, PA
- Civil Engineers: Keller Engineers, Inc. — Holidaysburg, PA
- Structural Engineers: Fando, White, & Associates — Altoona, PA
- Fire Protection: D.C. Goodman & Sons, Inc — Huntingdon, PA
- Geotechnical Engineers: CMT Laboratories Inc. — State College , PA

Dates of Construction (Start-Finish): Jan of 2005 – Jan of 2006

Cost: $15,200,000 of Total Cost

Project Delivery Method: Design-Bid-Build

Zoning and Historical: General Commercial

Major National Codes: IBC 2003, BOCA, NFPA

Staffing Plan

The LSF Contractors were assigned for general contractor for this project and through out the project, three superintendents were placed. For the pre-construction part and layout of the building, Tim Moore was in charge. After the first phase, Rick Lascoli was assigned for the main construction. At the very end of the project, which includes finishes of some small shops, Ron took over to wrap up the whole construction. Although Tim was present during actual construction phase, most of the work was done by Rick. Project manager, Richard Fiore Jr. was assigned from the main office to direct the meetings and conduct overall construction.

Architecture

Benner Pike Shops is a shopping plaza consisting of multiple stores congested together side by side. The mall is basically divided into two sections: the new shell building containing two large stores (Bed Bath & Beyond, ROSS Dress for Less), and combination of smaller shops (14 in quantity). Although the building itself could be considered as a one building (since the shops are attached), each shop is unique and has different architectural features to it. In addition, all the stores are one story in height. The new shell building has an interior elevation of 24 feet and the rest with 18 feet in interior elevation. The main goal of designing this facility is to give comfortable feelings and pleasure to the customers coming to the shops. One of the key designing issues is that the building itself is concave in toward the parking space of the mall. This will give the customers better view of the stores and form a space within space. The other designing issue is that the smaller units have uniformity in style exteriorly. The same kind of doors and showcase formations will provide cleaner expression of the shops.

Building Envelope

To keep the uniformity within the different shops, the majority portion of the exterior of the Benner Pike Shops is finished with EIFS (Exterior Insulation Finish System). The back portion of the building faces are finished with paint over concrete blocks. The openings of the shops are consisted of Aluminum framing with temperature insulated glass. Again, the same type of doors and glass are used for the uniformity reason. Each store has double sliding doors of 3 feet by 7 feet in size with integrated windows of 1 3/4 inches thickness. Decorative column cover is placed consistently at the exterior hallway of the stores. Surface of the roof is flat through out the building, and it is sloped toward the back of the building so when it rains, water can flow and fall behind the building where the customers are not likely to be present. Roofs are finished with membrane roofing with two layers of 2-inch rigid insulation.

Construction

One of the key issues that were brought up often during the construction of the shops was to work along with several units of shops, because each unit has different features and characteristics in both the surface and the inside (electrical and mechanical). Different electrical and mechanical plans necessitated good organization and formation of the phases of the work and the relationships with number of various subcontractors. As in general contractor's point of view, it was a stressful job with hard coordination to look at different sets of drawings for each unit.

Structural Steel Frame

Considering that the building height is not higher than 30', only one 120-ton mobile crane was used for erection of the steel. Based on the concrete wall footings and column footings, TS 10 x 8 steel columns were typically erected for the support. Wide flange

beams were then braced to the columns along with numerous steel joists. Typical brace used among a steel column and two joining beams were knee bracing. Two beams joining at the top of the steel column were welded together to the steel column with 3/8" plate stiffeners. In addition, Two Angles 5" x 3 1/2" x 5/16" (one for each beam) were welded to the beam and the column with 3/8" plate gussets. On top of the stiffeners, fill pieces were provided in each brace to support the roof metal deck sitting on top of the beams.

Cast in Place Concrete

For this project, no mass placing of concrete was needed except for footing and slab on grade. Since the building is only one story high, concrete was placed in the sub-grade level. Direct pour was adequate in a fact that there is no concrete placing in high elevation. Typically, thick exterior graded plywood was used for the horizontal formwork, and the connection was made with metal junction plates. When the concrete was poured, temporary waterproofing polyethylene sheet was installed.

Mechanical System

The air handling units are located on the rooftop for all the shops. Each shop has its own HVAC units generated from AHU's located on top of each store. The number of AHU's varies between the sizes of shops; in which it varies from 2 to 9. Small – scale mechanical rooms are located on the back of each store for the control purpose. Equipments and ductwork are insulated with rigid fiber glass board and flexible blanket. For the exposed ductwork, aluminum jacket and PVC jacket are used.

A pipe sprinkler system serves the majority portion of the building. Its heads are semi-recessed, chrome plated, so the heads are exposed to the heat for sensitivity and give faster response. For the spaces with ceiling height less than 8 feet, the heads are fully recessed with white covers for aesthetic reason and to allow better interior view.

Electrical System

For the conduit raceways, minimum size of ¾" EMT was used, and they were concealed except in mechanical rooms and janitor closets. Conductors have voltages of 120/208, 277/480, 120/240 for the ungrounded systems. Panelboards are also 120/208 and 277/480 volts, three - phase with copper bus system. Circuit breaker is 480 volts and has interrupting rating of 64,000 amperes.

Lighting

All the lamps are manufactured by General Electric and Sylvania, in which include incandescent lamps with 125 volts, fluorescent lamps, mercury vapor HID lamps, metal halide HID lamps, and high pressure sodium HID lamps. Ballasts are provided for fluorescent lamps.

Telecommunications

An empty conduit system is being provided for owner installation of voice/data cable. Telephone cabinets and fire-treated plywood backboards for mounting of telephone equipments were furnished. Each single telephone outlet would be served by an empty conduit 3/4" in size and it will extend from outlet and stud up through ceiling, and then above corridor ceiling to cable tray location. A 12 gauge 200 pound test galvanized fish wire with 12" of free wire is provided in each conduit.

Masonry

Exterior CMU's were stacked up among the exterior steel beam. The purpose of the CMU walls was to give the building enclosure, in which the walls are not load bearing. Only about 10 – feet high scaffolding was needed since more than half of the job could be done from the ground.

Support of Excavation

The site before excavation had a slope in which the difference between the highest point and the lowest point was approximately 10 feet. Starting from the top of the hill, excavation took place and decent amount of excavated soils were used for fill in the low elevation area. As mentioned in the local conditions, more than 90% of the soil excavated was limestone which led to no work in de-watering the soil. For the excavation support, temporary tieback sheeting system (tiebacks, soldier piles and wood lagging) was integrated which is the most economical method.

Analysis #1 – Close out Planning and Communication

Overview

The general contractor for the Benner Pike Shops replaced their current superintendent of the project to a different one. The issue for the replacement is that the new superintendent is not as familiar as the previous one, and it could take some time for the new superintendent to adapt to the project. Plus, final closing out could be really stressful resulting in possible delay in the project. Another issue that could delay the project is lack of communication among the project team. The project was actually delayed one and a half weeks because the GC did not communicate with the tenants of the shops well enough. This analysis will focus more on research.

This analysis focuses on research of close out planning. First, close out literature was investigated in order to study the closing out of the Benner Pike Shops project. Based on the literature review of close out planning, the general contractor of the project was interviewed with several questions. The same concept concerning were sent out in survey format via electronic mail to number of PACE members. The analysis concludes the research with the comparison of different close out planning and some suggestion for the planning of the Benner Pike Shops project.

Well created planning of a project done in preconstruction phase holds the power to either shorten the schedule or delay it. Certainly, the Benner Pike Shops project could have prevented one and a half weeks delay if their close out planning had been finely oriented. Since the project is a mall, one day delay is crucial for them. On the other hand, if the project was shortened in duration and the mall had opened early, the general contract might end up with incentives.

Close out literature

Closing out a project would seem that all that needed to close out would be to inspect it, accept it for the owner, and see that the contractor receives the final payment. But, there are more items in that such as, the guarantees, operating instructions for equipment, keying schedule, record drawings, bonds, liens that may have been filed, and etc. Generally, there may be at least two inspections required to close out the project. The first will establish those areas still requiring correction or other remedial work, and the final inspection will be a check off to assure that all work is considerably complete and that all corrections have been made.

During close out phase of the project, the contractor is in charge of cleaning up the site prior to the final check up. The final cleanup is of significantly greater proportions than previous cleanup work done during the project, as all of the various items of demobilization technically are included under the cleanup category. This includes removal of temporary utilities, haul roads, temporary fences, field offices, detours, stockpiles, surplus materials, scrap, replacement of landscaping where it had been temporarily removed, street cleaning, and the obtaining of releases from the various city, county, or other governmental authorities having jurisdiction.

Probably the biggest portion of the close out planning would be the punch list or check list. There is no period during construction that is concerned with more time-consuming delays and the resulting frustration than the period involving the corrective work prior to final acceptance. It is the contractor and its subcontractors who must assume the greatest responsibility for the existence of work that must be corrected. It is also the contractor's responsibility to create a punch list and make sure there is no error in it.

To prepare for close out, following process can be performed:

1. Perform close out inspections as outlined under the punch list.
2. Begin a partial reduction of field office inspection staff.
3. Complete final reduction of the field office inspection staff to the minimum number of persons necessary to complete the close out administrative activities.
4. Prepare for final inspection. All items indicated as requiring correction on the preliminary punch list should be re-inspected, and all tests that were originally unsatisfactory should be conducted again.
5. Check for all changes and variations from the original contract drawings have been marked.
6. Prepare a Certificate of Completion or Substantial Completion once all items in punch list have been accomplished to the satisfaction of the inspecting team.
7. Receive the contractor's request for its final progress payment.
8. Check all work quantities and the value of the work completed from the punch list.
9. Submit contractor's payment request to the owner through the design or construction management firm with recommendation to pay.
10. Obtain signatures of the architect/engineer, the contractor, and the owner on the Certificate of Completion or Certificate of Substantial Completion.
11. Notify the owner, through the architect/engineer, that the project is ready for occupancy.
12. Request to the owner for final payment and retainage to be released.

Questionnaire given to industry members

Total of how many superintendents and project managers were put into the Benner Pike Shops Project?

Were you supposed to leave the job at the closeout phase and hand the project to the third superintendent? Was it planned during preconstruction planning?

How often did your company hold meetings while the project is in progress?

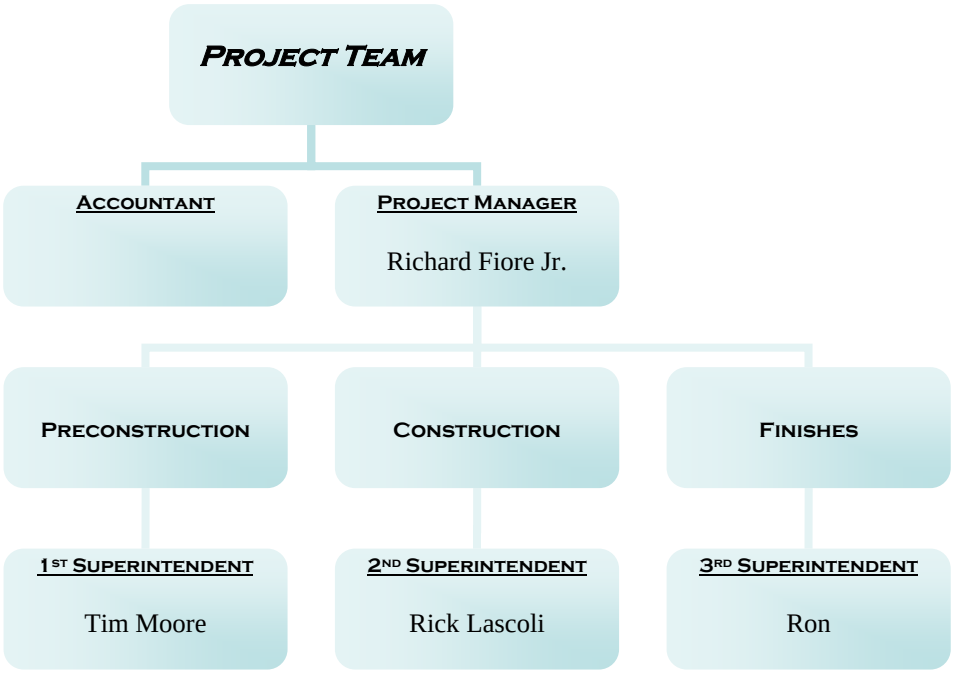
Who else was in the meeting except members from general contractor (architect, subcontractor, client, etc)?

Were there any meetings with shop tenants during the construction?

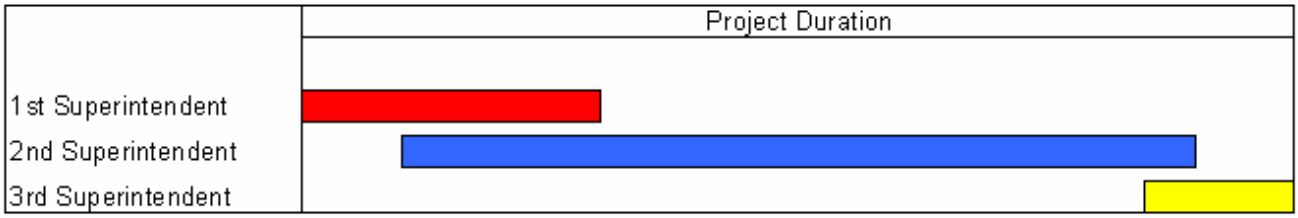
Why do you think that your company had planned the closeout planning like that?

