DORMITORY BUILDINGS C & D

MANSFIELD UNIVERSITY, MANSFIELD PA

SENIOR THESIS FINAL REPORT

APRIL 3, 2013

MIKE MAHONEY

The Pennsylvania State University
Department of Architectural Engineering
Construction Management Option

AE482 – Spring 2012
Faculty Advisor: Ray Sowers

Mansfield University Dormitories

Buildings C and D | Mansfield, PA

Mike Mahoney | Construction

FEATURES

Size: Building C: 79,500 SF	Delivery: GMP Contract
Building D: 135,400 SF	Stories: 4 Stories
Cost: $39 Million	Height: 58.5 FT

MECHANICAL

- 13 - 3,000 CFM Energy Recovery Units
- 2 - Geothermal Well Fields
- 2 - Water-to-Air Water Source Heat Pumps

ELECTRICAL

- 34.5kV 208Y/120V Oil Filled Transformer
- 2 - 208Y/120V Natural Gas Generators
- Primary Lighting - Energy Efficient T5 Bulbs

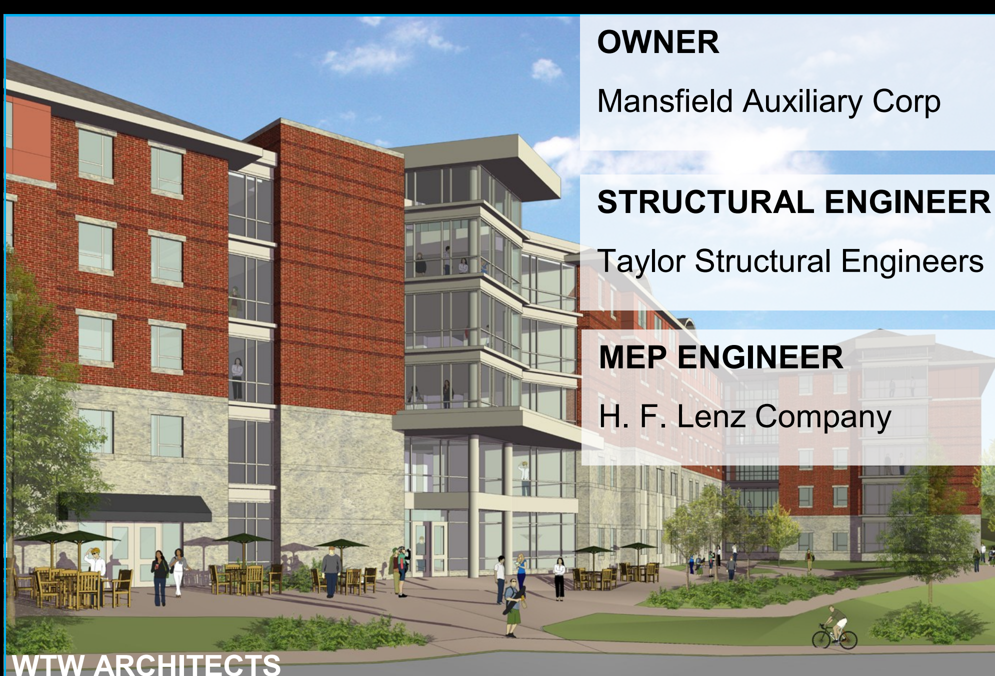
STRUCTURAL

- Concrete Strip Footers and Slab on Grade
- Structural CMU Block Ground and 1st Floor
- Structural Wood Units on Floors 2-4
- Steel Framing in Core Areas
- Dimensional Lumber Supported Flooring

ARCHITECTURE

- Both Buildings Will Hold Over 750 Students
- Provides Suite-Style Student Living Options
- Brick Façade to Match Campus Style
- Modular Unit Construction Increases Speed
- Design-Build MEP Subcontractors

WTW ARCHITECTS



OWNER

Mansfield Auxiliary Corp

STRUCTURAL ENGINEER

Taylor Structural Engineers

MEP ENGINEER

H. F. Lenz Company

ARCHITECT

WTW Architects

LANDSCAPE ARCHITECT

LaQUATRA BONCI Assoc.

GENERAL CONTRACTOR

Wohlsen Construction

Wohlsen works.

http://www.engr.psu.edu/ae/thesis/portfolios/2013/mdm5274/index.html

EXECUTIVE SUMMARY

The Senior Thesis Final Report is the compilation of four individual analyses. These analyses emphasize critical industry issues, value engineering, constructability and schedule reduction of the construction process for the Mansfield University dormitory project. In addition to these construction process analyses, there are structural and acoustic breadth topics reviewed to further investigation into the four individual analyses.

Analysis 1: Flooring System Analysis

An alternative flooring system to the current structural steel and wood was investigated. A 10 inch thick concrete flat plate system was checked during the structural breadth to meet all of the design loads. The acoustical breadth showed that the concrete floor stops the sound transmission about 14 dB better than the steel and wood flooring. Costs estimates were configured using RS Means. The concrete system was estimated to cost $401,974.50. The steel and wood system was estimated to cost $484,358.08. There is an about a $82,000 difference. Other factors that influence the constructability of the concrete system is the availability of large concrete subcontractors in the north central Pennsylvania area and the cold winters of the area. The steel and wood system was found to be easier to construct given the these factors.

Analysis 2: Modularization Preconstruction Planning

After a schedule was created for the stick built construction, the difference between the stick built construction and the modular construction was 82 days or 4 months. For those 4 months, the general conditions savings was estimated at $680,000. The owner saved 4 months of general conditions costs, but also paid for 4 months of preconstruction fees.

During preconstruction, BIM would have increased productivity for the MEP rough ins during the first set of modular units, and created a great starting point for the 3D modeling for the onsite MEP subcontractors. BIM would not have been as effective for the modular MEP crews after the first set of units were completed though, because the units are extremely repetitive. Also, the modular MEP crews work for the same company which promotes better coordination. Most issues that would arise out in the field are easier and faster to fix when building in a factory.

Analysis 3: Exterior Façade Redesign

There was an investigation into a panelized façade system instead of the traditional masonry façade. The owner's expectations influenced the investigation into a thin brick panelized façade and a precast concrete panel system. After cost estimates were completed, the thin brick panels cost about $926,154.06 more than the masonry brick, and the precast concrete system costs $193,928.80 more than the masonry cast stone, with a total difference of $1.12 million dollars more for the panelized façade systems. The schedule showed that the panelized systems reduced the schedule by 60 days in Building C and 89 days in Building D. The owner's expectations made the panelized façade system impossible to have a similar price.

Analysis 4: Modular Unit Connection Procedure

A GPS system similar to the one that dozers use to grade terrain was investigated to see its possible uses during the modular unit setting. After seeing how the modular subcontractor ensured precision, the GPS positioning system would really be helpful, when setting the very first column of units. After the first column, the system would not be needed, because the crew can use the previously set units as a reference. The extreme precision in the factory really made it easy for the crew in the field to set the units. When evaluating the GPS positioning system, the extra value of precision was compared to the cost of over $14,000.

CONTENTS

PROJECT INFORMATION

The following report is based on the construction process of the two dormitory buildings located on the southwest corner of Mansfield University's campus. Both buildings consist of 4 floors above grade with a partial basement level. Building C is approximately 79,500 square feet, and Building D is approximately 135,400 square feet.

Building D has the same layout as Building C, with an added wing, see Figure 1. Both buildings provide suite-style student living options for just under 700 students. The suite-style rooms include private bathrooms, individual bedrooms and a living area. These buildings also contain recreational, laundry, lounge, kitchen, and study spaces on each floor. The ground floor of Building D has a snack shack and health center.

According to their Mansfield's department of geography and geology website, Mansfield University has seen growth in recent years due to the increase in natural gas exploration in northern Pennsylvania. Mansfield University has added programs that supply these new businesses with educated employees. They now have a natural gas production and services bachelor's degree (mansfield). The increase in students has caused a strain on on-campus housing. This pushed the Board of Trustees to start analyzing possible solutions. According to Cheryl Clarke of the Sun Gazette, at the current project site there were dormitory buildings that were unsuitable for student use because of their decrepit status. They sat there unused for years. The Board of Trustees decided to demolish the existing buildings and create two new dormitories (sungazette).

Building C is situated north of Morris Dr. and Building D is just south. Equipment cannot travel across Morris Dr. during peak traffic hours. Clinton St. is the main road marking the west end of the campus. Most of the utilities needed for the project are located underneath Clinton St. This project is the second phase of a completely new dormitory rejuvenation movement on Mansfield's campus. The first phase of dormitories was constructed in 2011 located 100 yards east of Building D. They both have a similar layout to Building C. The town is located in the north central region of Pennsylvania. This area is known for harsh winters. The construction schedule must be created around the weather. Most of the earthwork, will be completed during this time. Foundations and basement walls were constructed during the better weathered days. There were several snow storms that delayed the progress a few days.

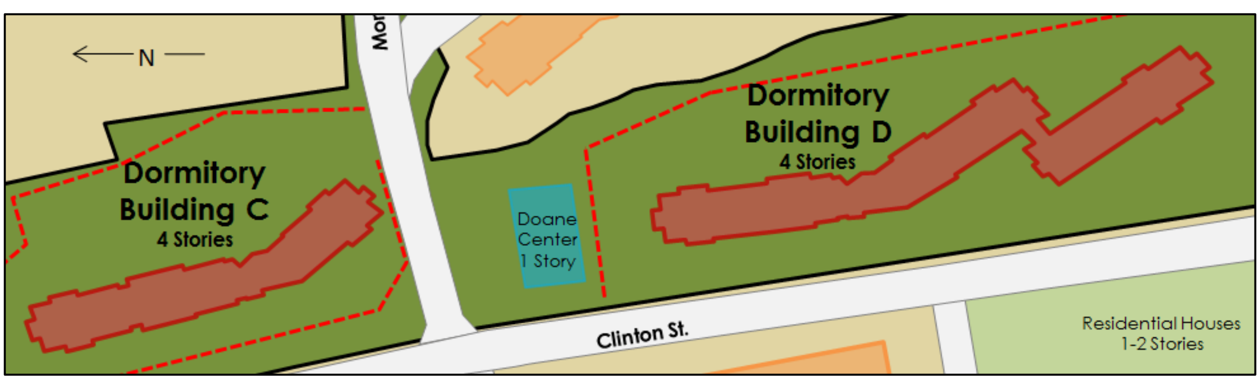


Figure 1 Site Plan

For this phase of dormitory construction, the owner decided to implement modular construction to speed up the construction schedule. Modular units can be placed as fast as 12 units per day. The Phase 1 dormitories were completely stick built. The owner made it clear that he wanted the architecture of these dormitories to match the architecture of the other buildings on campus. A brick and cast stone masonry façade was used for most of the exterior. In the central core area, a glass curtain façade was used. The core area is the only part of these buildings that are stick built.

Figure 2 Modular Unit

On August 16, 2012, the Mansfield Auxiliary Corp. awarded the Phase 2 dormitory project to Wohlsen Construction Company. The contract was a GMP valued at $39 million. Initially, the project was bid at $41 million. The owner asked the CM to perform value engineering. Eventually, they got the project cost down $2 million, and the owner received the needed financing to start the project. Wohlsen Construction would take the role of Construction Manager at risk. There was a savings sharing that awarded 20% of savings to the CM. The liquidated damages for finishing the job late are $65 per a bed per a day. So that equals $16,640/day for Building C and $27,690/day for Building D.

Wohlsen holds lump sum contracts with all of the subcontractors except for the mechanical/plumbing, electrical and fire protection (MEP) subcontractors. The MEP's hold design-build contracts with the CM, because at the time of bidding, there wasn't a complete set of MEP design documents for the modular units. Building C's substantial completion date was scheduled for August 5, 2013, and Building D's was set at October 17, 2013.

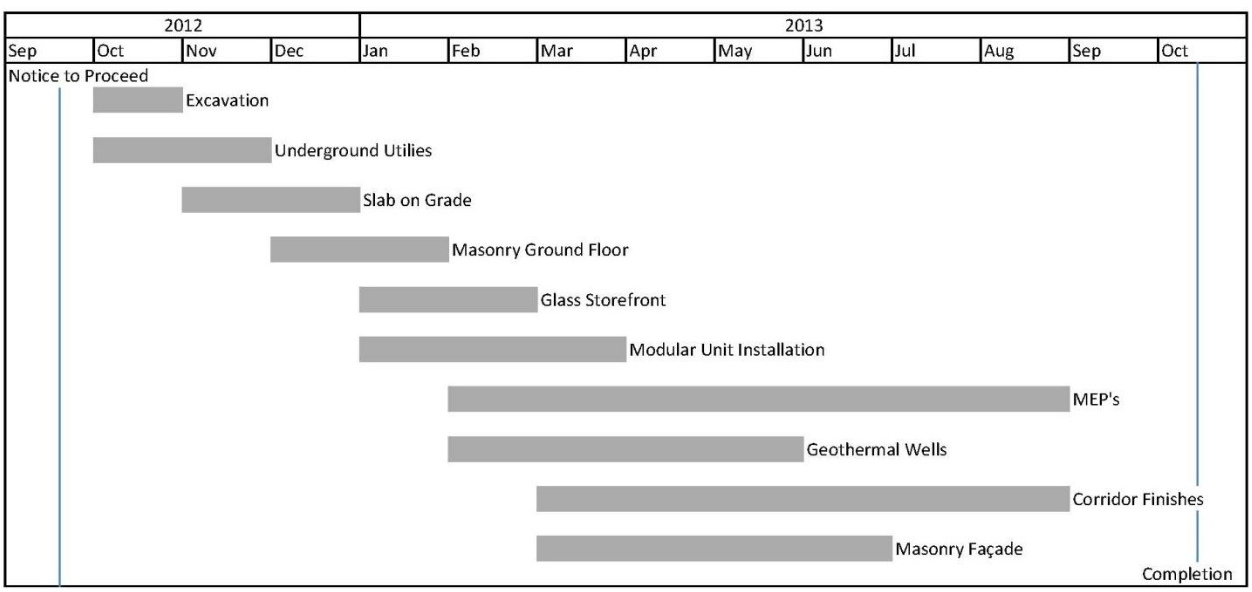


Figure 3 Total Building Schedule

Because Building C's completion date was earlier than Building D's, excavation started on Building C's site first. During excavation of Building D's site, there was poor quality soil and debris unearthed. The demolition contractor that took down the buildings that stood on the site before construction started, filled in the site with building debris and unsuitable soil. More time was spent cleaning out all of the bad material than previously expected. This created a 2 month delay that caused the start of modular unit placement to shift to the middle of Feburary. The Construction Manager began to look for accelleration techniques. The most effective technique was shift work for the MEP sub contractors.

The owner expects construction to cause as little disturbance to all university activities as possible. While students are on campus, construction cannot start before 7:00 AM. During university breaks, there are no restrictions on construction work hours. Driveways, footpaths and entrances adjacent to the site cannot be blocked at any time. Deliveries are expected to be scheduled so they do not interfere with regular university traffic. The contractor must give a two week notice before interrupting any services to existing buildings. The entire site is to be fenced in with a locked gate when no one is working.

BUILDING SYSTEMS OVERVIEW

STRUCTURAL STEEL

Structural steel is used mostly on the first floor and the core spaces of these buildings. Figure 4 shows the structural drawing for core area of the second floor of Building C. Most of these buildings are modular units. The modular units are created to structurally support themselves. The core is the only part that is not modular. The structural steel used in the core space is W10, W12 and W14 girders with HSS 6x6 steel columns. The girders range from 15 lbs/ft to 53 lbs/ft. All girder to beam connections are shear with optional moment reinforcement. All girder to column connections are welded-moment.

On the basement and first floor, structural steel columns and girders are used to provide additional support the modular units. HSS columns used were similar to the core space, but the girders are bigger. The girders range from W14 to W18. The weight ranges from 40 lbs/ft to 67 lbs/ft.

A separate, smaller, crane from the one used for the modular units will be used to erect the steel. The crawler crane was mostly set at the inside of the angle of the core area.