Problem identification

The Benner Pike Shops project was wrongly executed from the beginning. Its staffing plan shows how the entire project is divided into three major sections: preconstruction, construction, and finishes. Each section was covered by different superintendents.



During the preconstruction phase, the superintendent probably had set up plans how the construction should go according to the schedule. Obviously, closeout planning was part of preconstruction. If the first superintendent had stayed on the project until the completion, there could be less risk completing the project. However, he had only stayed until the middle of the project, which the second superintendent was in charge of the project for about 90% of the time.



It is not good for the second superintendent to be not present during preconstruction period, but it is not going to affect the project hugely since he joined the project at the early stage. Even though there was a project manager in charge of the entire project, it is not efficient to coordinate staffs as shown above. The project manager is only conducting the project from the overview. It is the superintendents who need to appear at the construction site and check if the structure is building properly.

This also affects the communication and the meetings within the job. The project is about a year long and meetings with subcontractors were held weekly. Because the second superintendent was replaced by the third one, the meetings had to be reorganized. In another word, the subcontractors had to be familiar with the new superintendent which is going to take some time. Since the third superintendent was not quite used to the project, it was necessary for him to review the project from the beginning and how the construction went before he came. There could be some communication struggles between the superintendent and subcontractors, because one was at the site the whole time and the other was not. It would not make the project to fail at the last stage, but it certainly is not the best way to coordinate the staffing plan that way.

Conclusion

As said in the closeout literature, it is important how a company sets up the closeout planning during preconstruction. Mr. Conner from Saddleback Development Corporation replied,

"I think close-out is extremely important and I don't like it when personnel changes at this critical time. Contractors should start to 'pride themselves' and market themselves as close-out specialist (meaning they really care about it, have systems for it and do it better than anyone else). They may get more jobs out of it. Owners and Architects, who have gone through poor close-outs don't want to go through it again. The relationships can go bad in a hurry."

Every participant of the questionnaire said that they had the same supervisor through out the project including closeout phases. Most of them were cautious about closeout, because last impression is sometimes the most important. After all, one has to satisfy their owner when the project is completed. Once the client is satisfied, there is a better chance for him/her to contact again for another project. This is why companies pay good attention when it comes to closeout of a project.

In order to assure satisfaction of tenant and client requirements, constant communication is necessary at all levels. By communicating well, construction sequences can be nicely coordinated with each trade in the right order. This would shorten project schedule which will eventually cause decrease in cost.

Analysis #2 – Exterior Wall Tilt-up Construction

Overview

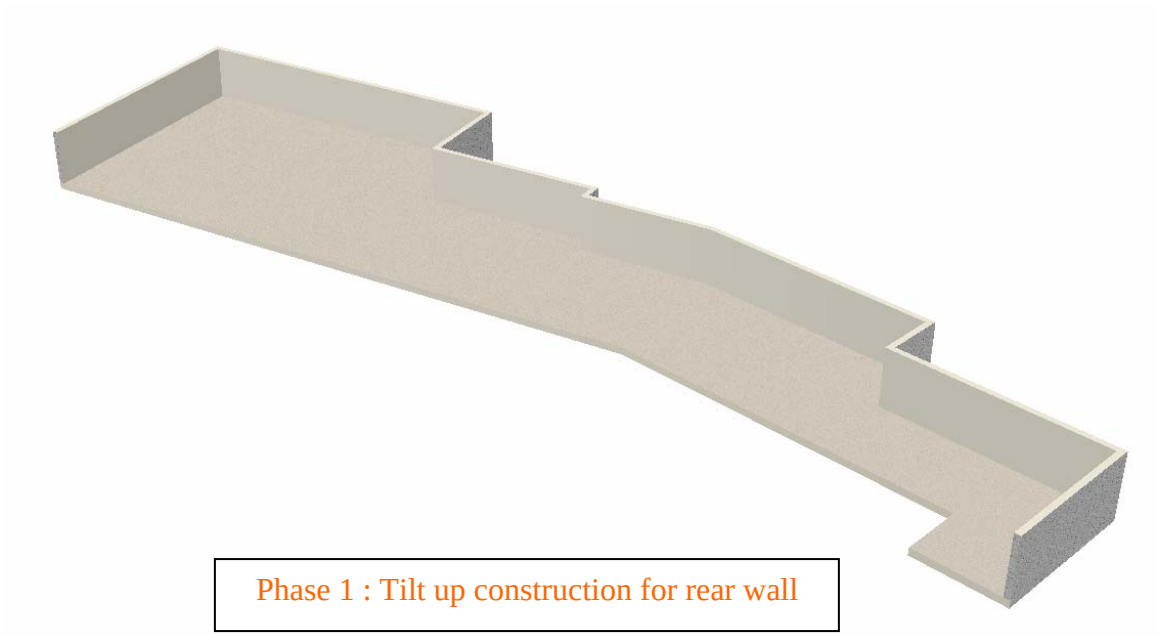
The majority portion of the exterior wall in the Benner Pike Shops is created with 12" concrete blocks with horizontal wall reinforcing at every other course. Because of the massiveness, the total masonry job for the projects takes about three months of the total schedule. In addition, there are number of other trades that could not start until the exterior wall has been set up. Tilt-up concrete panels can substitute the existing CMU walls to increase efficiency, and workability while reducing the cost and the schedule. The advantage of tilt-up construction is in the low cost of forms and the placing of concrete and reinforcing.

Tilt-up has repeatedly proven to be more economical than competing construction methods for similar types of buildings. A shorter construction duration, together with the elimination of scaffolding and elevating devices, result in lower construction costs. Tilt-up construction suits well with the Benner Pike Shops because of the large construction site area. Since Tilt-up construction can be performed for any reasonable shapes and sizes, the exterior walls of the shops have the perfect potential for the job. Walls will be broken into several sections so that it is easier to work with.

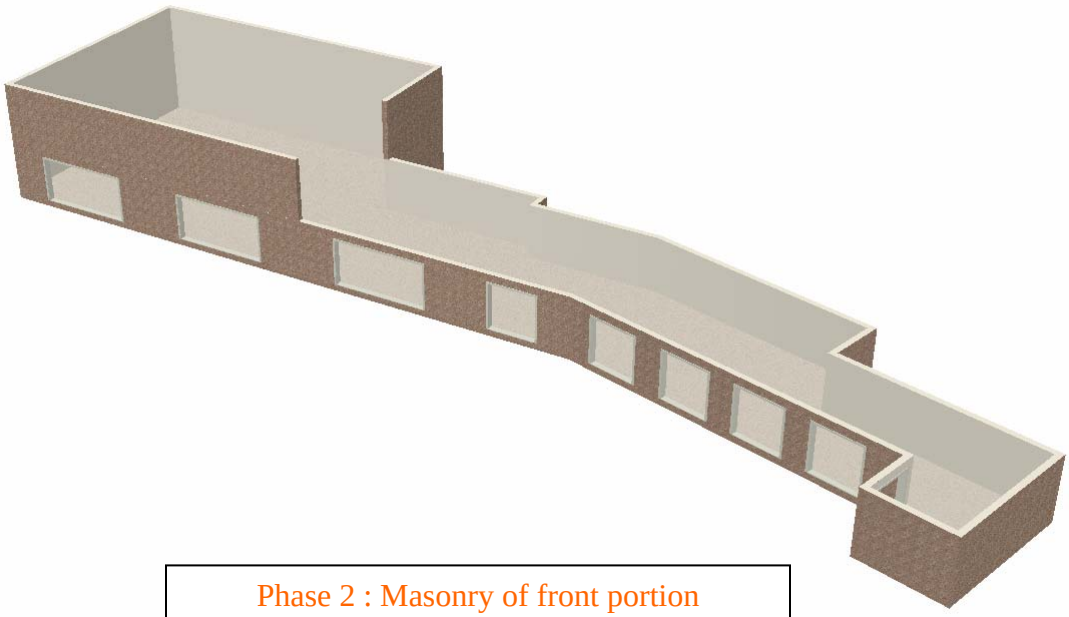
The following analysis contains thorough items that need to be emphasized when designing a Tilt-up construction. Site congestion is determined since the system needs decent amount of concrete pouring area. Site logistics are to be redefined to incorporate Tilt-up construction into the project. The building was considered to have four sides to it. Since the majority portion of the front facade is consisted of glass walls and doors, two sides and the back of the building exterior walls were suggested to be switched to tilt-up construction.

Layout Plan

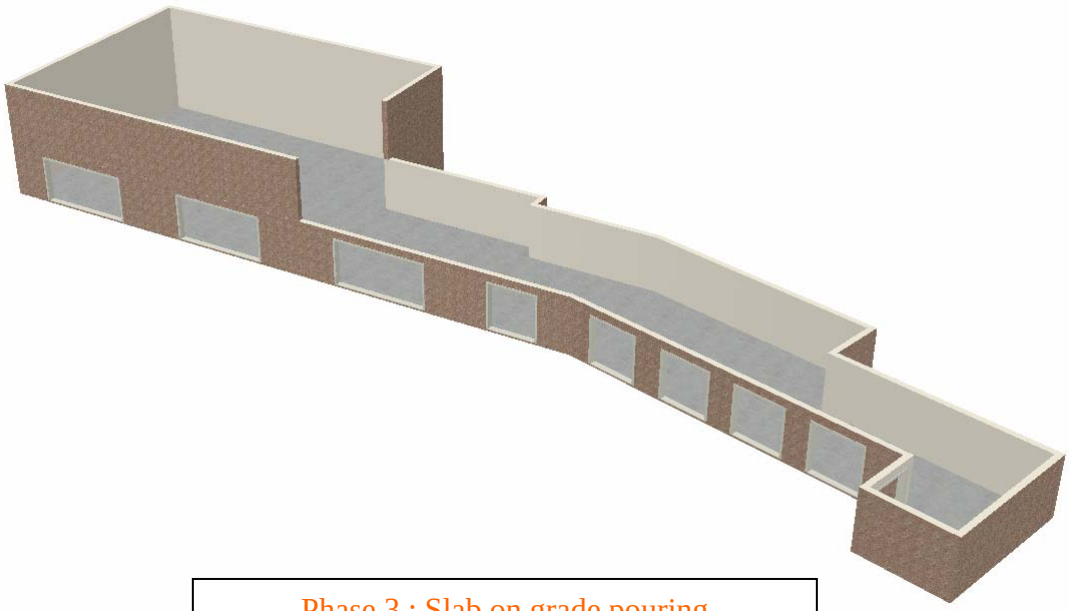
As mentioned earlier, only the rear portion of the exterior wall is going to be replaced to tilt-up construction. Since there is not enough space for the poured concrete to be tilted up, the pour will occur at the inside of the building space. In another words, there needs to be slight change in the schedule of enclosing the building. As shown in the following drawings, rear wall is going to be poured first then tilted. As soon as the walls go up, necessary masonry job is going to take place for front walls and miscellaneous. Since there is going to be openings for front windows and doors, slab on grade can be poured through the opening by a pump. The longest reach that the pump should make is 200 feet which falls within the range. Building floor slabs should be poured first and be a minimum of 5" thick with 100% compaction. The slab on grade for the Benner Pike Shops has thickness of only 4". This is another reason why tilt-up construction would be executed before the floor slab.



Phase 1 : Tilt up construction for rear wall

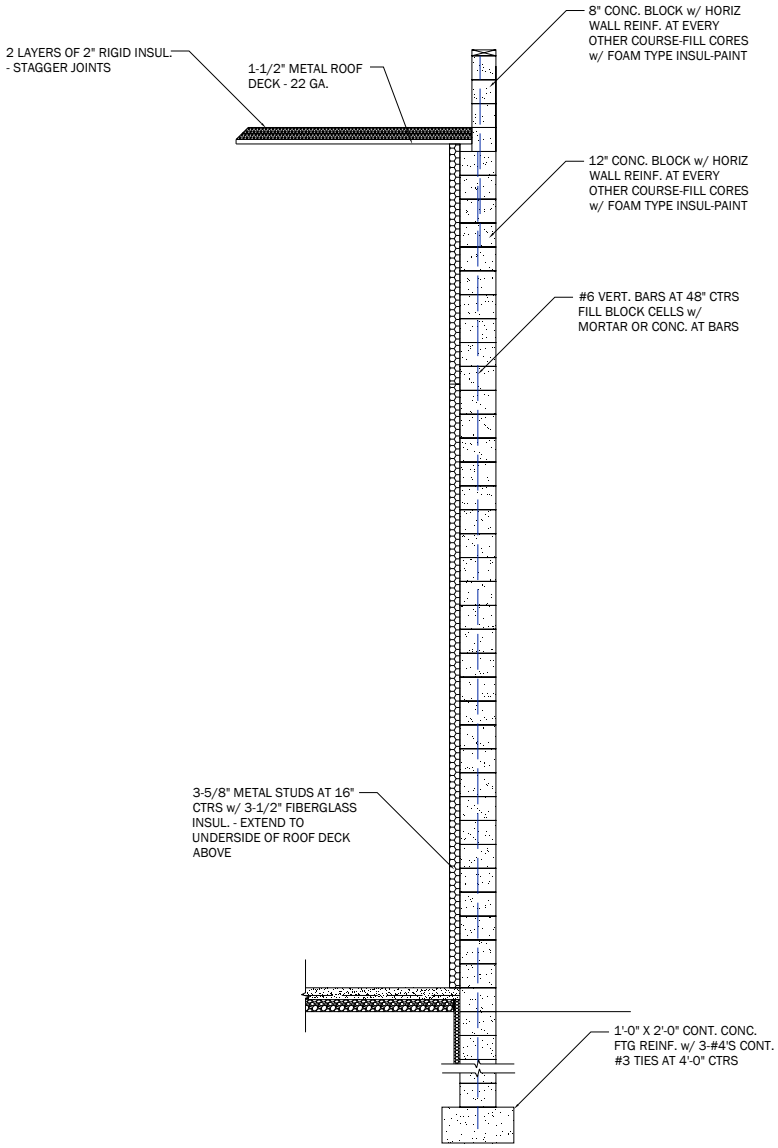


Phase 2 : Masonry of front portion



Phase 3 : Slab on grade pouring

Structural design



As seen in the typical section of exterior wall, it is consisted of 12” CMU’s with reinforcement at every other course. For vertical reinforcing, #6 bars are installed at 48” on center. The walls stick out 3’ higher than the top elevation for protection from falling at the roof. Those 3’ portion is finished with 8” CMU’s with the same reinforcing.

Tilt-up construction is going to have the same characteristics as CMU's except for its thickness. Instead of 12" thickness, 8" will be poured with the same horizontal and vertical reinforcing placed. After the panels are tilted, metal studs with insulation will be installed to the inside of the panels and the same painted finish will be executed to the outside of the panels.

Schedule reduction

The advantage of tilt up construction is in the high efficiency of productivity. Once slabs are poured, they can be tilted after seven days of curing. This is one of the reasons why tilt up construction is becoming popular in the industry. For the Benner Pike Shops, following duration could be saved from switching to tilt up system:

	Daily Output	Quantity	Total Duration	
Tilt up Construction	1550 S.F. per day	26808 S.F.	15.36	15 days
CMU Construction	250 S.F. per day	23808 S.F.	95.232	96 days

This is a save of approximately 81 days, which is 11 weeks. It is a critical reduction especially when the project is a shopping mall. Indirect cost saving could be tremendous if the mall could open 11 weeks earlier than it was supposed to. Possible incentives could take place because of the early finish.

Cost Estimate

Description	Size	Quantity	Unit	Unit Cost			Total Cost
				Material	Labor	Equipment	
Existing System							
Concrete Block	8"x16"x12" thick	23808	S.F.	3.59	6.15		$231,890
	reinforced alt. courses						
Vertical	Walls, #3 to #7	4.47	ton	810.00	420.00		$5,498
Reinforcement							
TOTAL							$237,388
Modified System							
Tilt-up	Wall panel construction	23808	S.F.	4.93	4.52		$224,986
	walls only, 8" thick						
Vertical	Slab, #3 to #7	4.47	ton	810.00	550.00		$6,079
Reinforcement							
Horizontal	Slab, #3 to #7	5.96	ton	810.00	550.00		$8,106
Reinforcement							
Crane Rental	120 ton hydraulic	3	week				$22,650
TOTAL							$261,820

Just looking at the cost comparison, it is clear that tilt up construction has about 10% cost increase compared to CMU construction. Despite the cost swell, it is still recommended to apply tilt up system because one will eventually save money considering long run. Fast installation results in shortened project schedule that causes project staff to be on site less time. Following general conditions estimate shows how much is saved.

Description	Quantity	Unit	Unit Cost	Total Cost
Project Staff - Previous				
Project manager	40	Week	$1,625	$65,000
Superintendent	40	Week	$1,500	$60,000
Superintendent	24	Week	$1,500	$36,000
Field engineer	48	Week	$995	$47,760
Field engineer	48	Week	$995	$47,760
Field engineer	48	Week	$995	$47,760
Total				$304,280
Project Staff - Modified				
Project manager	29	Week	$1,625	$47,125
Superintendent	29	Week	$1,500	$43,500
Superintendent	13	Week	$1,500	$19,500
Field engineer	37	Week	$995	$36,815
Field engineer	37	Week	$995	$36,815
Field engineer	37	Week	$995	$36,815
Total				$220,570

Impact on R-Value

CMU Construction	R-Value
Outside Air Film	0.17
12" Concrete Block	1.28
3 1/2" Fiberglass Batt	11
1/2" Gypsum Board	0.45
Inside Air Film	0.68
Total	13.58
Tilt up Construction	
Outside Air Film	0.17
Poured Concrete (8" thick)	0.64
3 1/2" Fiberglass Batt	11
1/2" Gypsum Board	0.45
Inside Air Film	0.68
Total	12.94

There is a different of 0.64 for R-value of tilt up system. Since two values are pretty high and the difference is not significant to affect any thermal insulation issues.

Safety issue

Since Tilt-up construction involves movements of massive concrete walls, contractors need to pay attention to safety issues. Especially, the braces between the walls and the structure should be examined very carefully. OSHA regulations require the following before braces can be removed:

Welders connect the wall panel to the roof trusses with structural fillet welds
The Tilt-up contractor stabilizes the wall panels by grouting at the base, between the panels and the footing
The Tilt-up contractor completes the structural connection from the wall panels to the floor with concrete in the pour-back / leave-out strip

Some of the safety issues that need to be considered for the construction are follows:

Lack of training and understanding of tilt-up construction and its hazards
Inadequate support of Tilt-up panels
Failure to ensure the panel's permanent connections to the structure (welds, grout, pour-back strip) were complete and acceptable before removing temporary braces
Failure to train inspection employees on job specifications and hazards of Tilt-up construction

Analysis #3 – HVAC Units Reconfiguration

Overview

The existing HVAC units located on the rooftop of the Benner Pike Shops are distributed with too many in quantity. Some of the stores have more than five HVAC units with its capacity ranging from 1000 to 3000 lbs. Having too many HVAC units would draw issues on maintenance, and equipment installation. Since the front of the shops is exposed to outside with its glass show window and doors, separate HVAC systems should be integrated between front and back of each store. The main idea is to have a small HVAC unit in the front and larger units in the back for each store. This will definitely decrease cost in equipments and labor, and also possible shortening in total duration of the project.

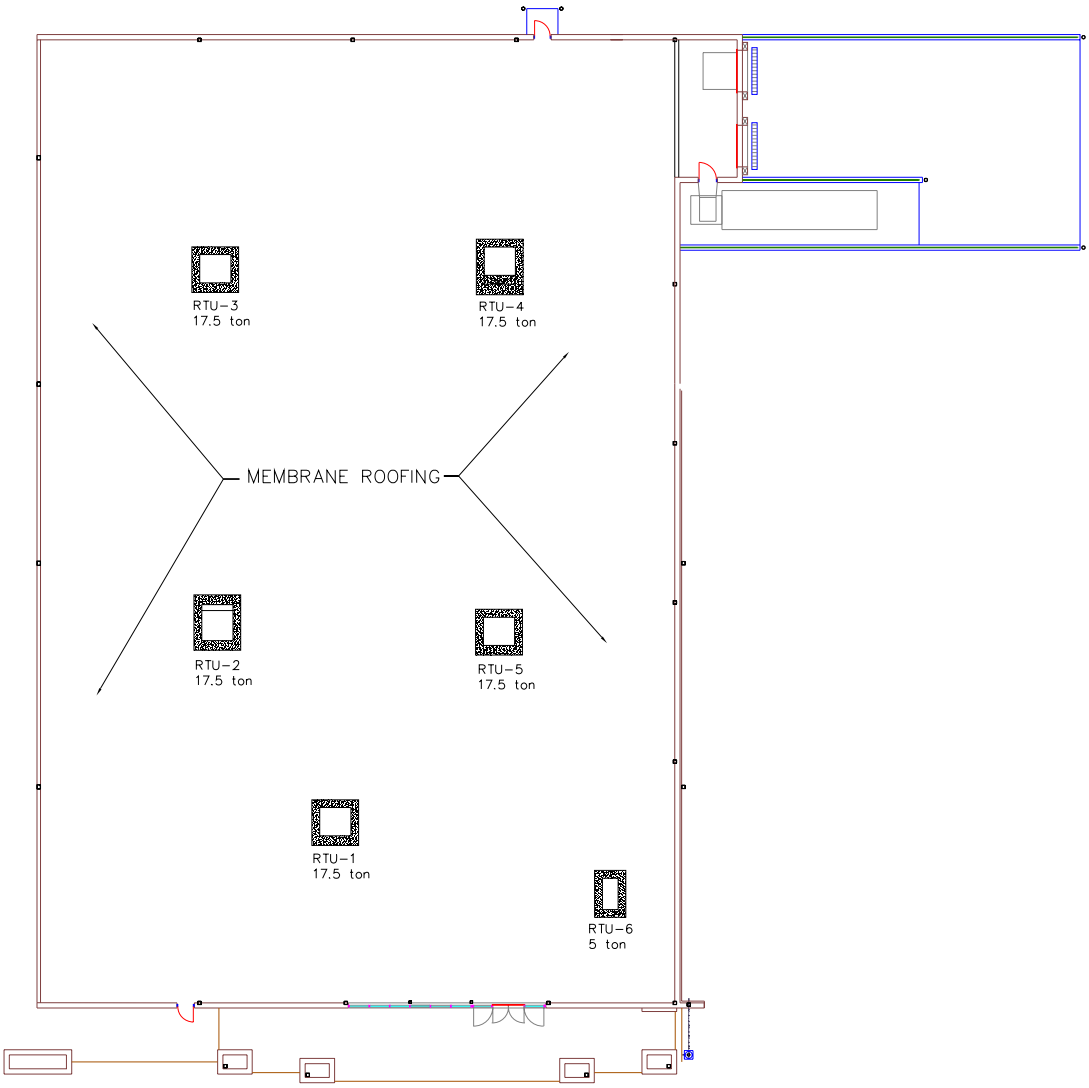
This analysis will focus on two large shops in the Benner Pike Shops; Bed Bath & Beyond and Ross Dress For Less. Based on current roof plans, Bed Bath has total of six HVAC units and Ross has seven of them. Since the shops have glass wall in their front entrance, they need to have two different controls for their HVAC system. Because of the large heat loss due to glass wall, it could be necessary for the shops to heat the front area while cooling the inner portions.

Since all of the existing rooftop units were provided by Lennox International Inc., it is better to have the redesigned products provided by the same company. The units are packaged air handling systems, and newly designed units will produce the same performance as the previous units.

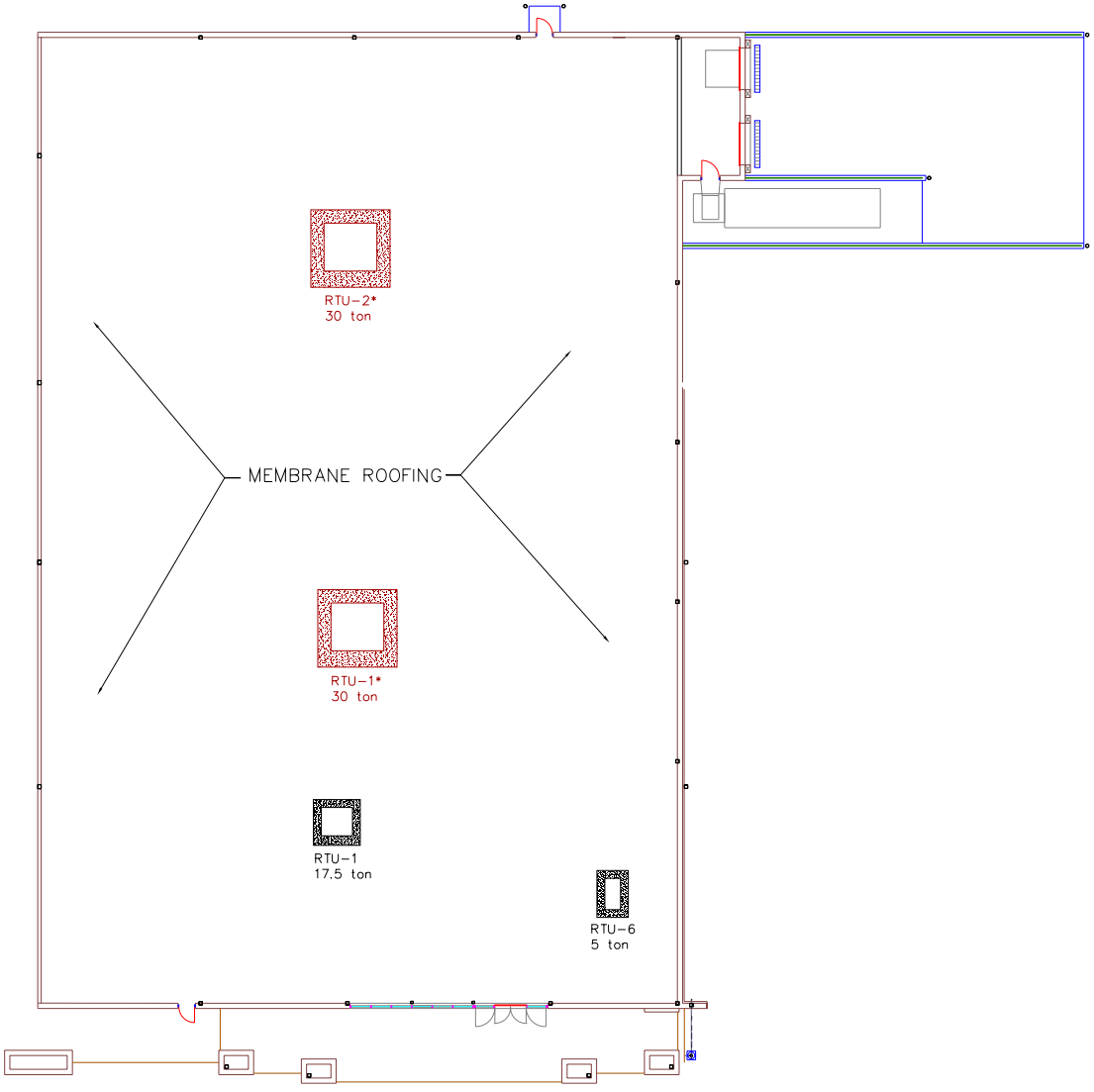
Bed Bath & Beyond

For Bed Bath, roof top units for the front and the office area will have no change. Four backside units will be combined into two large units. Since the store has rectangular shape and has its back wall exposed to the outside, it is more efficient to place two large units in the center of the shop. Also, the existing ductwork could be kept without any major modification.