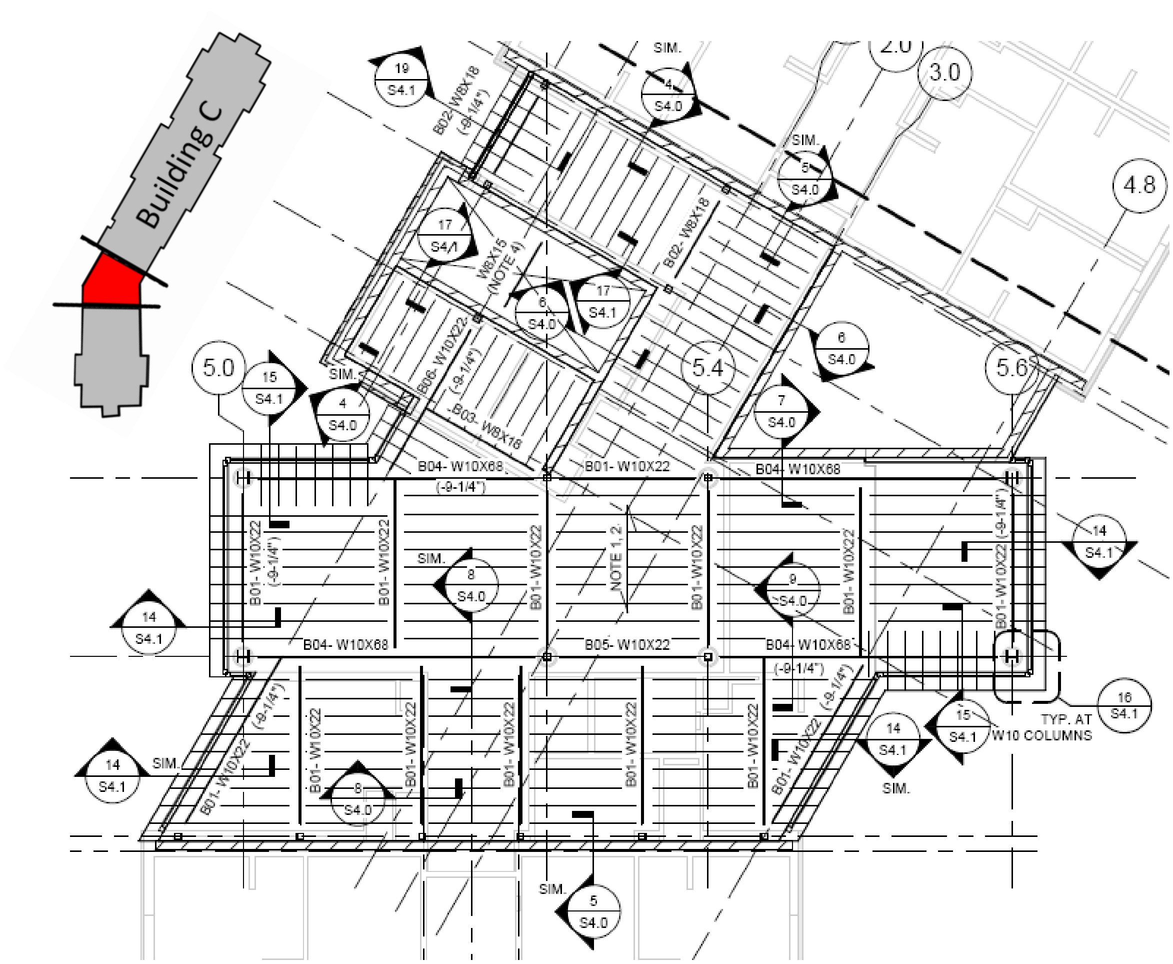


Figure 4 Building C Steel Core

Details from Sheets S1.3C - Architectural Plans – WTW Architects

MASONRY

Masonry block is used in these buildings mostly as a 2 hour fire rating around stairwells and elevators. There are three stairwells and two elevators. Also, CMU walls are in between the core spaces and the modular units. The block used in these walls is typically 16" x 8". Temporary scaffolding will be used to construct these walls.

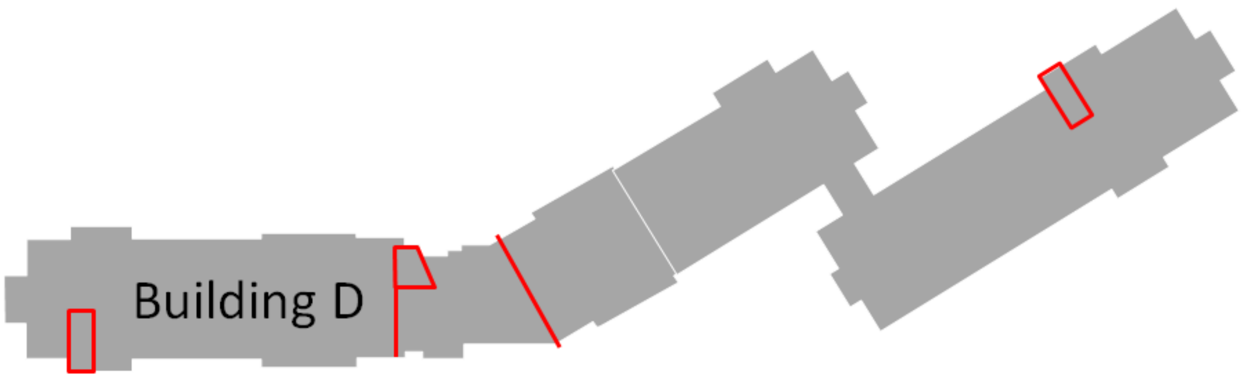


Figure 5 CMU Stairwells/Partitions Building D

CMU walls are used as the exterior walls on the basement level of the buildings. The CMU below grade are 14" thick typically. Once above grade, the block is typically 10" because of the façade. The walls connect to the spread footings with grouted rebar as shown below. The exterior façade of the top three floors of the buildings is mostly brick veneer. The basement and first floor exterior facade is masonry stone block. There are precast stone heads and sills around the windows. Behind the brick and precast stone are the modular units above the basement. The masonry facade ties into the modular units' sheathing which will help support the block. Metal lintels are used around window openings. A scaffolding structure will be built to complete the exterior façade.

CAST-IN-PLACE CONCRETE

Because the buildings are built on a hill, the basement level is only under a portion of the first floor. Some of the first floor sits on grade. A building footer will be poured under the basement level and parts of the first floor. This will provide support for the structural masonry block on the exterior of the building up to the second floor. The footer and spread footings are to be designed for a soil bearing pressure of 4000 psf. On both buildings, a 4" concrete slab on grade will be poured on the basement floor and parts of the first. Lumber forms will be used for these flat pours. The foundation has 3000 psi concrete and the slabs have 4000 psi concrete. There are also 24" x 24" rebar reinforced concrete piers. Plywood sheathing with lumber reinforcing will be used for formwork for the piers. These piers are only under the core spaces of the buildings to withstand the support of the structural steel above. The concrete will be poured using a pumping truck with labor to screed.

CURTAIN WALL

In the core areas, there is a glass store front façade. The architect, WTW Architects, is responsible for the design. The mullions are aluminum with a carbon steel reinforcing. The mullions are 2" think and extend out 4.5". The glazing used is insulating glass. It is 1" thick with a 1/2" air gap. The glazing has a low-emissivity coating and allows 62% visible light transmittance.

The metal frame will be constructed after the structural steel in the core is set. The storefront will start at the basement and work its way up. The glass will be set in the frame with two workers on a man lift and one in the building. After the glass is set, the gaskets can be installed and the frame can be finished. Ideally there would be three crews. One would initially install the frame; another would set the glass, and the last would finish the frame and seal the glass.

SUPPORT OF EXCAVATION

Excavation will be used for the basement floor and parts of the first floors on each building. The excavation will be supported by benching. Most of the site has been leveled to the required grade by the demolition contractor. Most of the underground utility work will use trench boxes to excavate. The water table is below the excavation of the buildings, so no dewatering is necessary. The ground source water pump wells will be below the water table. Dewatering will be used for well excavation.

MODULAR UNITS

The modular units are created in a factory located in Scranton, PA. The modular subcontractor, Simplex Inc. creates the structure of each unit, MEP rough ins, and completes most of the finishes on the interior. The hallway between the two rooms was not completed with interiors, because the MEP contractors still needed to connect the room MEP feeds to the mains located down the hall. It takes Simplex 10 days to create one unit in assembly line fashion. The modular units' structure is dimensional lumber. There are 2x6 wall studs with a double 2x10 perimeter sill plate at the bottom and top to create added strength during transportation.

Figure 6 CMU Modular Unit Structure

Figure 7 CMU Modular Unit MEP Rough

TECHNICAL ANALYSIS DESCRIPTIONS

ANALYSIS 1: CORE FLOORING SYSTEM ANALYSIS

INTRODUCTION

The current structural design has a 2x10 wood joist floor with plywood sheathing flooring in the core area of both buildings. The core also has a structural steel frame to support the flooring system. This type of structure and flooring is an unconventional pairing. Particularly, the steel beam connection with the wood 2x10 flooring joists is not ideal.

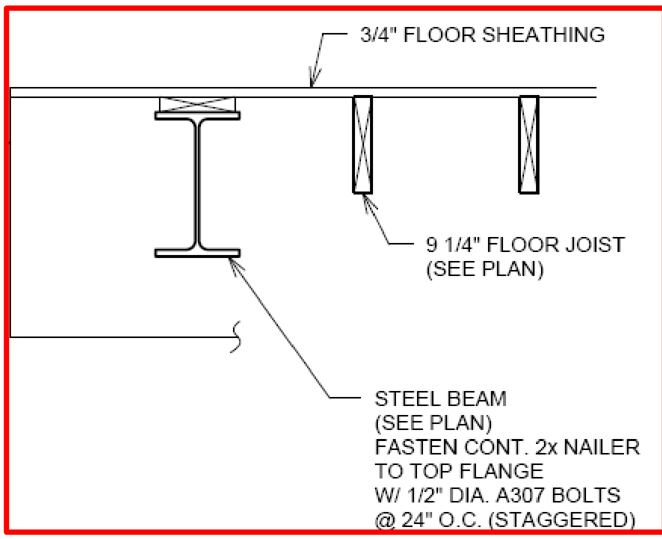


Figure 8 Building C Steel Core
Details from Sheets S4.0 - Architectural Plans – WTW

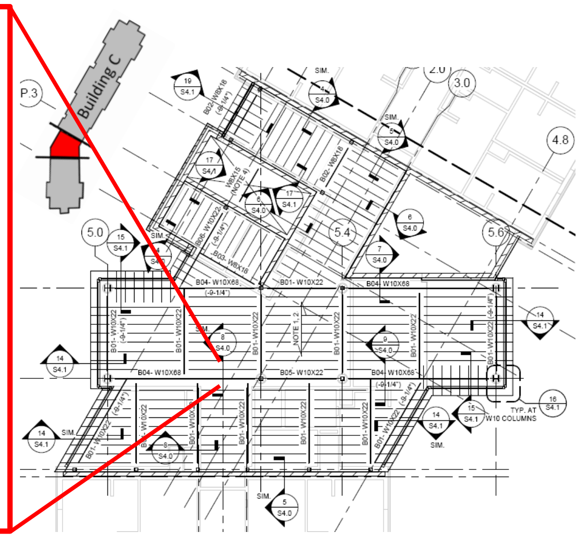


Figure 9 Building C Steel Core
Details from Sheets S1.3C - Architectural Plans – WTW

POTENTIAL SOLUTION

The first flooring system investigated was a metal deck with concrete topping flooring system. The steel structure was already there to support the deck. The metal deck flooring could provide schedule acceleration compared to the lumber framing. Instead of using a carpenter crew to finish the flooring, a concrete crew would be needed to follow the steel crew.

RESEARCH

The first work completed was a take-off of the current flooring system. There are four floors with an area of 2,040 square feet each. The total area equals 8,160 SF. The vertical height of the columns is 52 feet. There are (4) W10 steel columns and 15 HSS steel tube columns spanning from the bottom floor to the roof. The surface area of the CMU wall that encases the stairwells and elevator shafts equals 9531 SF. That also includes the CMU wall that separates the stick built core from the modular room construction.

STRUCTURAL BREADTH

Next, a structural analysis on the steel beams was checked. This check will conclude if there was a 10 inch depth restriction on the beams. The W10x68 beams were checked first. They span 22' 6", which would have the most deflection out of all of the beams in the steel core.

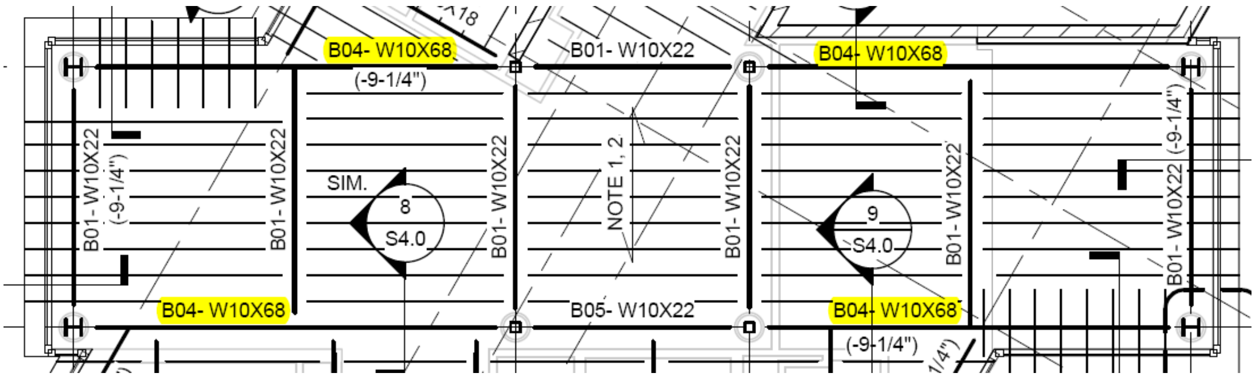


Figure 10 W10x68 in Steel Core
Details from Sheets S1.3C - Architectural Plans – WTW

The first thing that was checked was the design live load required by ASCE code. According to ASCE 7 code, for residential public rooms the design live load is 100 PSF. The dead weight of the wood flooring was calculated at 6 PSF. A 10 PSF superimposed weight was figured into the dead weight calculation.

For structural breadth calculations and sources see Appendix A

The maximum shear was found to be 19.1 Kips. The maximum moment was 107 ft-Kips. The deflection for the total load was 0.85 inches and for the live load was 0.73 inches. All of these passed the maximum allowable for the W10x68 beam. The deflection of the live load was .02 inches from the maximum. The W10x68 beam had a moment of inertia of 394 in^4, which was the only variable for the deflection of this span. The shear and moment were 13% and 33% respectively of the maximum. Clearly the deflection controlled the size of the beam. From the Z tables from the *AISC Steel Construction Manual*, the most cost effective beam for this moment, shear and deflection is a W18x35. It has a moment of inertia of 510 in^4, which means the deflection would be structurally stronger. This means there was a 10 inch depth restriction on the steel beams. There was very little plenum space in the building, because of the transportation restrictions on the modular units. The smaller the engineer could keep the beams, the more space the MEP's had for their work.

After finding out about this restriction, a metal deck flooring system was dismissed. The deck and concrete would add another 5.25 inches on the depth of the structure, decreasing the floor to ceiling height. If there was more space in the plenum, then the metal deck flooring system would become more applicable to the project.

POTENTIAL SOLUTION

After speaking with Professor Hanagan, a flat plate concrete structural system was examined. The concrete system would have a 10 inch thick slab and 2 way reinforcing. The 10 inch thick slab would take up just as much depth as the structural steel.

STRUCTURAL BREADTH

The dead load of the concrete on the slab was 125 PSF with an added 10 PSF for MEP hanging from the ceiling. A 100 PSF live load was used. #5 rebar was assumed to be used for the 2 way reinforcing. The maximum applied moment was found to be 27.2 ft-Kip. The maximum moment capacity of the 10 inch thick 2 way slab is 537.3 ft-Kip. The capacity is almost 20 times larger than the applied moment. This 10 inch thick slab is overdesigned and a thinner slab would probably be ideal. No further analysis was computed for this design, because the steel was 10 inches thick. If the MEP's fit all of their equipment with the steel then they can fit in the concrete design. The shear was not looked at throughout this process because the moment usually controls for a 27 foot span.

Finally, the rebar was designed for the concrete system. The CRSI Rebar Design tables were used to complete this analysis. Figures 11 and 12 below describe the 2 way rebar design.