Existing Roof Plan



Modified Roof Plan



Capacity Comparison

ID	Manufacturer	Area Served	Cooling Data				Heating Input				Air Flow Range			Physical Data	
			Nominal Ton	Gross Cap	Net Cap (Btuh)	ARI Rated CFM	Low	Standard	Medium	High	CFM Min. Cool	CFM Min. Heat	CFM Max.	Dim. HxWxD (in)	Weight (lbs)
Existing units to be kept															
RTU-1	Lennox	Retail	17.5	218,000	210,000	6,600	169,000	260,000	360,000	480,000	4,900	2,780-5,080	8,400	55x91x133	2,685
RTU-6	Lennox	Office	5	63,000	60,000	2,000	-	78,000	-	125,000	1,400	1,050-1,320	2,400	37x45x86	860
Combination of the existing units															
RTU-2	Lennox	Retail	17.5	218,000	210,000	6,600	169,000	260,000	360,000	480,000	4,900	2,780-5,080	8,400	55x91x133	2,685
RTU-5	Lennox	Retail	17.5	218,000	210,000	6,600	169,000	260,000	360,000	480,000	4,900	2,780-5,080	8,400	55x91x133	2,685
RTU-1*	Lennox	Retail	30	351,000	336,000	10,500	-	260,000	360,000	480,000	8,400	4,815-7,110	14,400	65x81x145	3,340
RTU-3	Lennox	Retail	17.5	218,000	210,000	6,600	169,000	260,000	360,000	480,000	4,900	2,780-5,080	8,400	55x91x133	2,685
RTU-4	Lennox	Retail	17.5	218,000	210,000	6,600	169,000	260,000	360,000	480,000	4,900	2,780-5,080	8,400	55x91x133	2,685
RTU-2*	Lennox	Retail	30	351,000	336,000	10,500	-	260,000	360,000	480,000	8,400	4,815-7,110	14,400	65x81x145	3,340

It is obvious that redesigned unit has less capacity in ton than the previous two units (17.5+17.5>30). It is still acceptable to have smaller nominal tons. Following load calculations show that redesigned units are suitable to cover the space.

Since the shop has medium condition for density of people, $1.3\frac{CFM}{ft^2}$ is needed.

Area = (122ft)(185ft) = 22,570 ft^2

CFM needed in the space = 22,570 $ft^2 \cdot 1.3\frac{CFM}{ft^2}$ = 29,341 CFM

Total CFM in Units = 6,600 + 2,000 + 10,500 + 10,500 = 29,600 CFM

Since the total CFM in units fall under 5% range of CFM needed in the space, the redesigned units are acceptable for the shop.

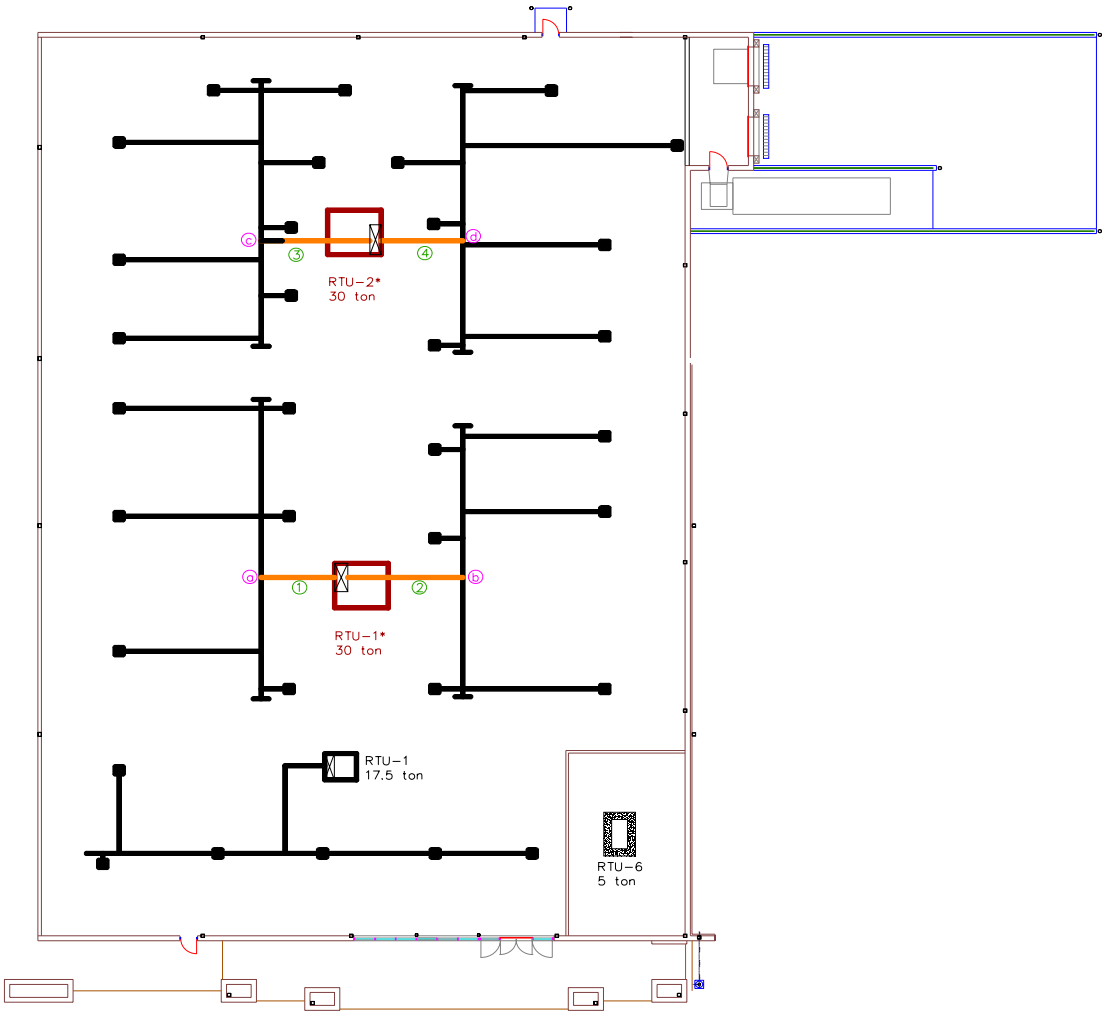
Load Bearing Roof Slab

Based on the joist catalog from Vulcraft, load capacity for the roof joists was calculated to match the weights of each HVAC unit. Minor load increase in the units did not affect roof slab for any critical failure. Allowable loads are calculated by multiplying units' dimension with the load capacity given in the catalog.

ID	Dim. HxWxD (in)	Dim. in ft	Joist type	Span (ft)	Load Capacity (lb/ft)	Allowable load (lb)	Actual load (lb)
Existing Units							
RTU-1	55x91x133	4.5x7.5x11	28K10	12	550	45,375	2,685
RTU-6	37x45x86	3x3.5x7	28K10	12	550	13,475	860
Modified Units							
RTU-1*	65x81x145	5.5x7.5x12	22K4	12	550	49,500	3,340
RTU-2*	65x81x145	5.5x7.5x12	22K4	12	550	49,500	3,340

Ductwork Modification

Most portion of the existing ductwork plan can be used with the newly designed HVAC units. Only a major duct stem is needed to be designed for each unit in order to serve the space with the existing ductwork system. In the following drawing, existing ducts are shown in black and new ducts in orange. Each duct and duct accessory are numbered to be taken off for cost estimate.



Cost Estimate

Description	Size	Quantity	Unit	Unit Cost			Total Cost
				Material	Labor	Equipment	
Existing System							
Rooftop HVAC	17.5 ton cooling, 330KBtuh	5	each	13,495.00	1,717.00		$76,060
	5 ton cooling, 112KBtuh	1	each	4,050.00	1,050.00		$5,100
Crane Rental	120 ton hydraulic	1	each				$7,550
TOTAL							$88,710
Modified System							
Rooftop HVAC	30 ton cooling, 540KBtuh	2	each	24,600.00	2,675.00		$54,550
	17.5 ton cooling, 330KBtuh	1	each	13,495.00	1,717.00		$15,212
	5 ton cooling, 112KBtuh	1	each	4,050.00	1,050.00		$5,100
Crane Rental	120 ton hydraulic	1	each				$7,550
Additional Ductwork	Galvanized steel, 1,000 to 2,000	1204	lbs	0.38	2.97		$4,033
Turning Vane	Double thick, 14" high set	8	L.F.	6.40	1.76		$65
TOTAL							$86,511

All of the cost was calculated based on RS Means. Crane rental cost came out to be the same since the rental is executed on a weekly base. Take off for duct system is given below and calculation for its weight is based on RS Means (refer to the Appendix). Only additional duct system was estimated for cost because the modified system uses the previous duct system.

	Description	Duct Size (in x in)	Quantity	Length (ft)	Weight (lbs)
Duct No.	1	60 x 14	1	10	215
	2	60 x 14	1	18	387
	3	60 x 14	1	17	365.5
	4	60 x 14	1	11	236.5
total				56	1204
Turning Vane	a	14" high set	1	2	
	b	14" high set	1	2	
	c	14" high set	1	2	
	d	14" high set	1	2	

** according to RS Means reference table, for 60 x 14 duct, the weight is 21.5 lbs per foot

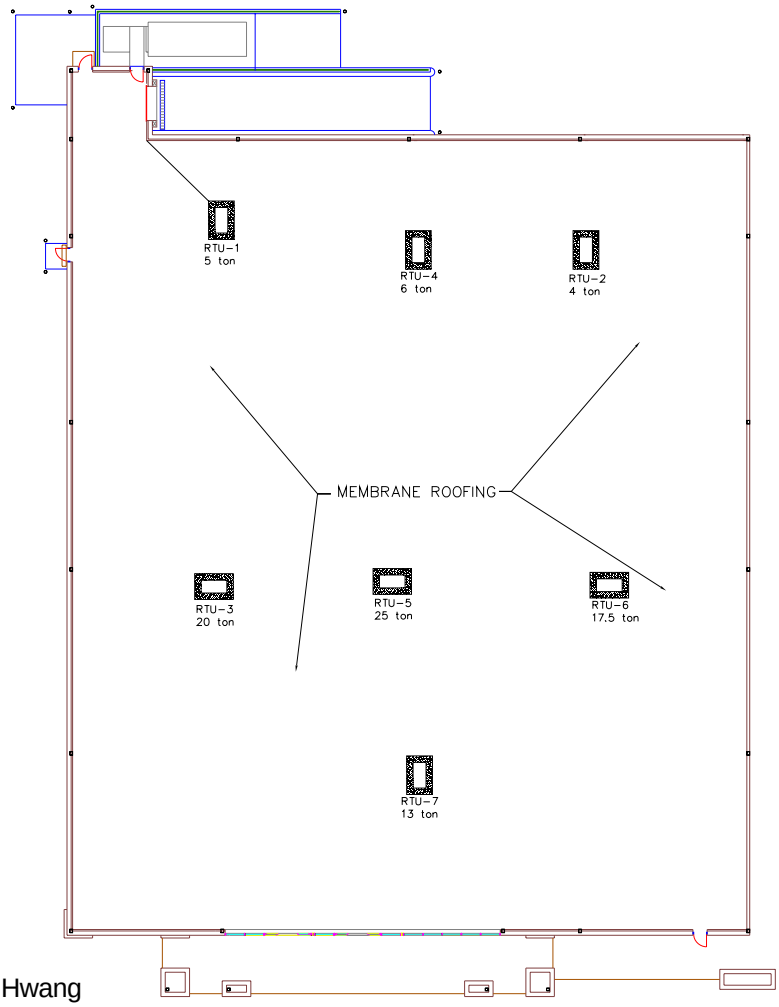
Crane Configuration

Through out the entire project, only one crane rental was performed for a week. 120 ton mobile crane was used for a week just to erect the existing rooftop HVAC units. The crane has enough capacity to hold the newly designed HVAC units. Therefore, there is no need for any change in crane configuration. General conditions estimate for crane rental will stay the same since the rental is performed on weekly basis. Delivered units will stage in the open area near the shop and erected starting from the back of the store.

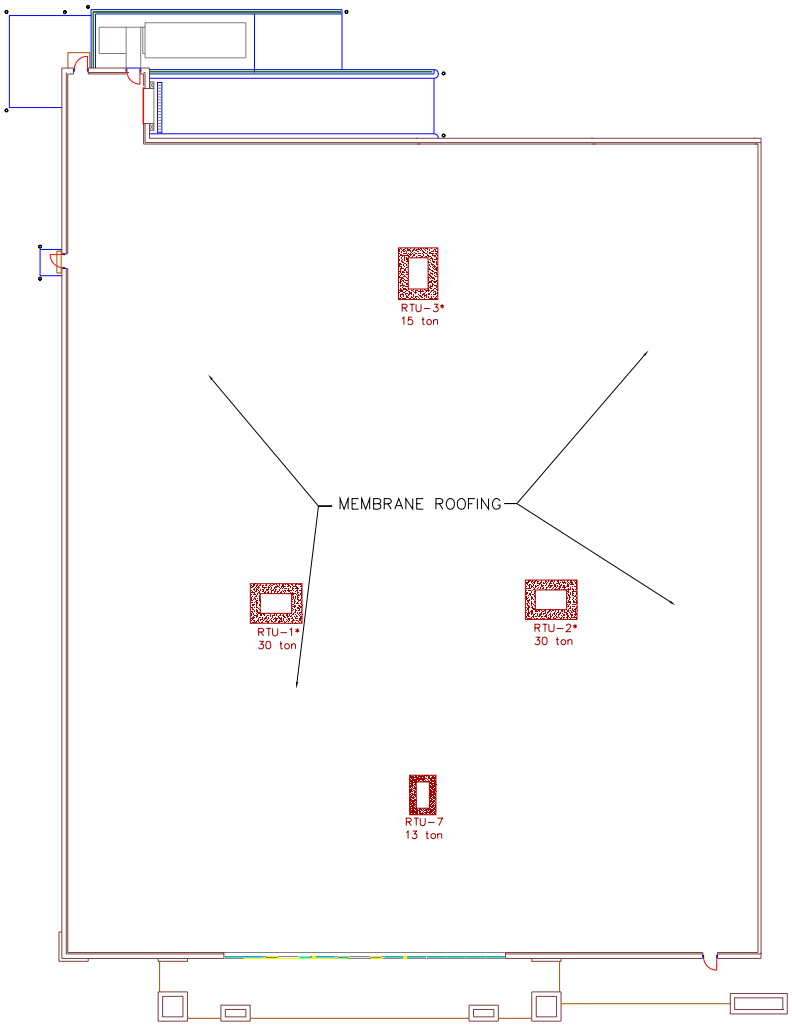
Ross Dress For Less

Ross Dress For Less one main retail store area and a much smaller space for storage and office purpose. The center HVAC unit will remain the same since it is the largest and it covers large portion of the store. Just like the Bed, Bath & Beyond, front of the shop is needed to be considered as separate space for heat loss due to window wall in the front. Front unit is replaced with slightly larger unit to cover the stockroom that is located at the side of the front portion. With the current center unit and the modified front unit, two symmetrical large units are redesigned to serve the store uniformly. Those two units are two equal systems with the same capacity.

Existing Roof Plan



Modified Roof Plan



Capacity Comparison

ID	Manufacturer	Area Served	Cooling Data				Heating Input				Air Flow Range			Physical Data	
			Nominal Ton	Gross Cap (Btuh)	Net Cap (Btuh)	ARI Rated CFM	Low	Standard	Medium	High	CFM Min. Cool	CFM Min. Heat	CFM Max.	Dim. HxWxD (in)	Weight (lbs)
Existing units to be kept															
RTU-7	Lennox	Retail	13	160,000	156,000	5,100	169,000	260,000	360,000	-	3,640	2,780-4,445	6,240	55x91x133	2,555
Combination of the existing units															
RTU-5	Lennox	Retail	25	311,000	300,000	9,500	-	260,000	360,000	480,000	7,000	2,780-7,110	12,000	65x91x145	3,340
RTU-3	Lennox	Retail	20	252,000	242,000	7,500	-	260,000	360,000	480,000	5,600	2,780-5,080	9,600	55x91x133	2,735
RTU-6	Lennox	Retail	17.5	218,000	210,000	6,600	169,000	260,000	360,000	480,000	4,900	2,780-5,080	8,400	55x91x133	2,685
RTU-1*	Lennox	Retail	30	351,000	336,000	10,500	-	260,000	360,000	480,000	8,400	4,815-7,110	14,400	65x91x145	3,340
RTU-2*	Lennox	Retail	30	351,000	336,000	10,500	-	260,000	360,000	480,000	8,400	4,815-7,110	14,400	65x91x145	3,340
RTU-1	Lennox	Retail	5	63,000	60,000	2,000	-	78,000	-	125,000	1,400	1,050-1,320	2,400	37x45x86	860
RTU-2	Lennox	Office	4	50,500	48,000	1,450	-	78,000	-	125,000	1,120	1,050-1,320	1,920	37x45x86	850
RTU-4	Lennox	Office	6	74,000	71,000	2,100	-	78,000	-	125,000	1,680	1,050-1,320	2,880	37x45x86	885
RTU-3*	Lennox	Office	15	188,000	182,000	5,700	169,000	260,000	360,000	480,000	4,200	2,780-5,080	7,200	55x91x133	2,685

It is obvious that redesigned units have smaller total capacity than the previous units (17.5+13>17.5). It is still acceptable to have smaller nominal tons. Following load calculations show that redesigned units are suitable to cover the space.

Since the shop has medium condition for density of people, $1.3\frac{CFM}{ft^2}$ is needed.

Area = (157ft)(162ft) = 24,624 ft^2

CFM needed in the space = 24,624 $ft^2 \cdot 1.3\frac{CFM}{ft^2}$ = 32011 CFM

Total CFM in Units = 5,100 + 10,500 + 10,500 + 5,700 = 31,800 CFM

Since the total CFM in units fall under 5% range of CFM needed in the space, the redesigned units are acceptable for the shop.

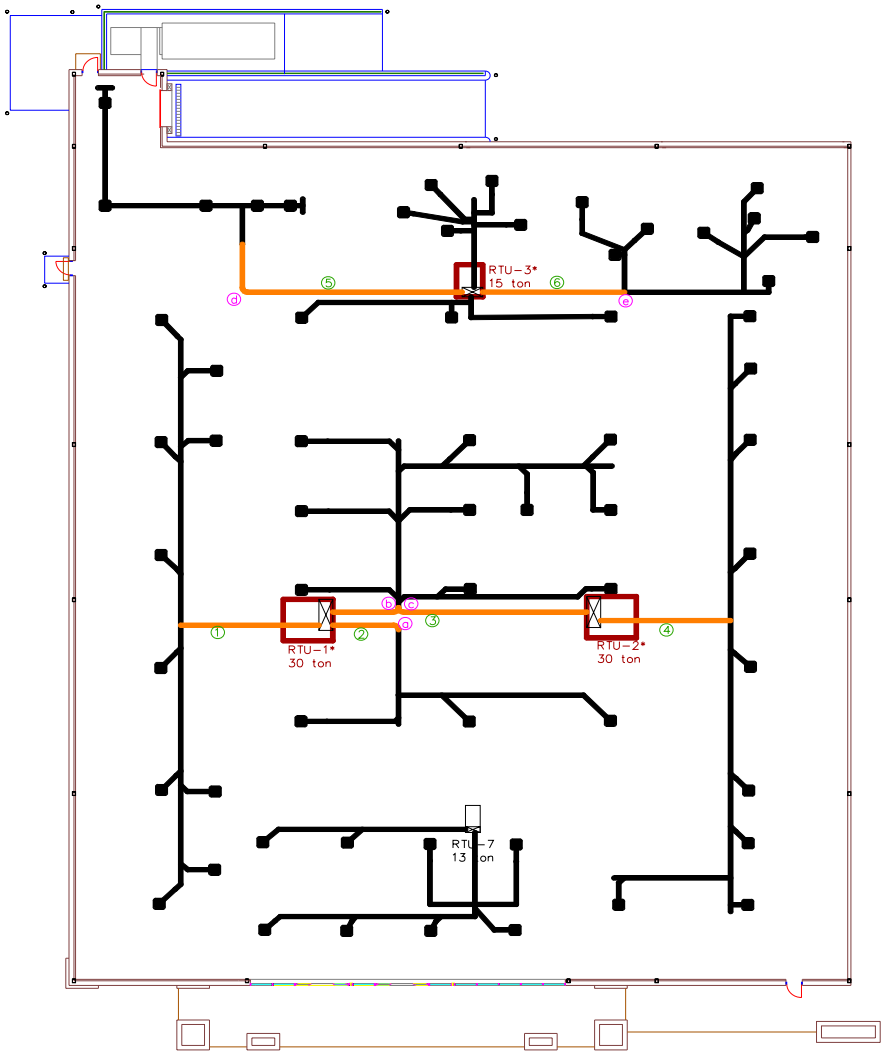
Load Bearing Roof Slab

Like Bed, Bath & Beyond, the roof framing for Ross Dress For Less is based on the joist catalog from Vulcraft. Load capacity for the roof joists was calculated to match the weights of each HVAC unit. Minor load increase in the units did not affect roof slab for any critical failure. Allowable loads are calculated by multiplying units' dimension with the load capacity given in the catalog.

ID	Dim. HxWxD (in)	Dim. in ft	Joist type	Span (ft)	Load Capacity (lb/ft)	Allowable load (lb)	Actual load (lb)
Existing Units							
RTU-7	55x91x133	4.5x7.5x11	26K9	16	550	45,375	2,555
Modified Units							
RTU-1*	65x91x145	5.5x7.5x12	28K10	16	550	49,500	3,340
RTU-2*	65x91x145	5.5x7.5x12	22K7	16	550	49,500	3,340
RTU-3*	55x91x133	4.5x7.5x11	22K7	16	550	45,375	2,685

Ductwork Modification

Several ductwork systems will be modified based on the existing plan. It is designed so that the reorganized HVAC system serves the store just the same as the previous system. Existing ductwork system could be recycled to fit the new HVAC units in order to minimize any additional cost in ductwork system. In the following drawing, existing ducts are shown in black and new ducts in orange. Each duct and duct accessory are numbered to be taken off for cost estimate.



Cost Estimate

Description	Size	Quantity	Unit	Unit Cost			Total Cost
				Material	Labor	Equipment	
Existing System							
Rooftop HVAC	25 ton cooling, 450KBtuh	1	each	19,500.00	2,250.00		$21,750
	20 ton cooling, 360KBtuh	1	each	15,800.00	1,875.00		$17,675
	17.5 ton cooling, 330KBtuh	1	each	13,495.00	1,717.00		$15,212
	13 ton cooling, 230KBtuh	1	each	9,255.00	1,483.00		$10,738
	6 ton cooling, 140KBtuh	1	each	4,750.00	1,125.00		$5,875
	5 ton cooling, 112KBtuh	1	each	4,050.00	1,050.00		$5,100
	4 ton cooling, 95KBtuh	1	each	3,700.00	975.00		$4,675
Crane Rental	weekly rental covered in Bed, Bath & Beyond						
TOTAL							$81,025
Modified System							
Rooftop HVAC	25 ton cooling, 450KBtuh	2	each	19,500.00	2,250.00		$43,500
	17.5 ton cooling, 330KBtuh	2	each	13,495.00	1,717.00		$30,424
Crane Rental	weekly rental covered in Bed, Bath & Beyond						
Additional Ductwork	Galvanized steel, 1,000 to 2,000 lb	1716.7	lbs	0.38	2.97		$5,751
Turning Vane	Double thick, 14" high set	13	L.F.	6.40	1.76		$106
TOTAL							$79,781

All of the cost was calculated based on RS Means. Crane cost was eliminated because it was put into consideration in the cost estimate of Bed Bath & Beyond. Take off for duct system is given below and calculation for its weight is based on RS Means (refer to the Appendix). Only additional duct system was estimated for cost because the modified system uses the previous duct system.

	Description	Duct Size (in x in)	Quantity	Length (ft)	Weight (lbs)
Duct No.	1	50 x 10	1	16	240
	2	22 x 14	1	12	93.6
	3	50 x 10	1	47	705
	4	48 x 16	1	10	160
	5	22 x 12	1	53	386.9
	6	28 x 10	1	16	131.2
total				154	1716.7
Turning Vane	a	14" high set	1	2	
	b	14" high set	1	4	
	c	14" high set	1	4	
	d	14" high set	1	2	
	e	14" high set	1	1	

** according to RS Means reference table, for 50 x 10 duct, the weight is 15.0 lbs per foot

for 22 x 14 duct, the weight is 7.8 lbs per foot

for 48 x 16 duct, the weight is 16.0 lbs per foot

for 22 x 12 duct, the weight is 7.3 lbs per foot

for 28 x 10 duct, the weight is 8.2 lbs per foot

Crane Configuration

As said in the above, 120 ton mobile crane will easily hold and erect HVAC units for Ross Dress For Less. Since it does not take much time to erect units, one crane rental is enough for the erection process of the entire mall. Delivered units will stage in the open area near the shop and erected starting from the back of the store.

Appendix 1

Questions answered by industry members

1. Total of how many superintendents and project managers were put into the Project?

2. Were there same supervisors in charge for the entire construction (including close out phase)?

3. How often did your company hold meetings while the project is in progress?

4. Who else was in the meeting except members from general contractor (architect, subcontractor, client, etc)?

5. Were there any meetings with building tenants, who will occupy the building after the completion) during the construction?