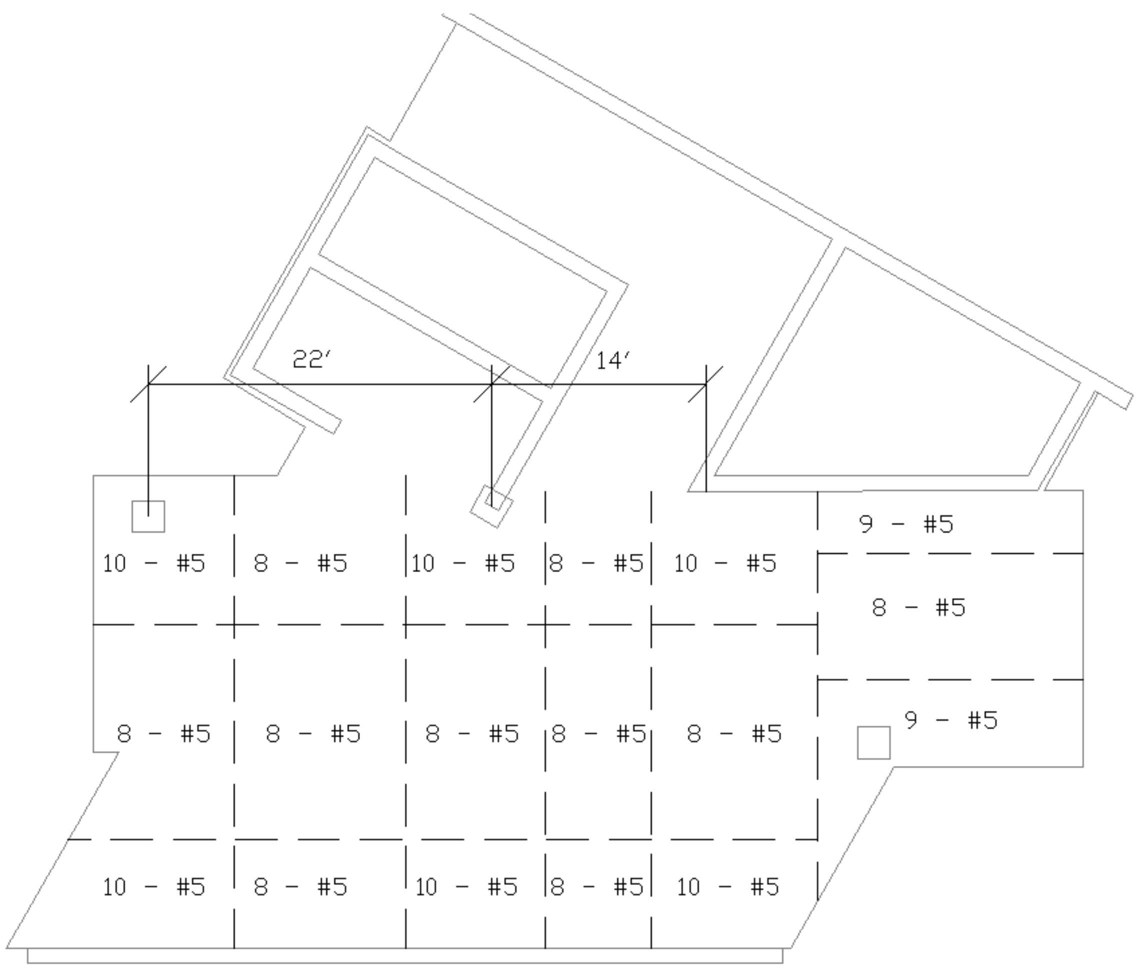


Figure 11 Horizontal Rebar

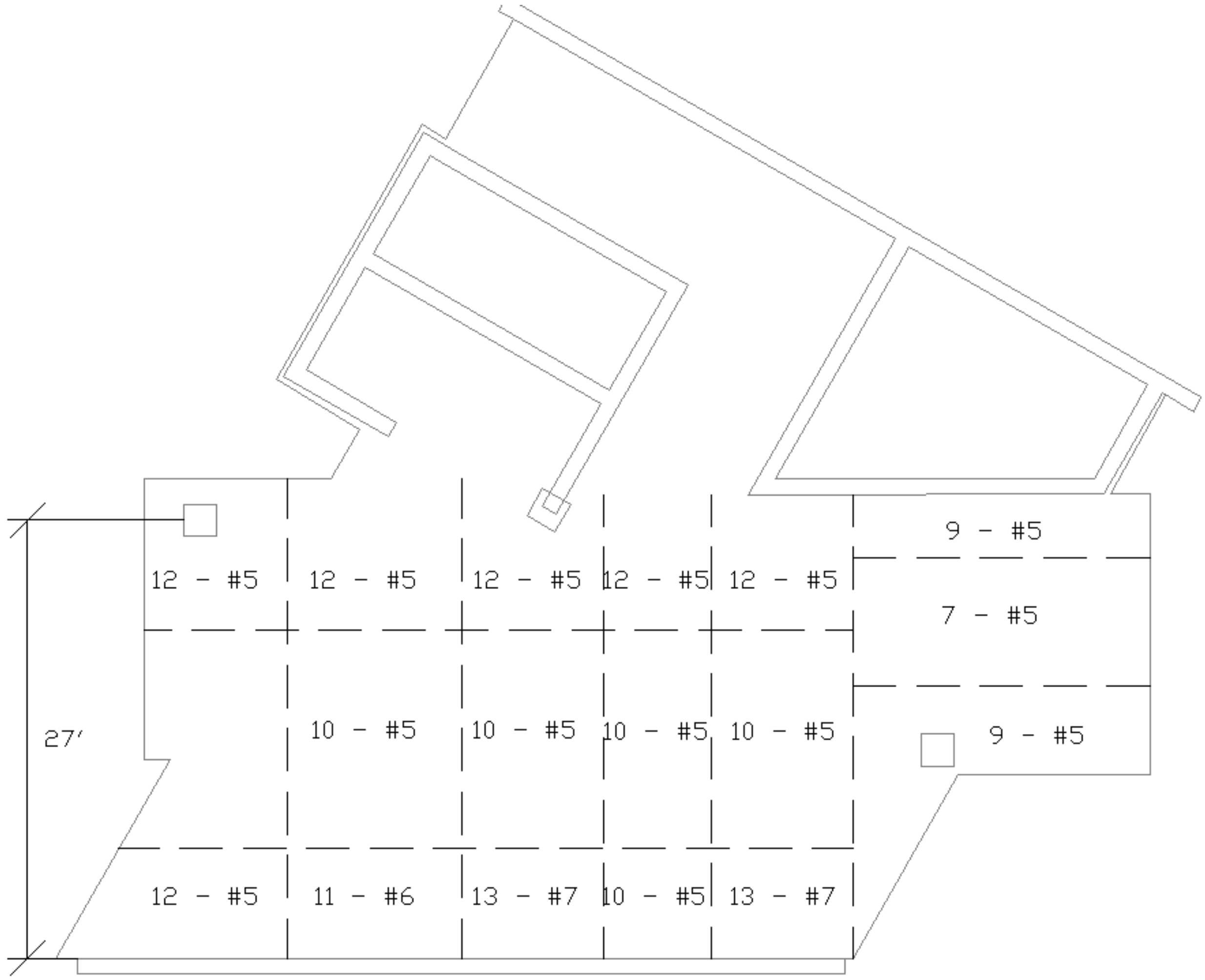


Figure 12 Vertical Rebar

ACOUSTIC BREADTH

Now that the concrete structural design has been checked and approved, the next analysis is the sound transmission through the flooring systems. After consulting Professor Vigeant, she reported that actual acoustical data for each of my flooring types would be impossible to do without vibration equipment. She did, however, provide STC and IIC information of various flooring types.

The IIC or impact insulation class is used for predicting the transmission of impact sound from one side of the floor to the other. It is increasingly harder to limit the impact sound transmission of lower frequencies. The type of architectural flooring impacts the IIC greatly. Carpet deafens the impact noise more than tile. If the surface is soft or resilient, there will be less impact noise transmission. It was decided that because the architectural flooring will stay the same between the two flooring systems, the difference in the IIC would be small or even negligible.

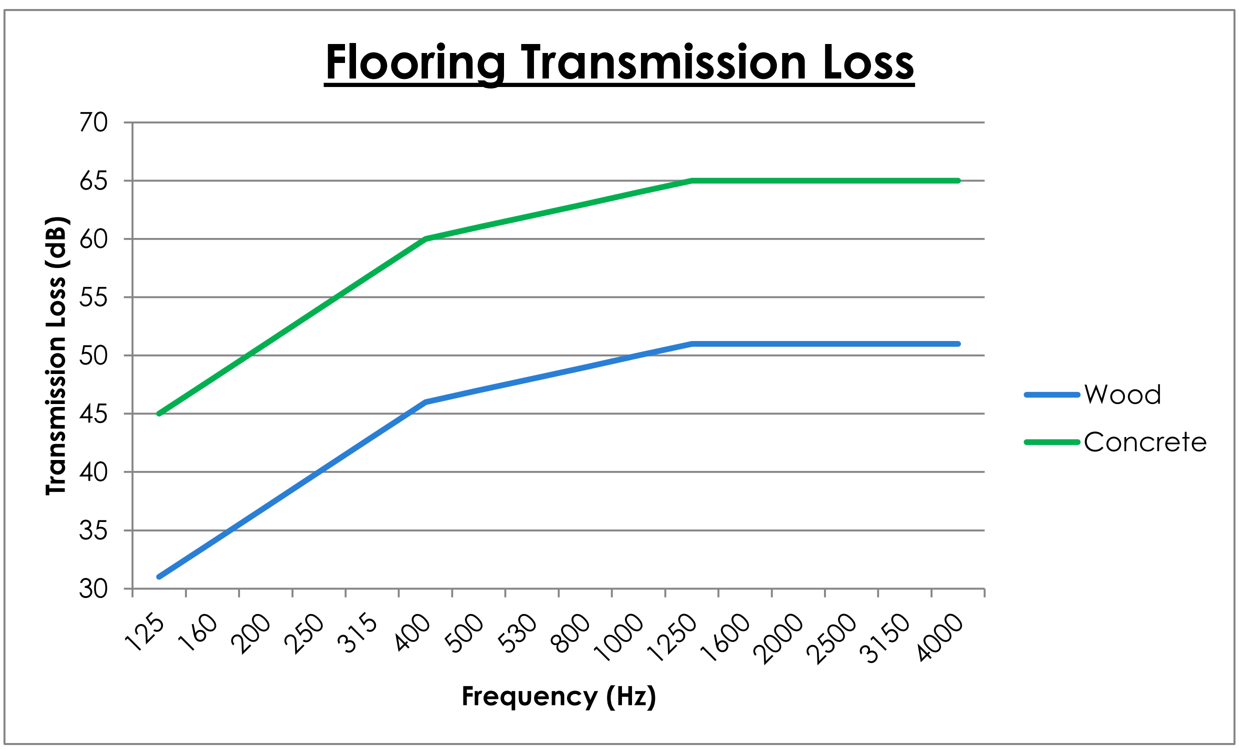
The STC or sound transmission class is used for predicting the overall sound transmission loss effects on speech noise. The curve's emphasis is on the speech bands of frequency. Sound transmission classes are not good for predicting the transmission loss for low frequency noise.

Source information of the STC curves can be found in Appendix B

A similar flooring system to the current wood floor was found. The chosen flooring system had 2x10 wood joists 16" o.c., two layers of plywood, resilient channels 16" o.c., 3 inch thick sound attenuation blanket, and ½ inch gypsum board ceiling. The difference between this floor and the actual floor is there are no resilient clips and there is 6" of insulation instead of 3". No resilient clips would decrease the TL, but the added 3 inches of insulation would increase the TL. No adjustments were made to the chosen flooring systems STC.

A similar flooring system to the designed concrete floor was found. The chosen flooring system had 8 inches of concrete at 95 PSF. The designed flooring system has 10 inches of concrete at 120 PSF. The more massive concrete floor would increase the transmission loss. From a 6 inch slab to an 8 inch slab, the STC increased 3 dB. A 3 dB adjustment was added to the chosen 8 inch to get it to the STC of the 10 inch thick slab.

The information given from the book is just one STC number. That number is the transmission loss at the 500Hz noise level. A best fit curve formula has been configured by acoustic researchers and has been widely accepted by the acoustics community. The curve increases 3 dB every third-octave from 125Hz to 400Hz, 1dB every third-octave from 500Hz to 1125Hz and levels off from 1125Hz to 4000Hz. The chart below describes the best fit lines for the two flooring systems. The wood flooring has a STC of 47 and the concrete flooring has a STC of 61.



Graph 1 Sound Transmission Loss

RESEARCH

Finally, the cost of both flooring systems was examined. *RS Means* was used for prices. For the concrete columns, an assembly was used that includes plywood formwork (4 uses), chamfer strip, reinforcing with ties, 4000 psi concrete, pumped and vibrated and finished. A 24 inch x 24 inch column that can handle a 900 Kip load with 14 feet story height was chosen. #5 rebar was estimated at $0.65/foot. An additional tie was added to the column per a vertical foot.

RS Means Data can be found in Appendix C.

For the concrete slab, an assembly was used that includes 15 feet high formwork (4 uses), edge forms (4 uses), reinforcing #4 - #7 bars, 3000 psi concrete, vibrated and pumped, finished with a steel trowel and cured with sprayed membrane curing compound. A slab thickness of 10 inches was chosen.

For the concrete walls, an assembly was used that includes plywood formwork (4 uses), reinforcing, 3000 psi concrete, pumped, vibrated and finished. A 12" thick plain finish wall was chosen. The reinforcing in this was seemed light, so an extra two #5 bars were added per a square foot.

Concrete Columns								
Cost Data		Amount		Cost		Number		Total Cost
$ 180.00	vert LF	52	vert LF	$ 9,360.00	/column	3	columns	$ 28,080.00
Additional Reinforcing								
$ 5.20	SF	52	SF	$ 270.40	/column	3	columns	$ 811.20
Concrete Flat Plate								
$ 16.05	SF	8160	SF	$ 130,968.00				$ 130,968.00
Concrete Walls								
$ 24.15	SF	9532	SF	$ 230,197.80				$ 230,197.80
Additional Reinforcing								
$ 1.25	SF	9534	SF	$ 11,917.50				$ 11,917.50
							Total	$ 401,974.50

Table1 Concrete Flooring System Estimate

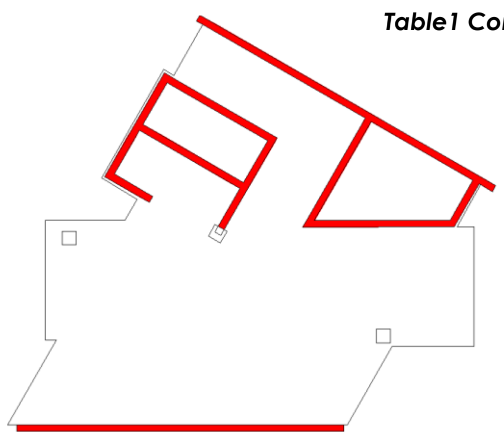


Figure 13 Concrete Walls

The total cost of the concrete system was calculated at $401,974.50. That includes the flat plate slabs, concrete columns, and concrete walls. The 12 inch thick walls accounted for 60% of the total cost. Figure 13 shows a view of the concrete walls in the core floor plan.

Next, the cost of the current flooring was estimated. For the steel columns, there were two different types: wide flange and square tube. A 300 Kip load was used for both types of steel columns. The wide flange was a 10 inch deep column with a story height of 14 feet. There was a 10 feet story height and 16 feet story height. Both of these numbers were used to interpolate the 14 feet story height cost. The square tube column was 6 inches in cross-section. It also only had a 10 feet and 16 feet story height so these numbers were interpolated to find the 14 feet story height cost.

The fire proofing on the columns were two layers of ½ inch fire rated gypsum board. The square steel columns were 6 inches thick and the W10's were 10 inches thick. RS Means gave this cost in cost per a vertical linear foot.

The steel frame closest to the frames in the core of both dormitories is shown in Figure 14. The structural steel and spray on fireproofing is included. The total load, as used in the structural breadth, was 200 PSF. There was a discrepancy in the depth of the steel framing. RS Means shows that the steel beams should have a depth of 24 inches, but only W10's were used.

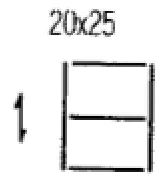


Figure 14 Steel Frame
RS Means page 78

There is wood framing running between the steel beams. The flooring assembly used had 2" x 10" floor joists 16 inches on center. There is also one layer of ½ inch plywood subflooring. Another ¾ inch plywood underlayment layer was added to match the actual flooring assembly. A layer of 6 inch thick batt insulation was also added.

The CMU walls have vertical reinforcing of #5's at 32 inches on center. The block size is 12"x8"x16". Horizontal joint reinforcing alternate courses and control joints were also included in the chosen assembly.

Steel Columns									
Type	Cost Data		Amount		Cost		Number		Total Cost
W10	$ 120.00	vert LF	52	vert LF	$ 6,240.00	/column	4	columns	$ 24,960.00
HSS	$ 97.00	vert LF	52	vert LF	$ 5,044.00	/column	15	columns	$ 75,660.00
Steel Column Fireproofing									
W10	$ 33.61	vert LF	52	vert LF	$ 1,747.72	/column	4	columns	$ 6,990.88
HSS	$ 31.83	vert LF	52	vert LF	$ 1,655.16	/column	15	columns	$ 24,827.40
Structural Steel Floor									
	$ 19.95	SF	8160	SF	$ 162,792.00				$ 162,792.00
2x10 Wood Joists									
	$ 3.47	SF	8160	SF	$ 28,315.20				$ 28,315.20
3/4 Plywood Underlayment									
	$ 1.13	SF	8160	SF	$ 9,220.80				$ 9,220.80
6" Batt Insulation									
	$ 0.59	SF	8160	SF	$ 4,814.40				$ 4,814.40
CMU walls									
	$ 15.40	SF	9531	SF	$ 146,777.40				$ 146,777.40
								Total	$ 484,358.08

Table 2 Structural Steel Floor System Estimate

The final cost of the steel structure, wood floor joists, plywood subflooring, and CMU walls is $484,358.08.

FINAL RECOMMENDATION

The current structural steel with wood floors was an unconventional system, which is the main reason why another flooring system was explored. At first, a metal deck flooring system was investigated, but the extra space required for a 2 inch thick deck and 3 ¼ inches of concrete topping would not leave enough space for the MEP's in the plenum. This was shown by the structural designer deciding to go with a more expensive, yet shallower beam. A 10 inch thick concrete flat plate system met all of the structural calculations. Actually, the 10 inch thickness was over designed. The flat plate could possibly have been designed down to 9 or 8 inches thickness.

Now that it is known that the structure of new concrete system can hold the design loads, they can be compared. The acoustical analysis showed that the sound transmission through the concrete floor was better than the wood floor. The sound transmission class, STC, of the wood floor was 47 dB and the STC of the concrete floor was 61 dB. The impact insulation class, IIC, was also investigated, but the floor covering has the most impact on the class. Because both flooring systems have the same floor covering, the IIC was the same. Acoustically, the concrete floor would be the better option. It has more mass to absorb the vibrations.

The cost of the two systems was calculated with numbers from RS Means. The concrete system cost $401,974.50. The steel and wood system cost $484,358.08. There is an estimated $82,000 difference. The 15 steel tube columns cost almost $100,000. This is where most of the difference is in the estimate. The 3 concrete columns cost $28,000. According to RS Means, the concrete design is drastically cheaper.