6. Was the closeout planning performed the way it was planned during preconstruction?

7. Why do you think that your company had planned the closeout planning like that?

Mr. Kenneth Catlow – Pentagon Renovation Group

1. "PENREN has one Project Manager assigned to the project and he has a staff of approximately 20 quality assurance and design managers. The design build contractor has a management staff of approximately 150. As this project will span 20 years from the beginning to the end, I am currently on my 4th Project Manager."

2. The PM I assign to the project is specifically responsible for ALL phases of construction to include close out. Supervisors are normally assigned to specific sub-elements of the project and again are accountable for the entire delivery process, beginning to end.

3. We hold many types of meetings on a daily basis. Over the next 10 months we will conduct 1100 tenant agency meetings alone. That does not include routine coordination, management review, scheduling and numerous other elements. I would estimate that the staff involved with the project average 10 to 20 meetings per day.

4. Depending on the specific type of meeting, we include building operators, safety representatives, tenants, designers, historic preservation interests, representatives from the disabled community, public affairs, local code authorities, and whoever else as necessary to assure we have all required decision makers.

5. Yes, 1100 over the next 10 months alone … that is just for Wedge 3, multiply that by 5 for the entire building. We have meetings with the tenant after occupancy to assure their space has met their needs.

6. We close out each Wedge of the building as we complete it and it is occupied by the permanent tenant. We have a transition team assigned to assure this close out is accomplished efficiently. Yes, it was planned during preconstruction.

7. As the owner's representative we want to assure satisfaction of tenant and owner requirements. Constant and regular communication at all levels of the organization and with all critical stakeholders is the only way to succeed.

Ms. Marilyn Juban – Gilbane Building Company

1. 1 PM; 1 General Supt & 1 Asst or MEP Supt

2. Yes

3. Weekly with the Owner & Weekly (sometimes more) with the Subs

4. The two major progress meetings were separate - Meeting #1 - Client, Architect, CM/GC, & sometimes consultants

Meeting #2 - Subs, GC/CM, & sometimes the Architect, Fire Marshal or other appropriate party based on schedule

5. No -- we only saw them for "jobsite tours" & they were encouraged to take tours only after 3pm, when the subs work was complete for the day (to discourage them from giving

direct orders to subs who should instead be getting that information thru the proper channels)

6. Yes, mostly.

7. Your last impression is sometimes the most important, so our preconstruction plan, reinforcement during construction, & follow through as planned is an important part of repeat work with that client.

The only suggestion I can share relative to our closeout process relates to the attention given by the team. It's necessary to keep the same team that built the job around for closeout to ensure proper follow through, but there is also a balance in keeping them confident they have a secure spot on a new project upcoming without distracting their attention to that new project too early!! Often, the resolution here is to have "newer" more "junior" employees assisting with the follow up during closeout while the PM & Superintendent manage closeout and consider start up for a new project.

Dr. Mark Konchar – Centex Construction

1. At a minimum we staff our projects with a full time PM and full time Super.

Both are stationed at the project site.

2. Yes - typically these people remain until closeout is complete.

3. This is a broad question - meetings are held constantly - also dependent upon the nature of the job, the phase you are in and issues at hand. At a minimum, the superintendent holds weekly sub meetings for the operations side. The PM does the same for all sub PM members.

4. All are invited. They are mandatory for the subcontractors. On our DB jobs, the A/Es are very active. Again, all are invited.

5. Typically no - although it depends on our terms and scope. Sometimes, like on our DB projects, we will need to have direct contact with the user group in order to properly establish the desired program and how they anticipate operating the facility. In these cases, we do engage the facility users.

6. Another tough question. We'd love to be able to say all plans run smoothly and just as we anticipate things but that is never the case in our business. The commissioning and closeout process is custom each time. We have standards procedures as a guide but must customize for each client.

Mr. Mike Hartman – The Clark Construction Group, LLC

1. On a typical Wash DC office building there will be one lead PM and Supt with Assistant PM's and Supt's on the team.
2. Same supervisors were in charge for the entire project. Supt. is pulled from the job just after substantial completion.
3. Owner and subcontractor meetings held once a week.
4. Owner meetings - owner, architect (and other consultants as needed). Subcontractor meetings generally just the subs foreman and periodically the project managers. Onan as needed basis the designers and subs would meet.
5. Building tenant was the same as owner.
6. Closeout planning was altered from original plan due to ownership issues.
7. Closeout planning has 2 primary goals - efficient closeout for the owner, subs, and tenant with the least expenditure of manpower.

Ms. Katie Lynahan – Barton Malow

1. 1 General Superintendent, 1 Assistant Superintendent, 1 Project Manager, 1 Assistant Project Manager, 2 Engineers
2. Usually the PM stays consistent throughout, but in the case of the project references, the PM left the company, and a new PM was used for the last 20% of the project.
3. We would have a Bi-Weekly Progress Meeting every two weeks with the project level players from the CM, Owner and A/E. An Owner's meeting once a month for the higher ups (very general) and a Subcontractor's Meeting once a week. There would also be MEP Coordination Meetings and Commissioning Meetings on a regular basis depending on the point in the project.

4. Project Architects and pertinent design engineers, the Project Manager from the Owner/ client for all of the Progress Meetings. The same team came to the Owner's meetings, along with basically everyone's superiors - the Owner's PM's boss, the Project Architects' boss, and the Project Executive or VP from our company.

The subcontractor meetings included all of the trades on site or those coming within the next two weeks. We require that it be someone who can make decisions for the company, so it is usually a sub's PM or Superintendent, or sometimes both.

5. Our Owner and our client are two different entities. The Owner is the state, and they procure the construction for the particular client we were building for. The client's PM was included at all of the Bi-Weekly and Progress Meetings. We did not meet with any of the actual tenants (mostly researchers) at any meetings.

6. Some was, some wasn't. During pre-con we were going to provide a certain level of commissioning services, which we integrate with the closeout documentation. The Owner was able to procure the funds to use an outside CA for particular systems, but not all of them (the CA is responsible for MEP, and we are responsible for all Lab and other equipment). We had to adjust our closeout procedures accordingly. This has created problems in the tracking and approval of some of our documentation.

7. See above - if we had known what we would be commissioning and what others would have been commissioning prior to the project starting, we would have had time to make a better close-out plan to include the times required for commissioning review of the submittals and close-out review. All of our internal paperwork for the closeout procedures is very easy to follow though, in regards to guarantees, and final payment. We really only have problems where we need to interface with another company's procedures.

Mr. Michael Arnold – Foreman Program and Construction

1. 1 pm and 1 sm
2. yes
3. every other week with the prime contractors + weekly foreman's meetings

4. architects representative, usually 2 representatives from the owner, on occasion upper management from our firm, prime contractors (we use multiple prime method)
5. yes, separate coordination meetings were held as we approached turnover.
6. yes - we stuck to the plan we introduced in the early stages of the project
7. so that we satisfy the client and we get out as soon as possible to avoid loss profits

Mr. Brendan Baloh – The Whiting-Turner Contracting Co.

1. 2 Supers, 1 Field Engineer, 2 Project Engineers, 1 Project Manager (This is what I am currently running & is planned for the end of the project. This greatly depends on the size of the project and the complexity. The job I gave you this information is for a $29 million dollar project.)
2. Yes
3. Foreman's Meeting Weekly, Project Manager's Meeting once a Month, OAC meetings every 2 weeks.
4. Foreman's Meeting-Foreman currently working on site and 2 weeks in advance of starting work. Project Manager's Meeting-Project Managers for all subcontractor's on the project. OAC Meeting-Owner, Architect, Owner's Rep, and us.
5. No. We are remotely involved with meetings that the Marketing Department have with the new residents of the apartment units for Upgrades & Customization.
6. On past projects it has as well as could be expected
7. The project manager is responsible for this planning with guidelines/Lessons Learned from past projects. This is very directly related to the type of work and schedule.

Mr. Brian Conner – Saddleback Development Corporation

1. 1 Super, 1 PM.
2. Yes.
3. 2 wks at beginning, then as structure went up, we went to weekly meetings.
4. Occasionally we added consultants and Operations teams as subject matter warranted their attendance.

5. With people from the user's team who were going to operate the building (no tenants for our projects).

6. It was done pretty close to the anticipated method.

7. We try to establish a consistent approach to closeout. Kind of a check list mentality. Things can get a little pushed at the end, when projects need to open, so sometimes close-out activities get a little re-arranged, or they get done incrementally as systems get completed (as opposed to one single close-out period)

I think close-out is extremely important and I don't like it when personnel changes at this critical time. Contractors should start to "pride themselves" and market themselves as close-out specialist (meaning they really care about it, have systems for it and do it better than anyone else). They may get more jobs out of it. Owners and Architects, who have gone through poor close-outs don't want to go through it again. The relationships can go bad in a hurry.

Mr. Bob Grottenthaler – Barton Malow

1. Four superintendents, two project managers, and three project engineers on a $100 million Dental School for the University of Maryland in Baltimore.

2. The staff stayed the same up to when the project reached substantial completion. Then only one superintendent stayed on to complete punchlist work. One Project Manager stayed on to complete close-out. We brought on another Project Manager three months before close-out started to assist the original team get ready for close-out.

3. Weekly meetings with our superintendents and the subcontractors' foremen. Bi-weekly meetings with the subcontractors' project managers and Bi-weekly meetings with the Owner and Architect.

4. Our close-out meetings involved the Owner and they were held once a month towards the end of the project. We dealt with the subcontractors on an individual basis because they closed-out at different stages.

5-6. Yes, close-out is a very important phase of the project that must be planned early and conveyed to the subcontractors at the start of the project.

7. Most projects involve different Owners and Architects who have different requirements for close-out. Meetings should be held during the preconstruction phase to discuss what the requirements are for close-out and these requirements need to be stated in the bidding documents with the subcontractors. These requirements need to be discussed at the Preconstruction conference with the subcontractors so that they know to start planning for close-out early in the project.

Appendix 2

Exterior Closure Take Off

Concrete Block			
Split faced concrete block		Painted concrete block	
Size	S.F.	Size	S.F.
12" x 8" x 16"	392	12" x 8" x 16"	1600
12" x 8" x 16"	128	12" x 8" x 16"	1260
12" x 8" x 16"	48	12" x 8" x 16"	384
12" x 8" x 16"	224	12" x 8" x 16"	320
12" x 8" x 16"	528	12" x 8" x 16"	400
12" x 8" x 16"	204	12" x 8" x 16"	640
12" x 8" x 16"	384	12" x 8" x 16"	608
12" x 8" x 16"	152	12" x 8" x 16"	352
12" x 8" x 16"	540	12" x 8" x 16"	720
12" x 8" x 16"	1080	12" x 8" x 16"	320
12" x 8" x 16"	100	12" x 8" x 16"	1600
12" x 8" x 16"	48	12" x 8" x 16"	2088
12" x 8" x 16"	280	12" x 8" x 16"	304
12" x 8" x 16"	280	12" x 8" x 16"	640
		12" x 8" x 16"	1008
		12" x 8" x 16"	960
		12" x 8" x 16"	736
		12" x 8" x 16"	5500
		12" x 8" x 16"	1464
		12" x 8" x 16"	1488
		12" x 8" x 16"	1920
Sum	4388		24312
		subtract doors	24(3'x7')
Total	8208		23808

Reinforcing bar weight

Bar No.	Nominal Weight (lb/ft)	Area (S.F.)	Side Length	At 48" on center	Linear Footage	Weight in lbs	Weight in ton
6	1.502	23808	154.2984122	38.57	5,952.00	8,939.90	4.47

Bar No.	Nominal Weight (lb/ft)	Area (S.F.)	Side Length	At 16" on center	Linear Footage	Weight in lbs	Weight in ton
4	0.668	23808	154.2984122	115.7238091	17,856.00	11,927.81	5.96

Appendix 3

STANDARD LOAD TABLE

OPEN WEB STEEL JOISTS, K-SERIES

Based on a Maximum Allowable Tensile Stress of 30,000 psi

Adopted by the Steel Joist Institute November 4, 1985; Revised to May 2, 1994 - Effective September 1, 1994

The black figures in the following table give the TOTAL safe uniformly distributed load-carrying capacities, in pounds per linear foot, of K-Series Steel Joists. The weight of DEAD loads, including the joists, must be deducted to determine the LIVE load-carrying capacities of the joists. The load table may be used for parallel chord joists installed to a maximum slope of 1/2 inch per foot.

The figures shown in RED in this load table are the LIVE loads per linear foot of joist which will produce an approximate deflection of 1/360 of the span. LIVE loads which will produce a deflection of 1/240 of the span may be obtained by multiplying the figures in RED by 1.5. In no case shall the TOTAL load capacity of the joists be exceeded.

The approximate joist weights per linear foot shown in these tables do not include accessories.

The approximate moment of inertia of the joist, in 4 inches is: $I_j = 26.767(W_{LL})(L^3)(10^{-6})$, where W_{LL} = RED figure in the Load Table and L = (Span - .33) in feet.

For the proper handling of concentrated and/or varying loads, see Section 5.5 in the Recommended Code of Standard Practice.

Where the joist span is equal to or greater than the span corresponding to the RED shaded area shown in the load table, the row of bridging nearest the mid span of the joist shall be installed as bolted diagonal bridging. Hoisting cables shall not be released until this bolted diagonal bridging is completed installed.

JOIST DESIGNATION	8K1	10K1	12K1	12K3	12K5	14K1	14K3	14K4	14K6	16K2	16K3	16K4	16K5	16K6	16K7	16K9
DEPTH (IN.)	8	10	12	12	12	14	14	14	14	16	16	16	16	16	16	16
APPROX. WT. (lbs./ft.)	5.1	5.0	5.0	5.7	7.1	5.2	6.0	6.7	7.7	5.5	6.3	7.0	7.5	8.1	8.6	10.0
SPAN (ft.)																
8	550															
	550															
9	550															
	550															
10	550	550														
	480	550														
11	532	550														
	377	542														
12	444	550	550	550	550											
	288	455	550	550	550											
13	377	479	550	550	550											
	225	363	510	510	510											
14	324	412	500	550	550	550	550	550	550							
	179	289	425	463	463	550	550	550	550							
15	281	358	434	543	550	511	550	550	550							
	145	234	344	428	434	475	507	507	507							
16	246	313	380	476	550	448	550	550	550	550	550	550	550	550	550	550
	119	192	282	351	396	390	467	467	467	550	550	550	550	550	550	550
17		277	336	420	550	395	495	550	550	512	550	550	550	550	550	550
		159	234	291	366	324	404	443	443	488	526	526	526	526	526	526
18		246	299	374	507	352	441	530	550	456	508	550	550	550	550	550
		134	197	245	317	272	339	397	408	409	456	490	490	490	490	490
19		221	268	335	454	315	395	475	550	408	455	547	550	550	550	550
		113	167	207	269	230	287	336	383	347	386	452	455	455	455	455
20		199	241	302	409	284	356	428	525	368	410	493	550	550	550	550
		97	142	177	230	197	246	287	347	297	330	386	426	426	426	426
21			218	273	370	257	322	388	475	333	371	447	503	548	550	550
			123	153	198	170	212	248	299	255	285	333	373	405	406	406
22			199	249	337	234	293	353	432	303	337	406	458	498	550	550
			106	132	172	147	184	215	259	222	247	289	323	351	385	385
23			181	227	308	214	268	322	395	277	308	371	418	455	507	550
			93	116	150	128	160	188	226	194	216	252	282	307	339	363
24			166	208	282	196	245	295	362	254	283	340	384	418	465	550
			81	101	132	113	141	165	199	170	189	221	248	269	298	346
25						180	226	272	334	234	260	313	353	384	428	514
						100	124	145	175	150	167	195	219	238	263	311
26						166	209	251	308	216	240	289	326	355	395	474
						88	110	129	156	133	148	173	194	211	233	276
27						154	193	233	285	200	223	268	302	329	366	439
						79	98	115	139	119	132	155	173	188	208	246
28						143	180	216	265	186	207	249	281	306	340	408
						70	88	103	124	106	118	138	155	168	186	220
29										173	193	232	261	285	317	380
										95	106	124	139	151	167	198
30										161	180	216	244	266	296	355
										86	96	112	126	137	151	178
31										151	168	203	228	249	277	332
										78	87	101	114	124	137	161
32										142	158	190	214	233	259	311
										71	79	92	103	112	124	147

STANDARD LOAD TABLE / OPEN WEB STEEL JOISTS, K-SERIES

Based on a Maximum Allowable Tensile Stress of 30,000 psi

JOIST DESIGNATION	18K3	18K4	18K5	18K6	18K7	18K9	18K10	20K3	20K4	20K5	20K6	20K7	20K9	20K10	22K4	22K5	22K6	22K7	22K9	22K10	22K11
DEPTH (IN.)	18	18	18	18	18	18	18	20	20	20	20	20	20	20	22	22	22	22	22	22	22
APPROX. WT. (lbs./ft.)	6.6	7.2	7.7	8.5	9.0	10.2	11.7	6.7	7.6	8.2	8.9	9.3	10.8	12.2	8.0	8.8	9.2	9.7	11.3	12.6	13.8
SPAN (ft.)																					
18	550	550	550	550	550	550	550														
	550	550	550	550	550	550	550														
19	514	550	550	550	550	550	550														
	494	523	523	523	523	523	523														
20	463	550	550	550	550	550	550	517	550	550	550	550	550	550							
	423	490	490	490	490	490	490	517	550	550	550	550	550	550							
21	420	506	550	550	550	550	550	468	550	550	550	550	550	550							
	364	426	460	460	460	460	460	453	520	520	520	520	520	520							
22	382	460	518	550	550	550	550	426	514	550	550	550	550	550	550	550	550	550	550	550	550
	316	370	414	438	438	438	438	393	461	490	490	490	490	490	548	548	548	548	548	548	548
23	349	420	473	516	550	550	550	389	469	529	550	550	550	550	518	550	550	550	550	550	550
	276	323	362	393	418	418	418	344	402	451	468	468	468	468	491	518	518	518	518	518	518
24	320	385	434	473	526	550	550	357	430	485	528	550	550	550	475	536	550	550	550	550	550
	242	284	318	345	382	396	396	302	353	396	410	448	448	448	431	483	495	495	495	495	495
25	294	355	400	435	485	550	550	329	396	446	486	541	550	550	438	493	537	550	550	550	550
	214	250	281	305	337	337	337	266	312	350	380	421	426	426	381	427	464	474	474	474	474
26	272	328	369	402	448	538	550	304	366	412	449	500	550	550	404	455	496	550	550	550	550
	190	222	249	271	299	354	361	236	277	310	337	373	405	405	338	379	411	454	454	454	454
27	252	303	342	372	415	498	550	281	339	382	416	463	550	550	374	422	459	512	550	550	550
	169	198	222	241	267	315	347	211	247	277	301	333	389	389	301	337	367	406	432	432	432
28	234	282	318	346	385	463	548	261	315	355	386	430	517	550	348	392	427	475	550	550	550
	151	177	199	216	239	282	331	189	221	248	269	298	353	375	270	302	328	364	413	413	413
29	218	263	296	322	359	431	511	243	293	330	360	401	482	550	324	365	398	443	532	550	550
	136	159	179	194	215	254	298	170	199	223	242	268	317	359	242	272	295	327	387	399	399
30	203	245	276	301	335	402	477	227	274	308	336	374	450	533	302	341	371	413	497	550	550
	123	144	161	175	194	229	269	153	179	201	218	242	286	336	219	245	266	295	349	385	385
31	190	229	258	281	313	376	446	212	256	289	314	350	421	499	283	319	347	387	465	550	550
	111	130	146	158	175	207	243	138	162	182	198	219	259	304	198	222	241	267	316	369	369
32	178	215	242	264	294	353	418	199	240	271	295	328	395	468	265	299	326	363	436	517	549
	101	118	132	144	159	188	221	126	147	165	179	199	235	276	180	201	219	242	287	337	355
33	168	202	228	248	276	332	393	187	226	254	277	309	371	440	249	281	306	341	410	486	532
	92	108	121	131	145	171	201	114	134	150	163	181	214	251	164	183	199	221	261	307	334
34	158	190	214	233	260	312	370	176	212	239	261	290	349	414	235	265	288	321	386	458	516
	84	98	110	120	132	156	184	105	122	137	149	165	195	229	149	167	182	202	239	280	314
35	149	179	202	220	245	294	349	166	200	226	246	274	329	390	221	249	272	303	364	432	494
	77	90	101	110	121	143	168	96	112	126	137	151	179	210	137	153	167	185	219	257	292
36	141	169	191	208	232	278	330	157	189	213	232	259	311	369	209	236	257	286	344	408	467
	70	82	92	101	111	132	154	88	103	115	125	139	164	193	126	141	153	169	201	236	269
37								148	179	202	220	245	294	349	198	223	243	271	325	386	442
								81	95	106	115	128	151	178	116	130	141	156	185	217	247
38								141	170	191	208	232	279	331	187	211	230	256	308	366	419
								74	87	98	106	118	139	164	107	119	130	144	170	200	228
39								133	161	181	198	220	265	314	178	200	218	243	292	347	397
								69	81	90	98	109	129	151	98	110	120	133	157	185	211
* 40								127	153	172	188	209	251	298	169	190	207	231	278	330	377
								64	75	84	91	101	119	140	91	102	111	123	146	171	195
41															161	181	197	220	264	314	359
															85	95	103	114	135	159	181
42															153	173	188	209	252	299	342
															79	83	96	106	126	148	168
43															146	165	179	200	240	285	326
															73	82	89	99	117	138	157
44															139	157	171	191	229	272	311
															68	76	83	92	109	128	146

***IT IS VERY IMPORTANT FOR JOIST SPECIFIERS AND ERECTORS TO KNOW THAT OSHA IS INTERPRETING 29CFR-1926.751(c)2 TO MEAN ALL JOIST FORTY (40) FEET (12192MM) AND LONGER TO REQUIRE A ROW OF BOLTED BRIDGING TO BE IN PLACE BEFORE SLACKENING OF HOIST LINES.**

STANDARD LOAD TABLE / OPEN WEB STEEL JOISTS, K-SERIES

Based on a Maximum Allowable Tensile Stress of 30,000 psi

JOIST DESIGNATION	24K4	24K5	24K6	24K7	24K8	24K9	24K10	24K12	26K5	26K6	26K7	26K8	26K9	26K10	26K12
DEPTH (IN.)	24	24	24	24	24	24	24	24	26	26	26	26	26	26	26
APPROX. WT. (lbs./ft.)	8.4	9.3	9.7	10.1	11.5	12.0	13.1	16.0	9.8	10.6	10.9	12.1	12.2	13.8	16.6
SPAN (ft.)															
24	520	550	550	550	550	550	550	550							
	516	544	544	544	544	544	544	544							
25	479	540	550	550	550	550	550	550							
	456	511	520	520	520	520	520	520							
26	442	499	543	550	550	550	550	550	542	550	550	550	550	550	550
	405	453	493	499	499	499	499	499	535	541	541	541	541	541	541
27	410	462	503	550	550	550	550	550	502	547	550	550	550	550	550
	361	404	439	479	479	479	479	479	477	519	522	522	522	522	522
28	381	429	467	521	550	550	550	550	466	508	550	550	550	550	550
	323	362	393	436	456	456	456	456	427	464	501	501	501	501	501
29	354	400	435	485	536	550	550	550	434	473	527	550	550	550	550
	290	325	354	392	429	436	436	436	384	417	463	479	479	479	479
30	331	373	406	453	500	544	550	550	405	441	492	544	550	550	550
	262	293	319	353	387	419	422	422	346	377	417	457	459	459	459
31	310	349	380	424	468	510	550	550	379	413	460	509	550	550	550
	237	266	289	320	350	379	410	410	314	341	378	413	444	444	444
32	290	327	357	397	439	478	549	549	356	387	432	477	519	549	549
	215	241	262	290	318	344	393	393	285	309	343	375	407	431	431
33	273	308	335	373	413	449	532	532	334	364	406	448	488	532	532
	196	220	239	265	289	313	368	368	259	282	312	342	370	404	404
34	257	290	315	351	388	423	502	516	315	343	382	422	459	516	516
	179	201	218	242	264	286	337	344	237	257	285	312	338	378	378
35	242	273	297	331	366	399	473	501	297	323	360	398	433	501	501
	164	184	200	221	242	262	308	324	217	236	261	286	310	356	356
36	229	258	281	313	346	377	447	487	280	305	340	376	409	486	487
	150	169	183	203	222	241	283	306	199	216	240	263	284	334	334
37	216	244	266	296	327	356	423	474	265	289	322	356	387	460	474
	138	155	169	187	205	222	260	290	183	199	221	242	262	308	315
38	205	231	252	281	310	338	401	461	251	274	305	337	367	436	461
	128	143	156	172	189	204	240	275	169	184	204	223	241	284	299
39	195	219	239	266	294	320	380	449	238	260	289	320	348	413	449
	118	132	144	159	174	189	222	261	156	170	188	206	223	262	283
* 40	185	208	227	253	280	304	361	438	227	247	275	304	331	393	438
	109	122	133	148	161	175	206	247	145	157	174	191	207	243	269
41	176	198	216	241	266	290	344	427	215	235	262	289	315	374	427
	101	114	124	137	150	162	191	235	134	146	162	177	192	225	256
42	168	189	206	229	253	276	327	417	205	224	249	275	300	356	417
	94	106	115	127	139	151	177	224	125	136	150	164	178	210	244
43	160	180	196	219	242	263	312	406	196	213	238	263	286	339	407
	88	98	107	118	130	140	165	213	116	126	140	153	166	195	232
44	153	172	187	209	231	251	298	387	187	204	227	251	273	324	398
	82	92	100	110	121	131	154	199	108	118	131	143	155	182	222
45	146	164	179	199	220	240	285	370	179	194	217	240	261	310	389
	76	86	93	103	113	122	144	185	101	110	122	133	145	170	212
46	139	157	171	191	211	230	272	354	171	186	207	229	250	296	380
	71	80	87	97	106	114	135	174	95	103	114	125	135	159	203
47	133	150	164	183	202	220	261	339	164	178	199	219	239	284	369
	67	75	82	90	99	107	126	163	89	96	107	117	127	149	192
48	128	144	157	175	194	211	250	325	157	171	190	210	229	272	353
	63	70	77	85	93	101	118	153	83	90	100	110	119	140	180
49									150	164	183	202	220	261	339
									78	85	94	103	112	131	169
50									144	157	175	194	211	250	325
									73	80	89	97	105	124	159
51									139	151	168	186	203	241	313
									69	75	83	91	99	116	150
52									133	145	162	179	195	231	301
									65	71	79	86	93	110	142