There are other factors that came into play for this project. First, there are not many concrete subcontractors that have the capacity to complete this size of work. There are not many large concrete buildings in the north-central Pennsylvania area. Also, lumber is readily available in this area. The price of the concrete should probably increase and the price of wood should probably decrease for the Mansfield area.

The second factor is the time of year. The core of the building would be constructed during the winter. Mansfield has very cold winters. Concrete needs to be kept insulated in order to correctly cure in cold temperatures. Also, it takes longer to cure concrete in the cold. Steel erection is a lot easier in the winter than cast in place concrete.

The final recommendation is either system would work. The concrete system in the middle of summer in an urban area would be a lot cheaper than the steel and wood system. For this situation, the steel and wood system's constructability is a lot easier for Mansfield in the middle of winter. The steel and wood system is probably the best system for this project, but the concrete system could be a great alternative.

ANALYSIS 2: MODULARIZATION PRECONSTRUCTION PLANNING

INTRODUCTION

Modularization requires additional planning and design in order to take full advantage. The preconstruction time can add months onto the project. Modularization also causes a reduction in the construction time. A shorter construction schedule reduces general condition costs. If modularization is installed correctly, the owner should come out with a cheaper project.

POTENTIAL SOLUTION

The amount of time used for preconstruction, to create the modular units and to place the modular units will be examined. The preconstruction method will be investigated. The inclusion of BIM in the preconstruction process could reduce time.

RESEARCH

The first part of research was contacting the modular subcontractor. Mark Russell of Simplex Industries was the contact for the Mansfield project. During the phone call, the following information was retrieved:

- Preconstruction started in February, 2012.
- Preconstruction took 4 months.
- The drawings from the stick-built Phase 1 project were altered to fit modular construction.
- The modular units took 10 days each to complete the structure, MEP's and finishes.
- The longest lead items were doors and windows. The lead time was 8 weeks.
- There was storage onsite for 100 modular units.
- Their two factories can have 41 units in production at one time.
- No BIM was used during the preconstruction process.

From the phone conversation, the preconstruction started with the architect coming to the modular subcontractor with the drawings from the first phase of dormitory construction. The modular subcontractor re-drew the drawings so the rooms would fit the modular unit dimensions.

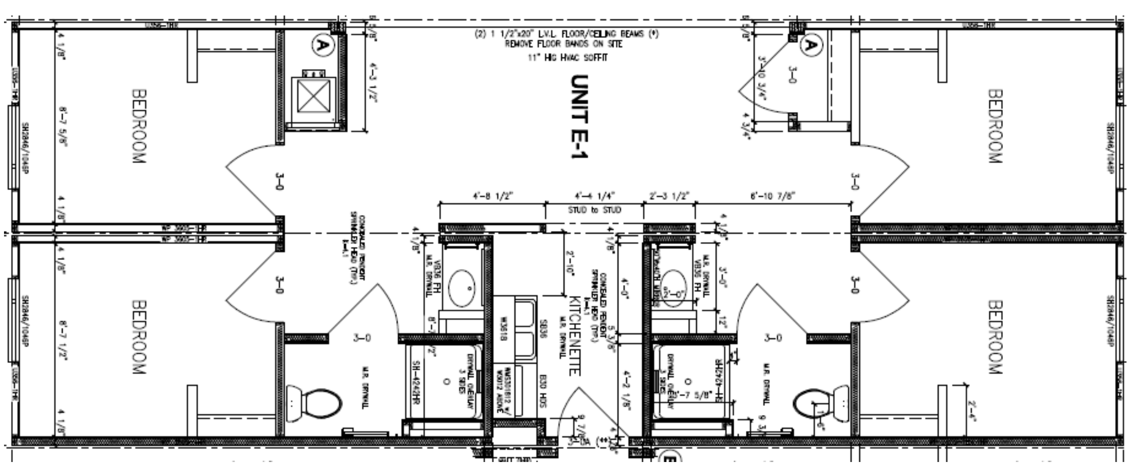


Figure 15 – E-1 Unit Modular Shop Drawing

Details from Sheet 2A – Modular Shop Drawings – Simplex Industries

The restrictions on the modular dimensions are set by the transportation of the units. The units must make it under all of the bridges which restricts the transportation height of the units to 13' 6". They also must fit in the road lanes. The size of one unit typically is 9' 8" x 49' 5" x 9' 11" tall. Once the drawings were modularized, the architect and engineers updated the rest of the drawings to match the modular design. The modular units are constructed with all of the MEP's installed. The modular subcontractor has mechanical and electrical engineers on staff to create the MEP drawings for their crew. Those MEP drawings then will have to be sent to the MEP subcontractors onsite to coordinate how each of the room's rough ins attach to the mains and feeders.

There are eight different types of rooms. The most common type of room is type C: a two bedroom suit with a personal bathroom and a foyer area. There are larger suites that contain full kitchens and a refrigerator. The room breakdown for each building is in Tables 3 and 4 below.

Building C								
Type	Gr	1	2	3	4	Total	Ppl/Rm	Residents
B	0	12	12	12	12	48	2	96
C	0	16	16	16	16	64	2	128
D	0	0	0	0	0	0	4	0
E	0	1	1	1	1	4	4	16
F	0	0	0	0	0	0	2	0
G	0	1	1	1	1	4	2	8
H	1	0	0	0	0	1	2	2
I	2	0	0	0	0	2	3	6
								256

Table 3 Building C Modular Units

Building D								
Type	Gr	1	2	3	4	Total	Ppl/Rm	Residents
B	0	14	14	14	14	56	2	112
C	6	29	29	29	29	122	2	244
D	0	1	1	1	1	4	4	16
E	0	1	1	1	1	4	4	16
F	1	2	2	2	2	9	2	18
G	0	1	1	1	1	4	2	8
H	0	1	1	1	1	4	3	12
								426

Table 4 Building D Modular Units

There are a total of 27 modular units on one floor of Building C and 4 floors total, so 108 modular units were used in Building C. In Building D, there were 48 units per a floor, with 192 total in the building. Simplex had to create a total of 300 units for this project.

At 10 days per a unit, the total length of construction for the units would be 3,000 working days. That's about 11 ½ years. There are some differences between the modular construction and stick built construction though. The crews that work on the units have 2 or 3 workers at one time. According to the project manager at Wohlsen, a stick built crew size on this project would be expected around 25 men. That's about 10 times the size of the crews working on the modular units. Also with this schedule, it is assuming that all of the carpentry is finished in the project before the MEP's can begin roughing in their work. This is not the case in most construction. Once a floor's carpentry is completed, the carpenters move up to the next level and the MEP's begin to rough in on that floor.

Schedules can be found in Appendix D

An initial schedule was created to show the flow of construction through the two dormitory buildings taking 320 days. 320 days was used instead of 3,000 days, because of the increased crew size. The amount of total construction time was divided by 10, because the crews are about 10 times larger. The activities were the carpentry of the floor and walls, MEP rough ins, door frames, drywall, and finishes. Durations for each activity on each floor were created. Finally, once the durations were set, the activities were given predecessors and successors in order to compact the schedule as much as possible. An example of this is after the MEP rough ins move up to the second floor, the drywalls begin on the first floor, instead of waiting for the MEP's to finish on every floor. The duration of projected schedule of the stick built construction is 112 days.

Next, there was analysis on the modular unit construction. According to Mark Russell, Simplex's facility can have 41 units in production at one time. With 300 total units needed for the Mansfield project, it would take 8 cycles of 10 days to complete them all. The total construction time of the modular units is 80 days.

February 12, 1:00 PM *February 13, 1:00 PM*

Figure 16 and 17 Modular Setting

The modular subcontractor can set 8 to 12 units in a day. Figures 16 and 17 show the progress of the modular unit setting in one day. With an average of 10 modular units per a day, all 300 units can be set in 30 days. This is 82 days less than the 112 day stick built schedule. This is over 16 weeks of schedule reduction. The schedule reduction isn't the only savings. The owner is saving 16 weeks of general condition costs. Everything seems great about modular construction, but there was a lot of planning needed in order to complete the modular construction without any issues.

According to the conversation with Mark Russell, the preconstruction process took approximately 16 weeks. The owner ended up paying for 16 weeks of preconstruction fees for the architect, engineers, and modular subcontractor. The preconstruction fees should cost less than the saved general conditions costs, but this shows that the general condition costs are completely saved.

Another thing that was found out from the conversation with Mark Russell was that BIM was not used during the preconstruction of the modular units. BIM is "building information modeling". It is the process when all of the construction plans are digitally represented in 3 dimensions. The most common construction drawing sets used in BIM are architectural, structural, mechanical, electrical, lighting, plumbing, and fire protection. Once each set of plans are loaded into the same file, a program looks for clashes. Clashes are where parts of the building wrongly intersect, as seen in Figure 19.

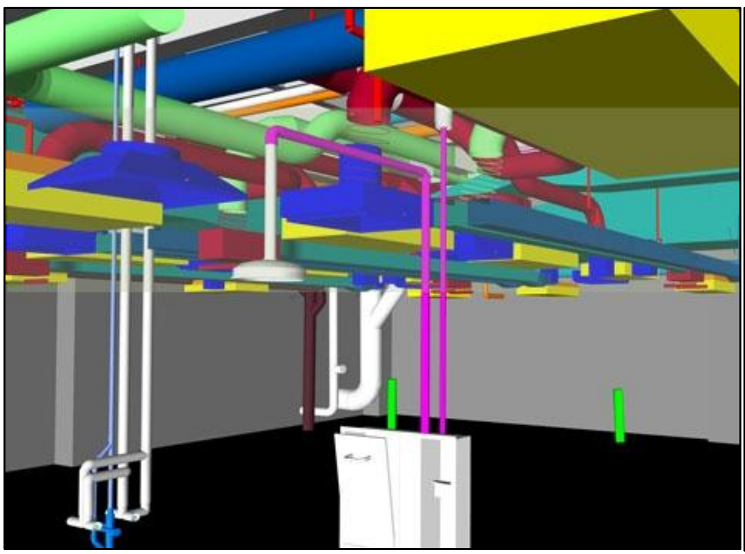


Figure 18 3D Modeling
Picture Courtesy of Allied Fire Protection

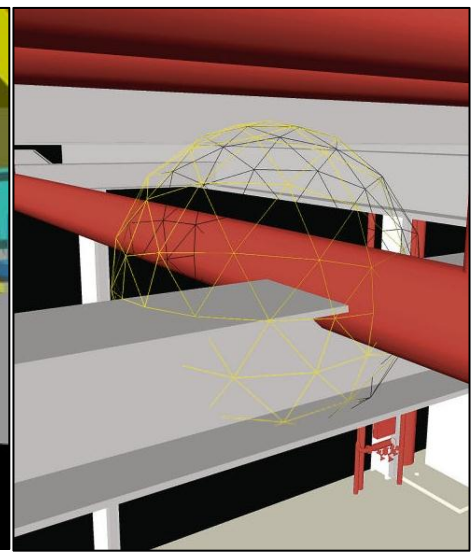


Figure 19 Clash Example
Picture Courtesy of Tec Channel

After clash detection, the architects and engineers will change their plans and submit again for clash detection. The changes that are made to avoid one clash may create another clash. This process is repeated until all of the clashes are fixed. Usually most of the changes are in the MEP plans, because it usually cheaper to move a pipe or duct than to move a structural steel beam.

BIM's main advantage is better productivity in the field. There are no clashes that need to be redesigned in the field. The crews can follow exactly what's on the plans, and not have any issues. Without BIM, work in the field would be stopped, an RFI would be sent to the architect and then the problem would be redesigned. This process can add days to the schedule. Also, having a 3D image of the work that is to be put in place adds clarity to the subcontractors that are building it.

During the construction of the modular units, no BIM was used. If BIM would have been added, it would have helped the modular construction workers complete the units faster. The cost of BIM during preconstruction may not always be worth it. In the case of the modular units, there are two reasons why BIM does not make sense.

The first reason why BIM would not be used is because of the repetitiveness of the units. Most of the rooms in Building C and D are type B and C rooms. There are over 180 type C rooms and 100 type B rooms. After the first set of type C room units were completed all of the clashes were found and redesigned, so they knew what to do for the next set. There was time lost for the first set, but after that, the units were created with the same speed as BIM would allow.

Second, all trades work for the same company. On a normal project, the trades will fight with each other over redesigned work. Both sides think it's the other contractor's issue. By working for the same company, crew members realize working together with other trades will look a lot better to their bosses rather than causing trouble. This creates a good atmosphere for collaboration and clashes get settled faster.

Figure 20 MEP Hallway Connections

There is one big positive advantage of the using BIM throughout the modular unit construction process. The modular contractor would have a 3D model of where every room's MEP connection entered the hallway. As written earlier in the report, the onsite MEP subcontractors have to take all of the room connections, and feed them down the hall to the vertical mains and feeders. By having the modular unit 3D model, the MEP subcontractors have a model to create their plans from.

The MEP subcontractors hold design-build contracts with construction manager. This means they designed the plans for their onsite work. They created a 3D model and preformed clash detection for their plans. Less time would have been wasted on modeling, if they could have started with the modular subcontractor's model.

FINAL RECOMMENDATION

The modular unit preconstruction process was examined. The process started with the modular subcontractor redesigning the first phase of Mansfield University's dormitory expansion drawings to modular dimensions. The complete preconstruction process took 16 weeks to complete.

About 10 modular units were set per a day. With 300 modular units ideally, all of the units could be set in 30 work days. After a schedule was created for the stick built construction, the stick built schedule was estimated at 112 work days. The difference was 82 days of over 16 weeks or 4 months. The general conditions of this project were estimated at $170,000 per a month. That is a total savings of $680,000.

This analysis shows that the 16 weeks used during preconstruction offset 16 weeks during construction. The owner saved 4 months of general conditions costs, but also paid for 4 months of preconstruction fees. The general condition costs should be higher than the precon fees, but this analysis still shows that not all of the general conditions costs were saved from modularization.

BIM was not used during the preconstruction process of the modular units, but was used by the onsite MEP subcontractors. BIM would have increased productivity for the MEP rough ins during the first set of modular units, and created a great starting point for the 3D modeling for the onsite MEP subcontractors. BIM would not have been effective for the modular MEP crews after the first set of units were completed though. The units are extremely repetitive, and once they figured out the issue on the first unit, they could repeat their fix the whole way through the rest of the units. Also, the modular MEP crews work for the same company which promotes better trade coordination. Stoppages don't take as long. Overall, BIM would not be recommended for the modular subcontractor. Most of the issues that would arise out in the field are easier and faster to fix when building in a factory. The designer can literally walk down the stairs and see the issue. There would not be as much lag time between questions and answers.

ANALYSIS 3: EXTERIOR FAÇADE REDESIGN

INTRODUCTION

These dormitories have a cast stone and brick façade. The masonry facade requires full four story scaffolding to complete. A different façade may accomplish the same aesthetic look taking less labor and installation time. Figure 21 below shows the masonry façade of the first phase of dormitory buildings.

Figure 21 Masonry Façade
Phase 1 Dormitory

POTENTIAL SOLUTION

For the brick façade on floors 2-4, a panelized thin brick would provide the schedule reduction and can look like masonry brick. The Convergence Center Building in Virginia Beach is using a panelized thin brick façade similar to the one proposed in this depth. This product was produced by Advanced Exterior Systems from Raleigh, North Carolina.

For the ground and 1st floors, a cast masonry stone façade is used. A precast concrete façade can provide the masonry look, and a reduction in schedule also. The aesthetics of precast concrete has come a long way.

Figure 22 Panelized Thin Brick Facade
Courtesy of Advanced Exterior Systems

RESEARCH

The first area of research was the owner's expectations. Mansfield University wanted these dormitories to match the existing facades of buildings around campus. Figure 23 and 24 shows the façades of two of the buildings on Mansfield's campus. The library building is the most important building on the campus. Both buildings have masonry brick and stone facades. They have a traditional style of architecture.

Figure 23 North Hall Library
Courtesy of Mansfield.edu

Figure 24 Straughn Hall
Courtesy of Mansfield.edu

Figure 25 Building C Rendering
Courtesy of WTW Architects

The architects tried to keep a similar architecture style to the other buildings on campus, with adding some modern style. Figure 25 shows the brick and stone masonry façade. The cast stone lintels and sills relate to the older buildings. The glass curtain façade integrates a more modern style of architecture.

Figure 26 Façade Types, South Elevation – South Wing – Building C
Details from Sheet A2.1C - Architectural Plans – WTW

The architect designed Building C and D with a masonry stone façade (blue), masonry brick façade (red) and a fiber cement panel façade (yellow). The fiber cement siding is only used on the fourth floor to accent the brick. The brick and stone masonry facades cover most of the buildings. There is an estimated 13,800 square feet of brick façade in Building C and 23,800 square feet in Building D. There is an estimated 9,100 square feet of stone façade in Building C and 14,200 square feet in Building D.

Take offs can be found in Appendix E

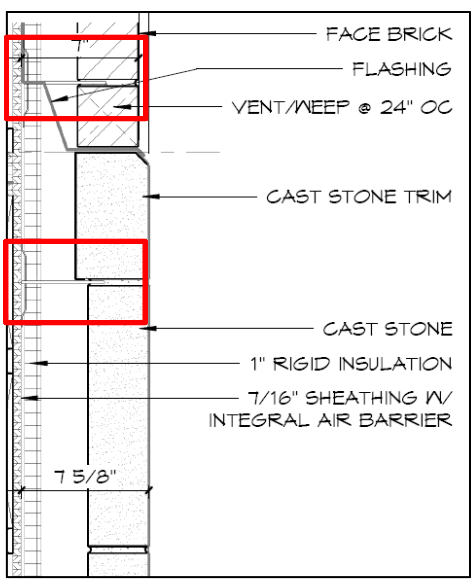


Figure 27 Stone and Brick Connections
Details from Sheet A4.1C - Architectural Plans – WTW

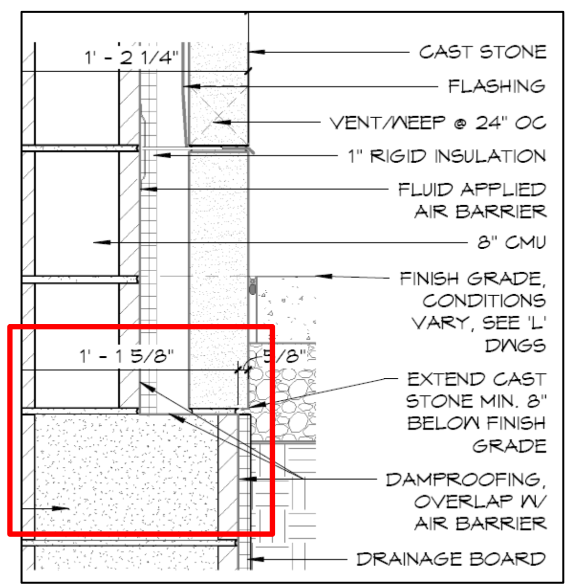


Figure 28 Stone Façade Foundation
Details from Sheet A4.1C - Architectural Plans – WTW

Figure 27 shows the masonry ties that are used to secure the stone and brick masonry units. The ties are between every other course of stone and every three courses for brick. The brick sits on steel relief angles every floor. The one to two stories of stone masonry units sit on the CMU block foundation. CMU block is 14 inches thick underground. The ground level has 8 inch thick CMU block. Figure 28 shows the detail of how the stone façade is supported on 14 inch thick CMU block.

At first, a panelized EiFS façade was investigated as a substitute for the brick façade. EiFS stands for exterior insulation finishing system. It is also called synthetic stucco. The EiFS would save money and the panels would reduce schedule. Before the project started, the owner asked the construction manager to preform value engineering to reduce the project cost $2 million. One of the CM's ideas was to change the brick to EiFS. This change would save approximately $780,000. The owner rejected the EiFS, because it did not look close enough to the other masonry brick facades of buildings on campus.

Because EiFS was rejected, a more expensive product was investigated. Advanced Exterior Systems makes a thin brick panelized façade system. The thin brick system uses a ½ inch thick brick and mortar exterior. Behind the thin brick, a water proof skim coat, Durrock substrate and 2x10 metal studs provide the structure of the panel.

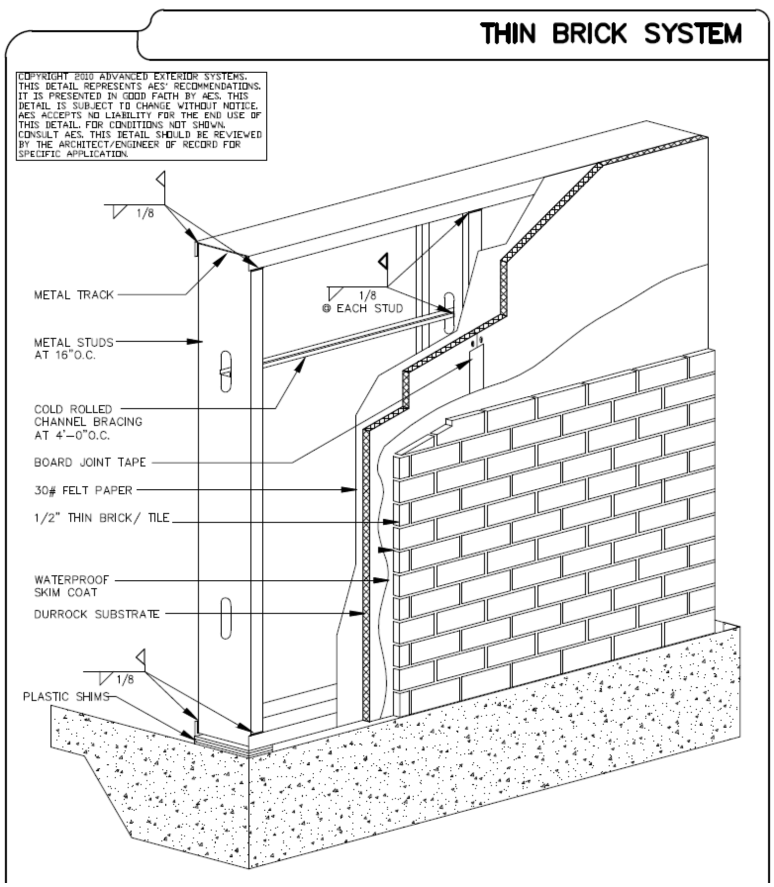


Figure 29 Thin Brick Panel Cut Sheet
Courtesy of Advanced Exterior Systems

Figure 30 Convergence Center
Courtesy of Advanced Exterior Systems

Figure 31 Thin Brick Panel
Courtesy of Advanced Exterior Systems

The Convergence Center was shown on Advanced Exterior Systems website. The thin brick system looks very similar to masonry brick. After seeing Figures 30 and 31, it was determined that this system has a more natural appearance and would be more likely to be approved by the owner than the EiFS system. The next step was to have a conversation with Tony Murphy at Advanced Exterior Systems. He told me that the material cost of the thin brick panels was approximately $35 per square foot. He also said that the EiFS equivalent would cost $15 per square foot. From their website, they can erect approximately 900 square feet of panelized façade per an 8 hour day.

Because the stone masonry units have a foundation, a precast concrete panel was investigated as a substitute. The concrete panels would add too much load for the wood structured modular units. As seen in Figure 28, the stone is sitting on the foundation walls. This means the walls are not holding all of the precast panels. From RS Means, a precast concrete panel that is 4 inches thick and is about 200 square feet costs $42.18 per square foot. 4 inches was chosen because the stone masonry units are 4 inches thick. The installation cost of the precast panels was $4.18 per square foot.

Figure 32 Cast Stone Finish
Courtesy of Craftstone 2000 Limited

Figure 33 Cast Stone Panels
Courtesy of Modern Pre-Cast Inc.

The next step was to design the types of panels needed for this project. Figures 33 and 34 show the 9 different types of panels needed for both buildings. These panels were counted and the outcome is shown in Table 5. The total cost of the panelized systems and the masonry façade is displayed in Tables 6 and 7.

Figure 34 Types of Panels

Figure 35 Types of Panels

Panel Type	Size (SF)	Total Number	Total Area (SF)
Thin Brick			
A	165	111	18,315
B	148	16	2,368
C	250	40	10,000
D	162	20	3,240
E	280	10	2,800
Precast			
Z	380	24	9,120
Y	270	36	9,720
X	170	16	2,720
W	215	40	8,600

Table 5 Area Panelized Facade

	Thin Brick			Precast Concrete		
	SF	Cost/SF	Cost	SF	Cost/SF	Cost
Building C	13,098.00	$ 43.18	$ 565,571.64	16,510.00	$ 42.18	$ 696,391.80
Building D	23,625.00	$ 43.18	$ 1,020,127.50	13,650.00	$ 42.18	$ 575,757.00
			$ 1,585,699.14			$ 1,272,148.80

Table 6 Cost of Panelized Facade

	Brick			Stone		
	SF	Cost/SF	Cost	SF	Cost/SF	Cost
Building C	13,098.00	$ 17.96	$ 235,240.08	16,510.00	$ 35.75	$ 590,232.50
Building D	23,625.00	$ 17.96	$ 424,305.00	13,650.00	$ 35.75	$ 487,987.50
			$ 659,545.08			$ 1,078,220.00

Table 7 Cost of Masonry Facade

The thin brick panelized façade cost an estimated $1,585,699.14. The masonry brick was estimated to cost $659,545.08. The thin brick façade costs $926,154.06 more than the masonry brick. The precast concrete costs $1,272,148.80. The cast stone masonry façade costs $1,078,220.00. The precast concrete costs an estimated $193,928.80 more than the cast stone.

These estimates show that the prefabricated systems do cost a fair amount more than standard masonry. They both should reduce the schedule though. First, the initial schedule of the masonry façade was examined. Figure 36 shows the plan for erecting the façade. Masonry started in the northwest corner of both buildings and proceeded around the building in the counter clockwise direction. This same plan was used for the panelized façade. Durations for the panelized façade were calculated using the information from Advanced Exterior System that they could construct 900 square feet of façade per a day.

Schedule can be found in Appendix F

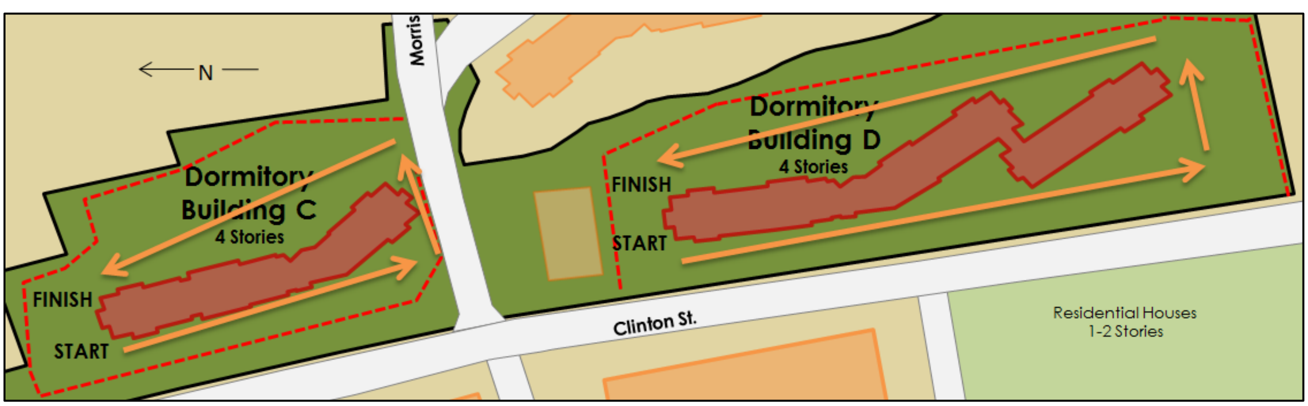


Figure 36 Façade Construction Plan

The schedule shows that, in Building C, the prefabricated façade would take 21 days versus the 81 days that were scheduled by the construction manager for the masonry façade. The schedule also shows that, in Building D, the prefabricated façade would take 31 days versus the 120 days for the masonry façade. The difference is 60 days in Building C and 89 days in Building D.

FINAL RECOMMENDATION

The owner's expectations had a lot of influence on the type of façade substitutes that were chosen to examine. The owner did not want EiFS or anything that did not look like the other buildings on campus. This lead to the decision to research a thin brick panelized façade system instead of the masonry brick and a precast concrete panel system instead of masonry cast stone.

The thin brick panels cost about $926,154.06 more than the masonry brick. The panelized system cost more than $25 more per a square foot. The precast concrete system costs $193,928.80 more than the masonry precast stone. There was a $6 per a square foot difference between the precast concrete and masonry stone facades. The schedule showed that the thin brick and precast concrete systems reduced the schedule by 60 days in Building C and 89 days in Building D.

The cost estimates did not include the scaffolding that is needed for the masonry. The scaffolding extends up four floors, and must be erected and taken down. There would need to be a lot of scaffolding rented in order to work simultaneously on both buildings. The prefabricated systems use a crane to place the panels. The cost of the crane also is not included in the estimate. One crane could be rented for a total of 52 work days. Because there were roads made for the delivery of the modular units, the tractor trailer trucks could easily back the panels up to the crane.

The masonry crew will be large in order to complete enough work on both buildings to meet the substantial completion date. The crew increases site congestion and traffic and decreases site safety. The general condition costs would rise for more bathroom facilities and possibly more safety supervision.

Having said all of these extra general condition costs that are associated with the masonry façade, there is no way that their cost gets close to the $1.12 million difference in cost between the two systems. It would be very hard to convince an owner to spend an extra $1.12 million dollars on a comparable looking façade. The owner's expectations made the prefabricated façade system impossible to have a comparable price. According to the conversation with Tony Murphy, from Advanced Exterior Systems, the panelized EiFS system starts at $15 per a square foot. This would be more comparable to the price of the masonry brick. The cost difference is just too high to switch to the prefabricated systems. The Construction Manager can have the masonry crew man-up to meet the schedule requirement.

ANALYSIS 4: MODULAR UNIT CONNECTION

INTRODUCTION

The quality inside the modular units should be better than any stick built building. They are built in factories, which takes out many variables such as weather. The one place where the quality of the units could be at question is at the joints between the units. These joints can be very hard to perfectly connect. There is a constructability challenge with setting modular units to avoid uneven joints.

RESEARCH

The first thing that was investigated was the actual modular setting procedure. Brian Laub, the project manager for the Construction Manager was contacted. He provided some insight on the process of modular subcontractor's setting techniques. The modular subcontractor had a 9 person crew. There was a crane operator, crane signaler, 3 men rigging the units and 4 men in lifts.

1. The first step is to move the modular unit next to the building.

Figure 37 Modular Unit on Trailer

2. The rigging crew men attach the lifting rig to the modular unit.

Figure 38 Modular Unit Crane Rigging

3. The crane lifts the modular unit close to its final placement. The crane operator is being helped by a signaler.

Figure 39 Modular Unit Moved by Crane

4. Crew members in lifts guide the unit to its final setting place. The crew members rotate and push the unit into the right position as the crane sets down the unit.

Figure 40 Men on Lifts Adjusting the Modular Unit

5. Crew men in lifts detach to rigging and start fastening the unit to the other units.

Figure 41 Anchoring Modular Unit

The main area for error during this process is when the men on lifts are adjusting the modular units. How do they know that their position is precise? The men on lifts can only do so much. Next is an example of how non precise setting could affect the gaps between units. Say the bottom unit is set with a 0.5˚ off. The next unit is set another 0.5˚ off. This problem compounds up all 4 floors. At the top, there would be a 10.5 inch gap between the units. This is a worst case scenario and obviously 10.5 inches would be noticeable. But just an 0.5˚ off for 4 stories makes a significant gap.

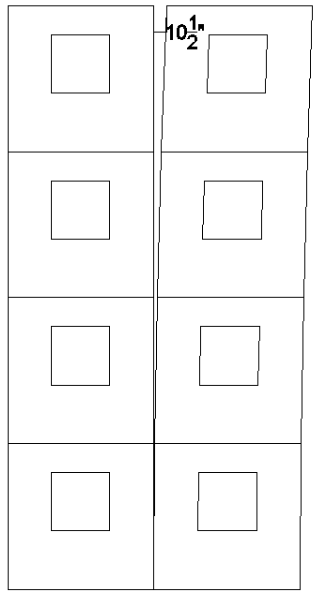


Figure 42 Modular Unit Setting Error

POTENTIAL SOLUTION

A potential solution is to a GPS system similar to the ones that are used in bulldozers. An 3D model of the site is loaded into the program. There is a sensor on the dozer that through GPS allows the program to know its location. The program then adjusts the blade to what the 3D model's design elevation. This system makes sitework so much faster. The dozer operator just drives and doesn't have to worry about the blade.

If this technology could be used with the crane operator and the men on lifts, then there would be less human error involved. The following are images of the Topcon 3D machine control system for dozers.

Figure 43 Operator Interface
Courtesy of Topcon Inc.

Figure 44 GPS Transmitter
Courtesy of Topcon Inc.

Figure 45 Sensor
Courtesy of Topcon Inc.

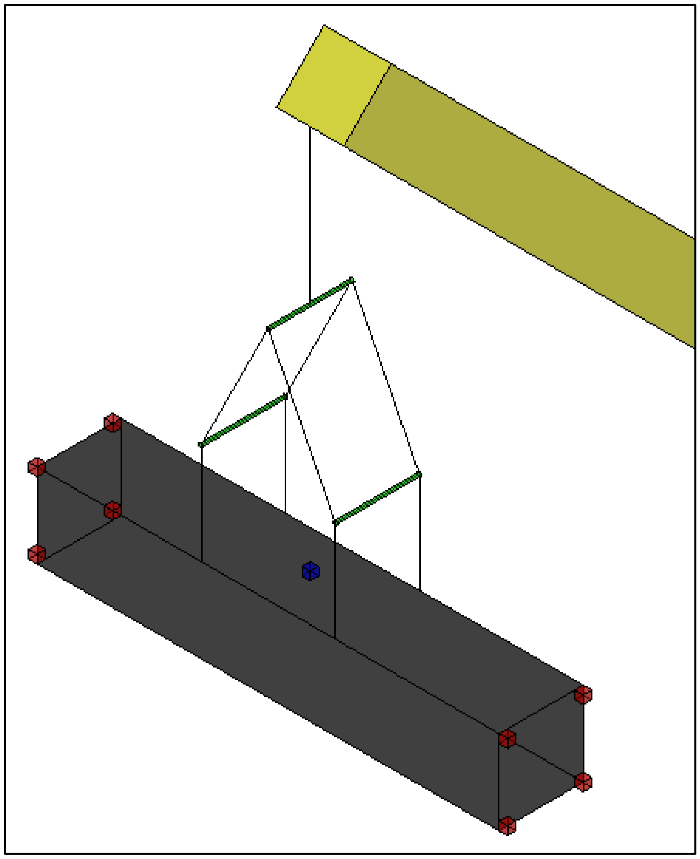


Figure 46 GPS Positioning System

Figure 46 shows the set up for a modular unit. Sensors would be placed on the corners of the unit and the GPS unit would be placed in the center of the unit. A 3D model of the construction project would be entered in the program. Then, the crane operator would enter in which unit in the model he is setting. While in the process of setting, the program can track the location of the unit. Once the unit is in the precise location according to the program where there is no angle or overhang, the men in lifts should shim and secure the unit. This system ensures that the modular unit is in the perfect location.