***IT IS VERY IMPORTANT FOR JOIST SPECIFIERS AND ERECTORS TO KNOW THAT OSHA IS INTERPRETING 29CFR-1926.751(c)2 TO MEAN ALL JOIST FORTY (40) FEET (12192MM) AND LONGER TO REQUIRE A ROW OF BOLTED BRIDGING TO BE IN PLACE BEFORE SLACKENING OF HOIST LINES.**

STANDARD LOAD TABLE / OPEN WEB STEEL JOISTS, K-SERIES

Based on a Maximum Allowable Tensile Stress of 30,000 psi

JOIST DESIGNATION		28K6	28K7	28K8	28K9	28K10	28K12	30K7	30K8	30K9	30K10	30K11	30K12
DEPTH (IN.)		28	28	28	28	28	28	30	30	30	30	30	30
APPROX. WT. (lbs./ft.)		11.4	11.8	12.7	13.0	14.3	17.1	12.3	13.2	13.4	15.0	16.4	17.6
SPAN (ft.) ↓													
28		548	550	550	550	550	550						
		541	543	543	543	543	543						
29		511	550	550	550	550	550						
		486	522	522	522	522	522						
30		477	531	550	550	550	550	550	550	550	550	550	550
		439	486	500	500	500	500	543	543	543	543	543	543
31		446	497	550	550	550	550	534	550	550	550	550	550
		397	440	480	480	480	480	508	520	520	520	520	520
32		418	466	515	549	549	549	501	549	549	549	549	549
		397	440	438	463	463	463	461	500	500	500	500	500
33		393	438	484	527	532	532	471	520	532	532	532	532
		329	364	399	432	435	435	420	460	468	468	468	468
34		370	412	456	496	516	516	443	490	516	516	516	516
		300	333	364	395	410	410	384	420	441	441	441	441
35		349	389	430	468	501	501	418	462	501	501	501	501
		275	305	333	361	389	389	351	384	415	415	415	415
36		330	367	406	442	487	487	395	436	475	487	487	487
		352	280	306	332	366	366	323	353	383	392	392	392
37		312	348	384	418	474	474	373	413	449	474	474	474
		232	257	282	305	344	344	297	325	352	374	374	374
38		296	329	364	396	461	461	354	391	426	461	461	461
		214	237	260	282	325	325	274	300	325	353	353	353
39		280	313	346	376	447	449	336	371	404	449	449	449
*		198	219	240	260	306	308	253	277	300	333	333	333
40		266	297	328	357	424	438	319	353	384	438	438	438
		183	203	222	241	284	291	234	256	278	315	315	315
41		253	283	312	340	404	427	303	335	365	427	427	427
		170	189	206	224	263	277	217	238	258	300	300	300
42		241	269	297	324	384	417	289	320	348	413	417	417
		158	175	192	208	245	264	202	221	240	282	284	284
43		230	257	284	309	367	407	276	305	332	394	407	407
		147	163	179	194	228	252	188	206	223	263	270	270
44		220	245	271	295	350	398	263	291	317	376	398	398
		137	152	167	181	212	240	176	192	208	245	258	258
45		210	234	259	282	334	389	251	278	303	359	389	389
		128	142	156	169	198	229	164	179	195	229	246	246
46		201	224	248	270	320	380	241	266	290	344	380	380
		120	133	146	158	186	219	153	168	182	214	236	236
47		192	214	237	258	306	372	230	255	277	329	372	372
		112	125	136	148	174	210	144	157	171	201	226	226
48		184	206	227	247	294	365	221	244	266	315	362	365
		105	117	128	139	163	201	135	148	160	188	215	216
49		177	197	218	237	282	357	212	234	255	303	347	357
		99	110	120	130	153	193	127	139	150	177	202	207
50		170	189	209	228	270	350	203	225	245	291	333	350
		93	103	113	123	144	185	119	130	141	166	190	199
51		163	182	201	219	260	338	195	216	235	279	320	343
		88	97	106	115	136	175	112	123	133	157	179	192
52		157	175	193	210	250	325	188	208	226	268	308	336
		83	92	100	109	128	165	106	116	126	148	169	184
53		151	168	186	203	240	313	181	200	218	258	296	330
		78	87	95	103	121	156	100	109	119	140	159	177
54		145	162	179	195	232	301	174	192	209	249	285	324
		74	82	89	97	114	147	94	103	112	132	150	170
55		140	156	173	188	223	290	168	185	202	240	275	312
		70	77	85	92	108	139	89	98	106	125	142	161
56		135	151	166	181	215	280	162	179	195	231	265	301
		66	73	80	87	102	132	84	92	100	118	135	153
57								156	173	188	223	256	290
								80	88	95	112	128	145
58								151	167	181	215	247	280
								76	83	90	106	121	137
59								146	161	175	208	239	271
								72	79	86	101	115	130
60								141	156	169	201	231	262
								69	75	81	96	109	124

***IT IS VERY IMPORTANT FOR JOIST SPECIFIERS AND ERECTORS TO KNOW THAT OSHA IS INTERPRETING 29CFR-1926.751(c)2 TO MEAN ALL JOIST FORTY (40) FEET (12192MM) AND LONGER TO REQUIRE A ROW OF BOLTED BRIDGING TO BE IN PLACE BEFORE SLACKENING OF HOIST LINES.**

R157-100 Sheet Metal Calculator (Weight in Lb./Ft. of Length)

Gauge	26	24	22	20	18	16	Gauge	26	24	22	20	18	16
Wt.-Lb./S.F.	.906	1.156	1.406	1.656	2.156	2.656	Wt.-Lb./S.F.	.906	1.156	1.406	1.656	2.156	2.656
SMACNA Max. Dimension – Long Side		30"	54"	84"	85" Up		SMACNA Max. Dimension – Long Side		30"	54"	84"	85" Up	
Sum-2 sides							Sum-2 Sides						
2	.3	.40	.50	.60	.80	.90	56	9.3	12.0	14.0	16.2	21.3	25.2
3	.5	.65	.80	.90	1.1	1.4	57	9.5	12.3	14.3	16.5	21.7	25.7
4	.7	.85	1.0	1.2	1.5	1.8	58	9.7	12.5	14.5	16.8	22.0	26.1
5	.8	1.1	1.3	1.5	1.9	2.3	59	9.8	12.7	14.8	17.1	22.4	26.6
6	1.0	1.3	1.5	1.7	2.3	2.7	60	10.0	12.9	15.0	17.4	22.8	27.0
7	1.2	1.5	1.8	2.0	2.7	3.2	61	10.2	13.1	15.3	17.7	23.2	27.5
8	1.3	1.7	2.0	2.3	3.0	3.6	62	10.3	13.3	15.5	18.0	23.6	27.9
9	1.5	1.9	2.3	2.6	3.4	4.1	63	10.5	13.5	15.8	18.3	24.0	28.4
10	1.7	2.2	2.5	2.9	3.8	4.5	64	10.7	13.7	16.0	18.6	24.3	28.8
11	1.8	2.4	2.8	3.2	4.2	5.0	65	10.8	13.9	16.3	18.9	24.7	29.3
12	2.0	2.6	3.0	3.5	4.6	5.4	66	11.0	14.1	16.5	19.1	25.1	29.7
13	2.2	2.8	3.3	3.8	4.9	5.9	67	11.2	14.3	16.8	19.4	25.5	30.2
14	2.3	3.0	3.5	4.1	5.3	6.3	68	11.3	14.6	17.0	19.7	25.8	30.6
15	2.5	3.2	3.8	4.4	5.7	6.8	69	11.5	14.8	17.3	20.0	26.2	31.1
16	2.7	3.4	4.0	4.6	6.1	7.2	70	11.7	15.0	17.5	20.3	26.6	31.5
17	2.8	3.7	4.3	4.9	6.5	7.7	71	11.8	15.2	17.8	20.6	27.0	32.0
18	3.0	3.9	4.5	5.2	6.8	8.1	72	12.0	15.4	18.0	20.9	27.4	32.4
19	3.2	4.1	4.8	5.5	7.2	8.6	73	12.2	15.6	18.3	21.2	27.7	32.9
20	3.3	4.3	5.0	5.8	7.6	9.0	74	12.3	15.8	18.5	21.5	28.1	33.3
21	3.5	4.5	5.3	6.1	8.0	9.5	75	12.5	16.1	18.8	21.8	28.5	33.8
22	3.7	4.7	5.5	6.4	8.4	9.9	76	12.7	16.3	19.0	22.0	28.9	34.2
23	3.8	5.0	5.8	6.7	8.7	10.4	77	12.8	16.5	19.3	22.3	29.3	34.7
24	4.0	5.2	6.0	7.0	9.1	10.8	78	13.0	16.7	19.5	22.6	29.6	35.1
25	4.2	5.4	6.3	7.3	9.5	11.3	79	13.2	16.9	19.8	22.9	30.0	35.6
26	4.3	5.6	6.5	7.5	9.9	11.7	80	13.3	17.1	20.0	23.2	30.4	36.0
27	4.5	5.8	6.8	7.8	10.3	12.2	81	13.5	17.3	20.3	23.5	30.8	36.5
28	4.7	6.0	7.0	8.1	10.6	12.6	82	13.7	17.5	20.5	23.8	31.2	36.9
29	4.8	6.2	7.3	8.4	11.0	13.1	83	13.8	17.8	20.8	24.1	31.5	37.4
30	5.0	6.5	7.5	8.7	11.4	13.5	84	14.0	18.0	21.0	24.4	31.9	37.8
31	5.2	6.7	7.8	9.0	11.8	14.0	85	14.2	18.2	21.3	24.7	32.3	38.3
32	5.3	6.9	8.0	9.3	12.2	14.4	86	14.3	18.4	21.5	24.9	32.7	38.7
33	5.5	7.1	8.3	9.6	12.5	14.9	87	14.5	18.6	21.8	25.2	33.1	39.2
34	5.7	7.3	8.5	9.9	12.9	15.3	88	14.7	18.8	22.0	25.5	33.4	39.6
35	5.8	7.5	8.8	10.2	13.3	15.8	89	14.8	19.0	22.3	25.8	33.8	40.1
36	6.0	7.8	9.0	10.4	13.7	16.2	90	15.0	19.3	22.5	26.1	34.2	40.5
37	6.2	8.0	9.3	10.7	14.1	16.7	91	15.2	19.5	22.8	26.4	34.6	41.0
38	6.3	8.2	9.5	11.0	14.4	17.1	92	15.3	19.7	23.0	26.7	35.0	41.4
39	6.5	8.4	9.8	11.3	14.8	17.6	93	15.5	19.9	23.3	27.0	35.3	41.9
40	6.7	8.6	10.0	11.6	15.2	18.0	94	15.7	20.1	23.5	27.3	35.7	42.3
41	6.8	8.8	10.3	11.9	15.6	18.5	95	15.8	20.3	23.8	27.6	36.1	42.8
42	7.0	9.0	10.5	12.2	16.0	18.9	96	16.0	20.5	24.0	27.8	36.5	43.2
43	7.2	9.2	10.8	12.5	16.3	19.4	97	16.2	20.8	24.3	28.1	36.9	43.7
44	7.3	9.5	11.0	12.8	16.7	19.8	98	16.3	21.0	24.5	28.4	37.2	44.1
45	7.5	9.7	11.3	13.1	17.1	20.3	99	16.5	21.2	24.8	28.7	37.6	44.6
46	7.7	9.9	11.5	13.3	17.5	20.7	100	16.7	21.4	25.0	29.0	38.0	45.0
47	7.8	10.1	11.8	13.6	17.9	21.2	101	16.8	21.6	25.3	29.3	38.4	45.5
48	8.0	10.3	12.0	13.9	18.2	21.6	102	17.0	21.8	25.5	29.6	38.8	45.9
49	8.2	10.5	12.3	14.2	18.6	22.1	103	17.2	22.0	25.8	29.9	39.1	46.4
50	8.3	10.7	12.5	14.5	19.0	22.5	104	17.3	22.3	26.0	30.2	39.5	46.8
51	8.5	11.0	12.8	14.8	19.4	23.0	105	17.5	22.5	26.3	30.5	39.9	47.3
52	8.7	11.2	13.0	15.1	19.8	23.4	106	17.7	22.7	26.5	30.7	40.3	47.7
53	8.8	11.4	13.3	15.4	20.1	23.9	107	17.8	22.9	26.8	31.0	40.7	48.2
54	9.0	11.6	13.5	15.7	20.5	24.3	108	18.0	23.1	27.0	31.3	41.0	48.6
55	9.2	11.8	13.8	16.0	20.9	24.8	109	18.2	23.3	27.3	31.6	41.4	49.1
							110	18.3	23.5	27.5	31.9	41.8	49.5

Example: If duct is 34" x 20" x 15' long, 34" is greater than 30" maximum, for 24 ga. so must be 22 ga. 34" + 20" = 54" going across from 54" find 13.5 lb. per foot. 13.5 x 15' = 202.5 lbs. For S.F. of surface area 202.5 ÷ 1.406 = 144 S.F.
Note: Figures include an allowance for scrap.