RESEARCH

The next step was to investigate how the modular subcontractor actually ensured precision in setting the modular units. The first check came in the factory. The dimensions of the structural shell of every unit were double checked before the other trades were allowed to start construction. This precision decreases the chance of overhang. After the modular units are completed, they are once again checked for plumbness. Usually the units stay plumb, because of the cross bracing in the structure. As the units leave the factory for transportation, they have been double checked for dimensions.

The next check comes in the order that they set the units. Figure 47 shows the order that units were set. The row furthest to the left is the most important during the process. The first one needs to be set in the exact right position and plumb, because the next unit will use the first one as a guide to the right location. If the first one is off, then the rest of the units will be off because they all use each other as references. The 3^{rd}, 6^{th} and 10^{th} also must be placed plumb, but their location is already set by the unit below them. Because the units have all been checked for dimensions and 90 degree angles, there is no need to worry about the units not fitting in their correct spot.

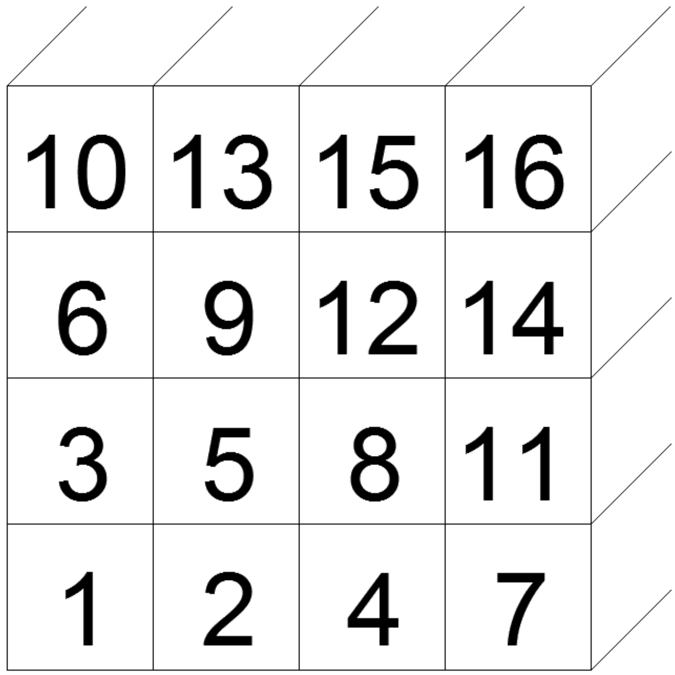


Figure 47 Unit Setting Order

The final check comes from the crew men in lifts and on the ground. The crew makes sure that the units are directly on top of each other before nailing them together. Once again because the dimensions were checked in the factory, the units should fit perfectly on top of each other. If there is a small gap somewhere, the crew will add shims in between the units to get them to the right location.

FINAL RECOMMENDATION

After seeing how the modular subcontractor ensured precision, the GPS positioning system would really be helpful when setting the very first column of units. After the first column, the system would not be needed, because the crew can use the previously set units as a reference. The extreme precision in the factory really made it easy for the crew in the field to set the units. According to the Project Manager, Brian Laub, the men in the lifts did not even use levels before fastening the units. They didn't even check for plumbness, because they were so confident in the dimensions of the units. This attention to detail in the preconstruction phases paid dividends during construction.

Overall the system would help at least in the beginning of setting. The crew set on average 10 units a day. That equals one every 48 minutes. According to the Project Manager, the very first unit did not take over an hour. This means that the GPS positioning system would take off 12 minutes for each unit in the first column at the most. The total time saved would be 48 minutes. According to Topcon's website, the dozer GPS machine control system costs about $14,000. That system only uses one sensor. The proposed modular unit GPS system uses 8 sensors.

When evaluating the GPS positioning system, the value of the system must be compared to the cost. Is a possible 48 minutes of reduced schedule worth over $14,000? The GPS positioning system would not be recommend for this project. In a more detailed modular project with different sized units, this positioning system would be more helpful. After investigating the setting process of the project, there were very few, if any, problems with the joints and connections of the units. Everything that modular subcontractor did to ensure precision worked perfectly. The modular subcontractor, Simplex Industries Inc., should have their setting procedure down by now, because they have been in the modular construction business since 1971. The GPS system technology is just too expensive now to be used this way in construction. It may come along in the future, but it just isn't worth it now.

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APPENDIX A

STRUCTURAL BREADTH INFORMATION

W10×68

$l = 22'\,6''$

$w_u = (1.2)\left(6\,psf + \frac{68\,lbs}{9'} + 10\,psf\right) + 1.6(100\,psf)$

$w_u = 189\,psf$

$V_{max} = 189\,psf \times 9' \times \frac{22.5'}{2} = 19.1^k < 147^k$ ✓

$M_{max} = \frac{1}{2}(19.1^k)\left(\frac{22.5}{2}\right) = 107'^k < 320'^k$ ✓

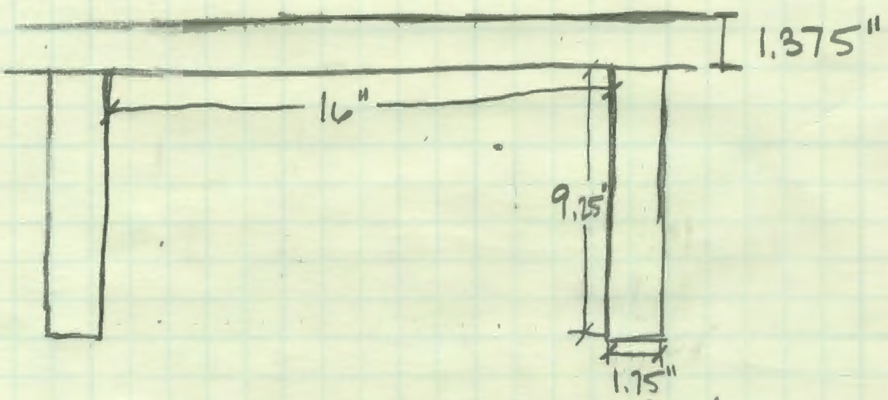
$\Delta_{max} = \frac{270''}{240} = 1.13''$

$M_{max} = \frac{wl^2}{8} = \frac{189 \times 9 (22.5')^2}{8} = 107'^k$

$\Delta_{Total} = \frac{5(189' \times 9' \times 1728)(22.5')^4}{384(29{,}000{,}000)(394\,in^4)} = 0.85'' < 1.13''$

$\Delta_{live} = \frac{5(160 \times 9' \times 1728)(22.5)^4}{384(29{,}000{,}000)(394\,in^4)} = 0.73'' < 0.75''$

$\Delta_{Total} = \frac{270}{360} = 0.75''$



Volume of wood in a square foot

$$\left(\frac{1.375''}{12''} \times 1' \times 1'\right) + \left(\frac{12''}{16''}\right)\left(\frac{9.25''}{12''} \times \frac{1.75''}{12''} \times 1'\right) = 0.199\ ft^3$$

Wood weighs: 30 lbs/ft^3

Weight per SF

$$30\ \frac{lbs}{ft^3} \times .199\ \frac{ft^3}{ft^2} = 6\ lbs/SF$$

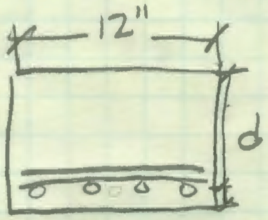
10 in thick slab from 2 way slab table
pg 9-35 of CRSI

Max span of 26 ft

DL : $150\left(\frac{10''}{12''}\right) = 125$ psf
10 psf Misc DL

LL : 100 psf (Residential Public Rooms) pg 42 404 notes

$w = 1.2(125+10) + 1.6(100) = 322$ psf



cover, #5 rebar

$A_s = 0.009\,(12')\left(10'' - \tfrac{3}{4}'' - \tfrac{5}{16}''\right) = 1.13$

$\#5\ A_s = 0.31$ ← Avoid congestion + deflection problems

$\frac{1.12}{12} = \frac{0.31}{?}$ 3.3 → 3"   #5's @ 3" O.C.

$A_s = .31 \times \frac{12''}{3''} = 1.24\ in^2$

$b = 12''$

$h = 10''$

$d = 10 - \frac{3}{4} - \frac{5}{16} = 8.94''$

$a = \frac{A_s f_y}{0.85 f'_c b} = \frac{60\,ksi\,(1.24\,in^2)}{0.85(4)(12'')} = 1.82''$

$$M_n = 60(1.24\,in^2)\left(8.94" - \frac{1.82"}{2}\right)$$

$$M_n = 597'k$$

$$M_u = \frac{w\ell^2}{8} \quad \frac{(322\,plf)(26')^2}{8} = 27.2'k$$

↗ Conservative (all positive moment)

$$\phi M_n = 0.9\,(597'k) = 537.3'k$$

$$M_u = 27.2'k \leq \phi M_n = 537.3'k \;\checkmark$$

Table 4-1 *(Continued)*

Occupancy or Use	Uniform psf (kN/m²)	Conc. lb (kN)
Office buildings		
File and computer rooms shall be designed for heavier loads based on anticipated occupancy		
Lobbies and first-floor corridors	100 (4.79)	2,000 (8.90)
Offices	50 (2.40)	2,000 (8.90)
Corridors above first floor	80 (3.83)	2,000 (8.90)
Penal institutions		
Cell blocks	40 (1.92)	
Corridors	100 (4.79)	
Recreational uses		
Bowling alleys, poolrooms, and similar uses	75 (3.59)[a]	
Dance halls and ballrooms	100 (4.79)[a]	
Gymnasiums	100 (4.79)[a]	
Reviewing stands, grandstands, and bleachers	100 (4.79)[a,k]	
Stadiums and arenas with fixed seats (fastened to the floor)	60 (2.87)[a,k]	
Residential		
One- and two-family dwellings		
Uninhabitable attics without storage	10 (0.48)[l]	
Uninhabitable attics with storage	20 (0.96)[m]	
Habitable attics and sleeping areas	30 (1.44)	
All other areas except stairs	40 (1.92)	
All other residential occupancies		
Private rooms and corridors serving them	40 (1.92)	
Public rooms[a] and corridors serving them	100 (4.79)	
Roofs		
Ordinary flat, pitched, and curved roofs	20 (0.96)[n]	
Roofs used for roof gardens	100 (4.79)	
Roofs used for assembly purposes	Same as occupancy served	
Roofs used for other occupancies		
Awnings and canopies		
Fabric construction supported by a skeleton structure	5 (0.24) nonreducible	300 (1.33) applied to skeleton structure
Screen enclosure support frame	5 (0.24) nonreducible and applied to the roof frame members only, not the screen	200 (0.89) applied to supporting roof frame members only
All other construction	20 (0.96)	
Primary roof members, exposed to a work floor		
Single panel point of lower chord of roof trusses or any point along primary structural members supporting roofs over manufacturing, storage warehouses, and repair garages		2,000 (8.9)
All other primary roof members		300 (1.33)
All roof surfaces subject to maintenance workers		300 (1.33)
Schools		
Classrooms	40 (1.92)	1,000 (4.45)
Corridors above first floor	80 (3.83)	1,000 (4.45)
First-floor corridors	100 (4.79)	1,000 (4.45)
Scuttles, skylight ribs, and accessible ceilings		200 (0.89)
Sidewalks, vehicular driveways, and yards subject to trucking	250 (11.97)[a,p]	8,000 (35.60)[q]
Stairs and exit ways	100 (4.79)	300[r]
One- and two-family dwellings only	40 (1.92)	300[r]

F_y = 50 ksi

Table 3-2 (continued)
W-Shapes
Selection by Z_x

Z_x

Shape	Z_x	M_{px}/Ω_b	$\phi_b M_{px}$	M_{rx}/Ω_b	$\phi_b M_{rx}$	BF/Ω_b	$\phi_b BF$	L_p	L_r	I_x	V_{nx}/Ω_v	$\phi_v V_{nx}$
		kip-ft	kip-ft	kip-ft	kip-ft	kips	kips				kips	kips
	in.^{3}	ASD	LRFD	ASD	LRFD	ASD	LRFD	ft	ft	in.^{4}	ASD	LRFD
W21×55	**126**	314	473	192	289	10.8	16.3	**6.11**	**17.4**	**1140**	156	234
W14×74	126	314	473	196	294	5.31	8.05	8.76	31.0	795	128	192
W18×60	123	307	461	189	284	9.62	14.4	5.93	18.2	984	151	227
W12×79	119	297	446	187	281	3.78	5.67	10.8	39.9	662	117	175
W14×68	115	287	431	180	270	5.19	7.81	8.69	29.3	722	116	174
W10×88	113	282	424	172	259	2.62	3.94	9.29	51.2	534	131	196
W18×55	**112**	**279**	420	**172**	258	**9.15**	13.8	**5.90**	**17.6**	**890**	**141**	212
W21×50	**110**	**274**	413	**165**	248	**12.1**	18.3	**4.59**	**13.6**	**984**	**158**	237
W12×72	108	269	405	170	256	3.69	5.56	10.7	37.5	597	106	159
W21×48[f]	**107**	265	398	162	244	9.89	14.8	**6.09**	**16.5**	**959**	144	216
W16×57	105	262	394	161	242	7.98	12.0	5.65	18.3	758	141	212
W14×61	102	254	383	161	242	4.93	7.48	8.65	27.5	640	104	156
W18×50	101	252	379	155	233	6.76	13.2	5.83	16.9	800	128	192
W10×77	97.6	244	366	150	225	2.60	3.90	9.18	45.3	455	112	169
W12×65[f]	96.8	237	356	154	231	3.58	5.39	11.9	35.1	533	94.4	142
W21×44	**95.4**	238	358	143	214	11.1	16.8	**4.45**	**13.0**	**843**	145	217
W16×50	92.0	230	345	141	213	7.69	11.4	5.62	17.2	659	124	186
W18×46	90.7	226	340	138	207	9.63	14.6	4.56	13.7	712	130	195
W14×53	87.1	217	327	136	204	5.22	7.93	6.78	22.3	541	103	154
W12×58	86.4	216	324	136	205	3.82	5.69	8.87	29.8	475	87.8	132
W10×68	85.3	213	320	132	199	2.58	3.85	9.15	40.6	394	97.8	147
W16×45	82.3	205	309	127	191	7.12	10.8	5.55	16.5	586	111	167
W18×40	**78.4**	196	294	119	180	8.94	13.2	**4.49**	**13.1**	**612**	113	160
W14×48	78.4	196	294	123	184	5.09	7.67	6.75	21.1	484	93.9	141
W12×53	77.9	194	292	123	185	3.65	5.50	8.76	28.2	425	83.5	125
W10×60	74.6	186	280	116	175	2.54	3.82	9.08	36.6	341	85.7	129
W16×40	**73.0**	182	274	113	170	6.67	10.0	**5.55**	**15.9**	**518**	97.6	146
W12×50	71.9	179	270	112	169	3.97	5.98	6.92	23.8	391	90.3	135
W8×67	70.1	175	263	105	159	1.75	2.59	7.49	47.6	272	103	154
W14×43	69.6	174	261	109	164	4.88	7.28	6.68	20.0	428	83.6	125
W10×54	66.6	166	250	105	158	2.40	3.75	9.04	33.6	303	74.7	112

ASD	LRFD
Ω_b = 1.67	ϕ_b = 0.90
Ω_v = 1.50	ϕ_v = 1.00

[f] Shape exceeds compact limit for flexure with F_y = 50 ksi.

Z_x

Table 3-2 (continued)
W-Shapes
Selection by Z_x

F_y = 50 ksi

Shape	Z_x	M_{px}/Ω_b	$\phi_b M_{px}$	M_{rx}/Ω_b	$\phi_b M_{rx}$	BF/Ω_b	$\phi_b BF$	L_p	L_r	I_x	V_{nx}/Ω_v	$\phi_v V_{nx}$
		kip-ft	kip-ft	kip-ft	kip-ft	kips	kips				kips	kips
	in.^{3}	ASD	LRFD	ASD	LRFD	ASD	LRFD	ft	ft	in.^{4}	ASD	LRFD
W18×35	**66.5**	166	249	101	151	8.14	12.3	**4.31**	**12.3**	**510**	106	159
W12×45	64.2	160	241	101	151	3.80	5.80	6.89	22.4	348	81.1	122
W16×36	64.0	160	240	98.7	148	6.24	9.36	5.37	15.2	448	93.8	141
W14×38	61.5	153	231	95.4	143	5.37	8.20	5.47	16.2	385	87.4	131
W10×49	60.4	151	227	95.4	143	2.46	3.71	8.97	31.6	272	68.0	102
W8×58	59.8	149	224	90.8	137	1.70	2.55	7.42	41.6	228	89.3	134
W12×40	57.0	142	214	89.9	135	3.66	5.54	6.85	21.1	307	70.2	105
W10×45	54.9	137	206	85.8	129	2.59	3.89	7.10	26.9	248	70.7	106
W14×34	**54.6**	136	205	84.9	128	5.01	7.55	**5.40**	**15.6**	**340**	79.8	120
W16×31	**54.0**	135	203	82.4	124	6.86	10.3	**4.13**	**11.8**	**375**	87.5	131
W12×35	51.2	128	192	79.6	120	4.34	6.45	5.44	16.6	285	75.0	113
W8×48	49.0	122	184	75.1	113	1.67	2.55	7.35	35.2	184	68.0	102
W14×30	**47.3**	118	177	73.4	110	4.63	6.95	**5.26**	**14.9**	**291**	74.5	112
W10×39	46.8	117	176	73.5	111	2.53	3.78	6.99	24.2	209	62.5	93.7
W16×26[v]	**44.2**	110	166	67.1	101	5.93	8.98	**3.96**	**11.2**	**301**	70.5	106
W12×30	43.1	108	162	67.4	101	3.97	5.96	5.37	15.6	238	64.0	95.9
W14×26	**40.2**	100	151	61.7	92.7	5.33	8.11	**3.81**	**11.0**	**245**	70.9	106
W8×40	39.8	99.3	149	62.0	93.2	1.64	2.46	7.21	29.9	146	59.4	89.1
W10×33	38.8	96.8	146	61.1	91.9	2.39	3.62	6.85	21.8	171	56.4	84.7
W12×26	**37.2**	92.8	140	58.3	87.7	3.61	5.46	**5.33**	**14.9**	**204**	56.1	84.2
W10×30	36.6	91.3	137	56.6	85.1	3.08	4.61	4.84	16.1	170	63.0	94.5
W8×35	34.7	86.6	130	54.5	81.9	1.62	2.43	7.17	27.0	127	50.3	75.5
W14×22	**33.2**	82.8	125	50.6	76.1	4.78	7.27	**3.67**	**10.4**	**199**	63.0	94.5
W10×26	31.3	78.1	117	48.7	73.2	2.91	4.34	4.80	14.9	144	53.6	80.3
W8×31[f]	30.4	75.8	114	48.0	72.2	1.58	2.37	7.18	24.8	110	45.6	68.4
W12×22	**29.3**	73.1	110	44.4	66.7	4.68	7.06	**3.00**	**9.13**	**156**	64.0	95.9
W8×28	27.2	67.9	102	42.4	63.8	1.57	2.50	5.72	21.0	98.0	45.9	68.9
W10×22	**26.0**	64.9	97.5	40.5	60.9	2.68	4.02	**4.70**	**13.8**	**118**	49.0	73.4
W12×19	**24.7**	61.6	92.6	37.2	55.9	4.27	6.43	**2.90**	**8.61**	**130**	57.3	86.0
W8×24	23.1	57.6	86.6	36.5	54.9	1.60	2.40	5.69	18.9	82.7	38.9	58.3
W10×19	**21.6**	53.9	81.0	32.8	49.4	3.18	4.76	**3.09**	**9.73**	**96.3**	51.0	76.5
W8×21	20.4	50.9	76.5	31.8	47.8	1.85	2.77	4.45	14.8	75.3	41.4	62.1

ASD	LRFD
Ω_b = 1.67	ϕ_b = 0.90
Ω_v = 1.50	ϕ_v = 1.00

[f] Shape exceeds compact limit for flexure with F_y = 50 ksi.

[v] Shape does not meet the h/t_w limit for shear in AISC *Specification* Section G2.1(a) with F_y = 50 ksi; therefore, ϕ_v = 0.90 and Ω_v = 1.67.

FLAT PLATE SYSTEM
(WITHOUT SHEARHEADS)

f'_c = 4,000 psi
Grade 60 Bars

SQUARE EDGE PANEL

10 in. = TOTAL THICKNESS OF SLAB — 0.833 c.f./s.f.

SPAN c.-c. Cols. $\ell_1 = \ell_2$ (ft)	Factored Superimposed Load (psf)	(1) Min. Square Column (in.)	(1) Min. Square Column γ_f	Total Panel Moments −M Ext. (ft-kip)	Total Panel Moments +M Int. (ft-kip)	Total Panel Moments −M 1st int. (ft-kip)	Reinforcing Bars Each Column Strip Top Ext. +	Reinforcing Bars Each Column Strip Bottom	Reinforcing Bars Each Column Strip Top Int.	Reinforcing Bars Each Middle Strip Bottom	Reinforcing Bars Each Middle Strip Top Int.	End Panel Steel (psf) Location of Panel E	End Panel Steel (psf) Location of Panel EC	End Panel Steel (psf) Location of Panel C
20	50	10	0.860	48	96	129	9-#5 1	7-#5	9-#5	7-#5	7-#5	2.22	2.22	2.23
20	100	13	0.836	59	118	159	9-#5 2	7-#5	11-#5	7-#5	7-#5	2.26	2.28	2.28
20	150	16	0.794	68	137	184	9-#5 2	7-#5	12-#5	7-#5	7-#5	2.34	2.36	2.36
20	200	18	0.797	78	156	210	9-#5 3	8-#5	10-#6	7-#5	7-#5	2.53	2.55	2.57
20	250	21	0.752	87	175	235	9-#5 3	9-#5	11-#6	7-#5	7-#5	2.68	2.69	2.65
20	300	24	0.643	96	192	259	9-#5 1	10-#5	9-#7	7-#5	7-#5	2.79	2.82	2.82
20	350	26	0.623	104	209	281	9-#5 1	8-#6	10-#7	8-#5	7-#5	3.05	3.07	3.03
21	50	11	0.864	55	111	149	10-#5 1	8-#5	10-#5	8-#5	8-#5	2.33	2.33	2.31
21	100	15	0.802	68	136	183	10-#5 1	8-#5	12-#5	8-#5	8-#5	2.43	2.45	2.45
21	150	18	0.780	79	158	212	10-#5 2	9-#5	10-#6	8-#5	8-#5	2.57	2.59	2.56
21	200	21	0.738	90	179	241	10-#5 2	7-#6	16-#5	8-#5	8-#5	2.72	2.73	2.65
21	250	24	0.714	100	201	270	10-#5 3	8-#6	10-#7	8-#5	8-#5	2.89	2.92	2.87
21	300	26	0.704	110	220	296	10-#5 3	12-#5	11-#7	8-#5	8-#5	3.01	3.05	3.18
21	350	29	0.656	119	238	320	11-#5 2	7-#7	12-#7	9-#5	8-#5	3.28	3.31	3.35
22	50	13	0.830	63	127	170	10-#5 1	8-#5	11-#5	8-#5	8-#5	2.29	2.29	2.31
22	100	17	0.785	77	155	208	10-#5 2	8-#5	10-#6	8-#5	8-#5	2.40	2.41	2.37
22	150	20	0.747	91	181	244	10-#5 2	10-#5	16-#5	8-#5	8-#5	2.58	2.59	2.52
22	200	23	0.730	103	205	276	10-#5 3	8-#6	10-#7	8-#5	8-#5	2.75	2.78	2.75
22	250	26	0.691	114	228	307	10-#5 3	12-#5	11-#7	8-#5	8-#5	2.95	2.95	3.03
22	300	29	0.673	124	249	335	11-#5 3	13-#5	12-#7	9-#5	8-#5	3.12	3.16	3.27
22	350	32	0.632	134	268	361	12-#5 2	10-#6	10-#8	10-#5	8-#5	3.41	3.44	3.54
23	50	15	0.836	72	144	194	11-#5 3	9-#5	13-#5	9-#5	9-#5	2.47	2.49	2.48
23	100	19	0.798	88	175	236	11-#5 4	9-#5	11-#6	9-#5	9-#5	2.62	2.62	2.53
23	150	22	0.737	102	204	275	11-#5 2	8-#6	13-#6	9-#5	9-#5	2.81	2.83	2.80
23	200	26	0.668	115	231	311	11-#5 2	12-#5	11-#7	9-#5	9-#5	3.00	3.00	3.02
23	250	29	0.656	128	256	345	11-#5 3	10-#6	13-#7	9-#5	9-#5	3.20	3.23	3.26
23	300	32	0.620	140	280	378	12-#5 2	8-#7	11-#8	10-#5	8-#5	3.47	3.49	3.47
23	350	36	0.612	151	301	406	13-#5 2	16-#5	12-#8	8-#6	9-#5	3.70	3.73	3.76
24	50	17	0.804	81	163	219	11-#5 3	9-#5	11-#6	9-#5	9-#5	2.46	2.48	2.43
24	100	21	0.769	99	197	266	11-#5 4	8-#6	13-#6	9-#5	9-#5	2.69	2.71	2.71
24	150	24	0.727	115	230	310	11-#5 3	12-#5	11-#7	9-#5	9-#5	2.84	2.85	2.90
24	200	28	0.723	130	260	350	12-#5 5	10-#6	13-#7	9-#5	9-#5	3.10	3.13	3.16
24	250	32	0.667	144	287	387	13-#5 4	8-#7	11-#8	10-#5	9-#5	3.35	3.37	3.40
24	300	35	0.641	157	315	423	14-#5 3	9-#7	12-#8	8-#6	9-#5	3.71	3.74	3.78
24	350	40	0.611	167	333	448	15-#5 2	8-#8	13-#8	12-#5	10-#5	3.97	4.02	4.13
25	50	18	0.810	92	183	247	12-#5 3	10-#5	16-#5	9-#5	9-#5	2.46	2.47	2.44
25	100	23	0.753	111	221	298	12-#5 4	12-#5	14-#6	9-#5	9-#5	2.73	2.75	2.69
25	150	27	0.704	128	257	346	12-#5 4	10-#6	13-#7	9-#5	9-#5	2.97	3.01	3.04
25	200	31	0.671	145	290	390	13-#5 4	11-#6	14-#7	10-#5	9-#5	3.23	3.25	3.29
25	250	35	0.617	160	321	432	14-#5 3	9-#7	12-#8	11-#5	10-#5	3.58	3.60	3.75
25	300	39	0.611	173	346	466	15-#5 3	10-#7	13-#8	12-#5	10-#5	3.84	3.89	4.14
25	350	46	0.610	181	361	486	16-#5 2	10-#7	14-#8	9-#6	11-#5	4.10	4.13	4.28

SQUARE INTERIOR PANEL

10 in. = TOTAL THICKNESS OF SLAB — 0.833 c.f./s.f.

(2) Span c.-c. (ft)	(3) Load (psf)	(1) Min. Sq. Col. (in.)	Reinforcing Bars Column Strip Top	Reinforcing Bars Column Strip Bottom	Reinforcing Bars Middle Strip Top	Reinforcing Bars Middle Strip Bottom	Steel (psf) Location of Panel I	Steel (psf) Location of Panel IE	Steel (psf) Location of Panel IC
20	50	10	9-#5	7-#5	7-#5	7-#5	2.21	2.21	2.21
20	100	10	10-#5	7-#5	7-#5	7-#5	2.27	2.28	2.30
20	150	15	12-#5	7-#5	7-#5	7-#5	2.42	2.42	2.42
20	200	18	9-#6	7-#5	7-#5	7-#5	2.49	2.52	2.54
20	250	19	11-#6	7-#5	7-#5	7-#5	2.69	2.68	2.68
20	300	21	16-#5	7-#5	7-#5	7-#5	2.70	2.73	2.76
20	350	24	10-#7	8-#5	7-#5	7-#5	3.04	3.04	3.04
21	50	10	10-#5	8-#5	8-#5	8-#5	2.35	2.35	2.35
21	100	10	12-#5	8-#5	8-#5	8-#5	2.47	2.47	2.47
21	150	15	13-#5	8-#5	8-#5	8-#5	2.55	2.57	2.59
21	200	18	11-#6	8-#5	8-#5	8-#5	2.74	2.74	2.74
21	250	20	12-#6	8-#5	8-#5	8-#5	2.84	2.88	2.91
21	300	24	10-#7	8-#5	8-#5	8-#5	3.00	3.04	3.07
21	350	27	20-#5	9-#5	8-#5	8-#5	3.14	3.20	3.25
22	50	10	11-#5	8-#5	8-#5	8-#5	2.30	2.30	2.30
22	100	12	13-#5	8-#5	8-#5	8-#5	2.42	2.44	2.46
22	150	15	11-#6	8-#5	8-#5	8-#5	2.60	2.60	2.60
22	200	19	17-#5	8-#5	8-#5	8-#5	2.69	2.72	2.76
22	250	23	11-#7	8-#5	8-#5	8-#5	2.98	2.98	2.97
22	300	27	11-#7	9-#5	8-#5	8-#5	3.09	3.12	3.15
22	350	31	12-#7	10-#5	8-#5	8-#5	3.30	3.33	3.36
23	50	10	12-#5	9-#5	9-#5	9-#5	2.48	2.49	2.50
23	100	13	11-#6	9-#5	9-#5	9-#5	2.70	2.70	2.70
23	150	18	17-#5	9-#5	9-#5	9-#5	2.79	2.81	2.83
23	200	22	11-#7	9-#5	9-#5	9-#5	3.06	3.06	3.06
23	250	26	12-#7	9-#5	9-#5	9-#5	3.20	3.22	3.25
23	300	30	13-#7	10-#5	9-#5	9-#5	3.40	3.42	3.45
23	350	34	11-#8	8-#6	9-#5	9-#5	3.69	3.73	3.77
24	50	11	14-#5	9-#5	9-#5	9-#5	2.48	2.51	2.53
24	100	15	12-#6	9-#5	9-#5	9-#5	2.67	2.69	2.71
24	150	20	11-#7	9-#5	9-#5	9-#5	2.92	2.92	2.92
24	200	24	12-#7	10-#5	9-#5	9-#5	3.11	3.14	3.16
24	250	29	13-#7	10-#5	9-#5	9-#5	3.24	3.28	3.32
24	300	33	11-#8	8-#6	9-#5	9-#5	3.53	3.56	3.60
24	350	40	12-#8	12-#5	9-#5	9-#5	3.74	3.79	3.84
25	50	12	16-#5	9-#5	9-#5	9-#5	2.49	2.49	2.49
25	100	17	14-#6	9-#5	9-#5	9-#5	2.72	2.72	2.72
25	150	22	12-#7	9-#5	9-#5	9-#5	2.91	2.94	2.96
25	200	27	13-#7	11-#5	9-#5	9-#5	3.18	3.21	3.23
25	250	32	12-#8	12-#5	9-#5	9-#5	3.55	3.56	3.57
25	300	39	12-#8	12-#5	10-#5	9-#5	3.62	3.66	3.69
25	350	48	13-#8	9-#6	10-#5	9-#5	3.89	3.94	3.99

(Continued on next Page)

(1) Columns same above and below plate.

(2) Center-to-center of columns; $\ell_1 = \ell_2$.

(3) Superimposed factored load (factored dead load has been deducted).

FLAT PLATE SYSTEM (WITHOUT SHEARHEADS)

f'_c = 4,000 psi
Grade 60 Bars

SQUARE EDGE PANEL

10 in. = TOTAL THICKNESS OF SLAB — 0.833 c.f./s.f.

SPAN c.-c. Cols. $\ell_1 = \ell_2$ (ft)	Factored Superimposed Load (psf)	(1) Min. Square Column (in.)	γ_f	Total Panel Moments −M Ext. (ft-kip)	+M Int. (ft-kip)	−M 1st Int. (ft-kip)	Reinforcing Bars: Each Column Strip Top Ext. +	Each Column Strip Bottom	Each Column Strip Top Int.	Each Middle Strip Bottom	Each Middle Strip Top Int.	End Panel Steel (psf), Location of Panel: E	EC	C
26	50	20	0.791	102	204	275	12-#5 4	11-#5	13-#6	10-#5	10-#5	2.59	2.61	2.55
26	100	25	0.723	123	247	332	12-#5 4	13-#5	12-#7	10-#5	10-#5	2.84	2.85	2.79
26	150	29	0.696	143	286	385	13-#5 4	11-#6	14-#7	10-#5	10-#5	3.11	3.13	3.13
26	200	34	0.617	161	322	434	14-#5 3	9-#7	12-#8	11-#5	10-#5	3.46	3.48	3.61
26	250	38	0.658	178	355	478	16-#5 5	10-#7	17-#7	9-#6	11-#5	3.81	3.84	4.05
26	300	45	0.610	188	376	507	12-#6 2	14-#6	14-#8	13-#5	11-#5	3.99	4.02	4.20
26	350	52	0.609	196	392	528	17-#5 2	9-#8	15-#8	10-#6	12-#5	4.32	4.37	4.43
27	50	22	0.760	113	227	305	12-#5 4	12-#5	20-#5	10-#5	10-#5	2.60	2.62	2.61
27	100	27	0.710	137	274	369	12-#5 5	11-#6	13-#7	10-#5	10-#5	2.92	2.93	2.91
27	150	32	0.639	159	317	427	14-#5 3	9-#7	12-#8	11-#5	10-#5	3.26	3.28	3.29
27	200	36	0.671	179	358	481	16-#5 5	10-#7	14-#8	9-#6	11-#5	3.69	3.74	3.93
27	250	43	0.610	193	386	520	12-#6 2	11-#7	15-#8	10-#6	12-#5	4.04	4.10	4.26
27	300	51	0.609	204	407	548	13-#6 1	9-#8	16-#8	10-#6	12-#5	4.24	4.31	4.55
27	350	58	0.608	212	423	570	19-#5 1	12-#7	16-#8	11-#6	9-#6	4.47	4.52	4.72
28	50	24	0.743	126	252	339	13-#5 4	13-#5	16-#6	10-#5	10-#5	2.64	2.65	2.63
28	100	29	0.698	151	303	407	13-#5 5	16-#5	15-#7	11-#5	10-#5	3.01	3.03	3.07
28	150	34	0.686	175	350	472	15-#5 6	10-#7	13-#8	12-#5	10-#5	3.42	3.44	3.54
28	200	41	0.611	195	390	525	17-#5 4	11-#7	15-#8	10-#6	12-#5	3.88	3.90	4.03
28	250	48	0.609	209	418	563	13-#6 1	12-#7	16-#8	11-#6	12-#5	4.19	4.24	4.46
28	300	56	0.608	220	440	592	19-#5 3	10-#8	17-#8	11-#6	13-#5	4.40	4.47	4.68
28	350	64	0.607	229	457	616	20-#5 1	10-#8	18-#8	16-#5	10-#6	4.67	4.75	4.93
29	50	26	0.711	139	277	373	13-#5 4	11-#6	13-#7	11-#5	11-#5	2.85	2.86	2.85
29	100	32	0.674	167	333	448	15-#5 5	10-#7	13-#8	12-#5	11-#5	3.29	3.32	3.38
29	150	37	0.638	192	385	518	17-#5 4	20-#5	15-#8	10-#6	11-#5	3.71	3.74	3.82
29	200	45	0.610	212	423	570	19-#5 3	12-#7	16-#8	11-#6	13-#5	4.07	4.12	4.31
29	250	54	0.608	226	451	607	14-#6 3	10-#8	17-#8	16-#5	13-#5	4.34	4.39	4.55
29	300	63	0.607	236	472	635	15-#6 0	11-#8	18-#8	12-#6	10-#6	4.72	4.77	4.94
29	350	71	0.607	245	490	659	16-#6 0	11-#8	19-#8	17-#5	11-#6	4.90	4.97	5.18
30	50	28	0.724	152	305	410	14-#5 6	16-#5	15-#7	11-#5	11-#5	2.92	2.94	2.90
30	100	34	0.665	183	366	493	16-#5 5	14-#6	14-#8	13-#5	11-#5	3.37	3.42	3.55
30	150	41	0.663	210	420	565	19-#5 6	12-#7	16-#8	11-#6	13-#5	3.96	3.97	4.00
30	200	50	0.609	228	457	615	20-#5 5	10-#8	18-#8	16-#5	10-#6	4.19	4.26	4.44
30	250	60	0.608	242	484	652	15-#6 3	11-#8	19-#8	12-#6	10-#6	4.57	4.64	4.81
30	300	69	0.607	254	507	683	16-#6 2	11-#8	20-#8	10-#7	11-#6	4.93	4.99	5.25
30	350	78	0.606	262	523	704	23-#5 1	10-#9	20-#8	10-#7	11-#6	5.16	5.23	5.60
31	50	30	0.708	167	334	450	15-#5 6	13-#6	16-#7	12-#5	11-#5	3.03	3.04	3.11
31	100	36	0.695	200	401	540	18-#5 7	15-#6	15-#8	14-#5	12-#5	3.51	3.57	3.70
31	150	46	0.610	226	452	608	14-#6 3	13-#7	17-#8	16-#5	13-#5	4.01	4.03	4.18
31	200	56	0.608	245	489	658	16-#6 2	11-#8	19-#8	12-#6	11-#6	4.45	4.52	4.71
31	250	66	0.607	259	519	699	23-#5 3	12-#8	20-#8	13-#6	11-#6	4.79	4.86	5.13
31	300	75	0.606	271	542	730	17-#6 2	12-#8	21-#8	14-#6	16-#5	5.05	5.12	5.45
31	350	85	0.606	279	558	752	18-#6 0	13-#8	22-#8	14-#6	12-#6	5.33	5.42	5.72

SQUARE INTERIOR PANEL

10 in. = TOTAL THICKNESS OF SLAB — 0.833 c.f./s.f.

(2) Span c.-c. (ft)	(3) Load (psf)	(1) Min. Sq. Col. (in.)	Reinforcing Bars: Column Strip Top	Column Strip Bottom	Middle Strip Top	Middle Strip Bottom	Steel (psf), Location of Panel: I	IE	IC
26	50	14	17-#5	10-#5	10-#5	10-#5	2.60	2.62	2.64
26	100	19	15-#6	10-#5	10-#5	10-#5	2.85	2.87	2.89
26	150	25	13-#7	10-#5	10-#5	10-#5	3.06	3.09	3.11
26	200	30	12-#8	12-#5	10-#5	10-#5	3.49	3.49	3.49
26	250	36	13-#8	9-#6	10-#5	10-#5	3.73	3.74	3.75
26	300	45	13-#8	13-#5	10-#5	10-#5	3.78	3.82	3.86
26	350	55	14-#8	10-#6	11-#5	10-#5	4.09	4.14	4.19
27	50	16	14-#6	10-#5	10-#5	10-#5	2.66	2.66	2.65
27	100	21	13-#7	10-#5	10-#5	10-#5	2.93	2.93	2.93
27	150	27	19-#6	12-#5	10-#5	10-#5	3.18	3.22	3.26
27	200	33	13-#8	9-#6	10-#5	10-#5	3.58	3.62	3.66
27	250	42	14-#8	10-#6	11-#5	10-#5	3.87	3.91	3.95
27	300	52	14-#8	11-#6	11-#5	10-#5	4.03	4.10	4.18
27	350	63	15-#8	11-#6	12-#5	10-#5	4.26	4.30	4.35
28	50	17	15-#6	10-#5	10-#5	10-#5	2.63	2.65	2.66
28	100	24	14-#7	11-#5	10-#5	10-#5	3.00	3.02	3.04
28	150	30	13-#8	13-#5	10-#5	10-#5	3.43	3.43	3.43
28	200	37	14-#8	10-#6	11-#5	10-#5	3.70	3.74	3.78
28	250	49	15-#8	11-#6	12-#5	10-#5	4.02	4.06	4.09
28	300	60	15-#8	11-#6	12-#5	10-#5	4.08	4.15	4.23
28	350	70	16-#8	16-#5	12-#5	11-#5	4.33	4.42	4.52
29	50	19	13-#7	11-#5	11-#5	11-#5	2.90	2.89	2.89
29	100	26	15-#7	12-#5	11-#5	11-#5	3.15	3.19	3.24
29	150	33	14-#8	10-#6	11-#5	11-#5	3.62	3.65	3.68
29	200	43	15-#8	11-#6	12-#5	11-#5	3.92	3.96	4.00
29	250	55	16-#8	16-#5	12-#5	11-#5	4.10	4.14	4.18
29	300	67	17-#8	12-#6	13-#5	11-#5	4.40	4.45	4.49
29	350	78	17-#8	12-#6	13-#5	11-#5	4.46	4.55	4.65
30	50	21	14-#7	11-#5	11-#5	11-#5	2.89	2.91	2.93
30	100	28	17-#7	13-#5	11-#5	11-#5	3.29	3.32	3.34
30	150	36	15-#8	11-#6	12-#5	11-#5	3.76	3.79	3.83
30	200	49	16-#8	16-#5	13-#5	11-#5	3.96	4.03	4.10
30	250	62	17-#8	12-#6	13-#5	11-#5	4.22	4.29	4.36
30	300	74	18-#8	10-#7	10-#6	12-#5	4.64	4.72	4.79
30	350	86	18-#8	10-#7	10-#6	12-#5	4.70	4.78	4.86
31	50	23	15-#7	12-#5	11-#5	11-#5	2.93	2.95	2.97
31	100	31	14-#8	14-#5	11-#5	11-#5	3.35	3.38	3.42
31	150	42	16-#8	16-#5	13-#5	11-#5	3.80	3.82	3.85
31	200	56	17-#8	17-#5	13-#5	12-#5	4.08	4.17	4.25
31	250	69	18-#8	13-#6	14-#5	12-#5	4.40	4.48	4.55
31	300	82	19-#8	14-#6	11-#6	13-#5	4.79	4.85	4.92
31	350	94	19-#8	14-#6	11-#6	13-#5	4.85	4.96	5.07

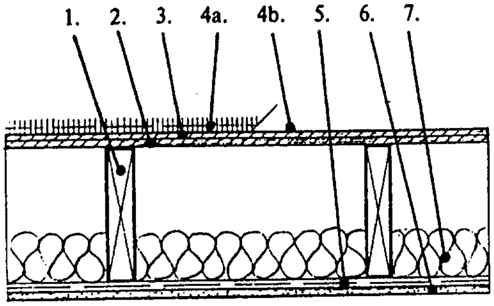
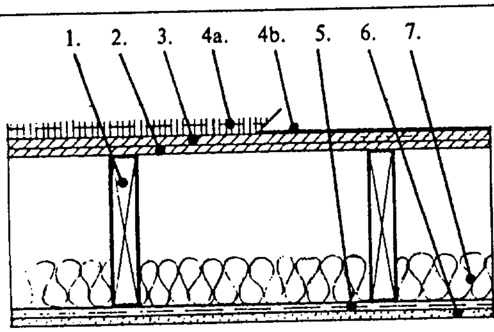
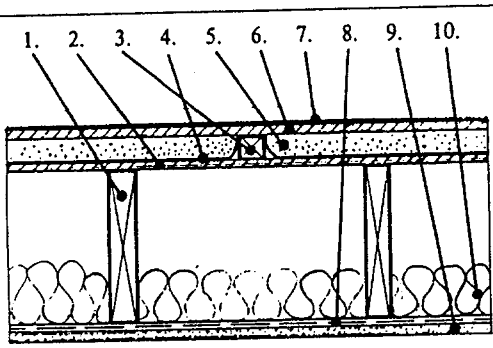
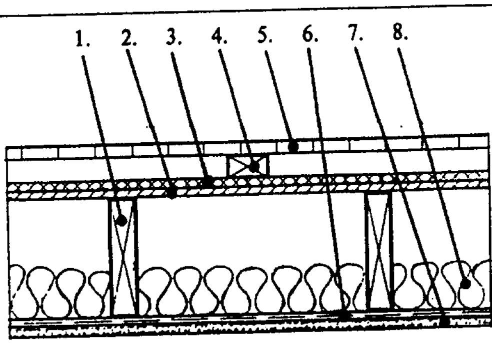
(1) Columns same above and below plate.

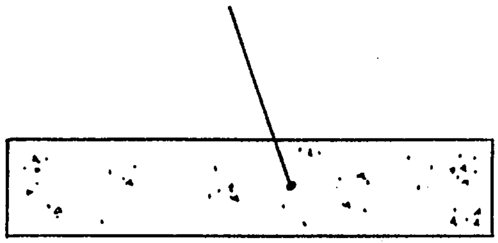
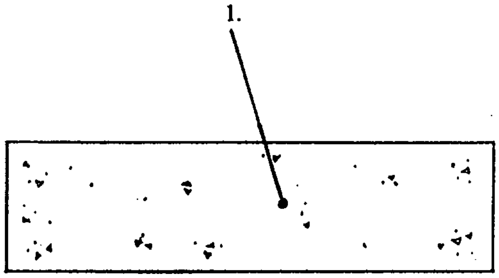
(2) Center-to-center of columns; $\ell_1 = \ell_2$.

(3) Superimposed factored load (factored dead load has been deducted).

APPENDIX B

ACOUSTICAL BREADTH INFORMATION

Sketch	Brief Description	...	Laboratory Test Number Year Frequencies Tested Source of Data	STC / IIC	Section Number
	1. 2x8 joists, 16"o.c. 2. 1/2" plywood subfloor nailed to joists. 3. 3/8" plywood nailed to joists. 4a. carpet and pad. 4b. no floor covering. 5. resilient channels, 24"o.c. 6. 5/8" type X gypsum board screwed 12"o.c. 7. 3" thick sound attenuation blanket.	...	National Gypsum Co. 4021 5027 5026 1964 16f Gypsum Association	47 a. 62 b. 43	2.1.2.2.1.5
	1. 2x10 joists, 16"o.c. 2. 1/2" plywood nailed with 6d nails 6"o.c. at edges and 10"o.c. in field. 3. 5/8" plywood stapled 3"o.c. at edges and 6"o.c. in field. 4a. 44 oz. carpet on 40 oz. hair pad. 4b. 1/16" vinyl asbestos tile. 5. resilient channels, 16"o.c. 6. 1/2" type X gypsum board screwed 12"o.c. 7. 3" thick sound attenuation blanket.	...	Cedar Knolls Acoustical Labs. 6712-8 6712-7 1967 16f Domtar Gypsum America Inc.	47 a. 59 b. 44	2.1.2.2.1.6
	1. 2x10 joists, 16"o.c. 2. 1/2" plywood glued continuously and nailed 12"o.c. 3. 2x2 sleepers between joists, 16"o.c., glued continuously and lightly nailed. 4. 4 mil. plastic over subfloor and sleepers. 5. 1 1/2" sand. 6. 5/8" tongue and groove plywood, stapled 12"o.c. 7. .07" vinyl asbestos tile. 8. resilient channels, 24"o.c. 9. 5/8" gypsum board screwed 12"o.c. 10. 3" thick sound attenuation blanket.	...	Riverbank Acoustical Labs. TL71-279 IN71-19 1971 16f U.S. Dept. of Agriculture	59 56	2.1.2.2.1.7
	1. 2x8 joists, 16"o.c. 2. 1/2" plywood nailed with 8d nails 6"o.c. at edges and 10"o.c. in the field. 3. 1/2" wood-fiber board stapled 24"o.c. each way. 4. 2x3 furring strips, 16"o.c. glued to insulation board, parallel to and between joists. 5. 25/32" wood strip flooring. 6. resilient channels, 24"o.c. 7. 5/8" gypsum board screwed 12"o.c. 8. 3" thick sound attenuation blanket.	...	Kodaras Acoustical Labs. 224-10-65 224-9-65 1965 11f 16f American Plywood Assn.	53 51	2.1.2.2.1.8

Sketch	Brief Description	...	Laboratory Test Number Year Frequencies Tested Source of Data	STC IIC	Section Number
1. 	1. 6" thick concrete slab, 75 psf.	...	Riverbank Acoustical Labs. NA NA 16f Prestressed Concrete Inst.	55 34	2.3.2.1.1.1
1. 	1. 8" thick concrete slab, 95 psf.	...	Riverbank Acoustical Labs. TL 76-77 1977 16f Prestressed Concrete Inst.	58 NA	2.3.2.1.1.2

Acoustics, Salter, 1998

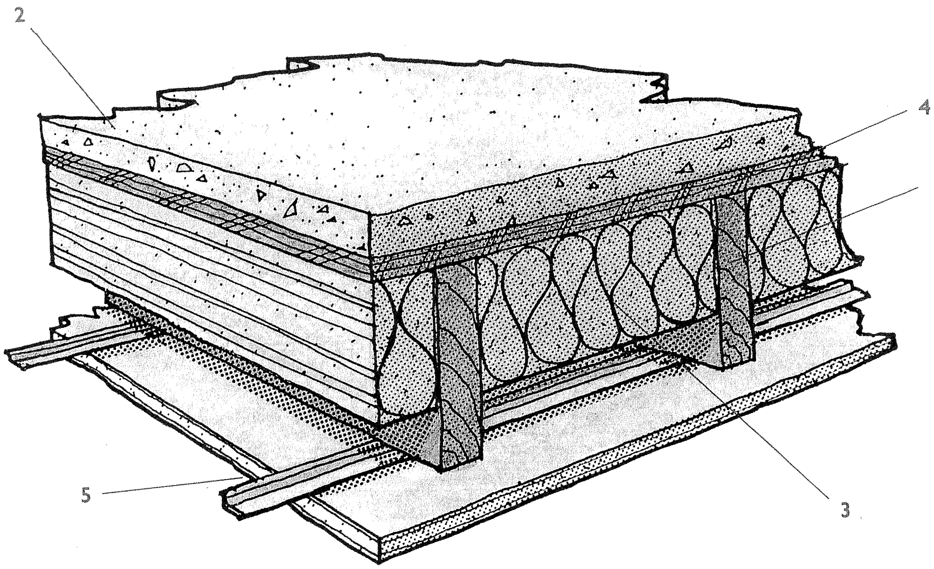


Figure 7.8 Wood-frame floor/ceiling construction. *Key:* (1) 38 x 235 mm (2 x 10) joists; (2) 38 mm (1½ in.) cellular concrete or 19 mm (¾ in.) gypsum cement topping; (3) batt insulation or mineral wool; (4) 16 mm (⅝ in.) plywood subflooring, (5) 13 mm (½ in.) resilient channels.

The following can be gleaned from the measured data for floor/ceiling constructions: (1) The combination of resilient channels and batt insulation increases the STC by 10 points; (2) 19 mm (¾ in.) gypsum cement or 38 mm (1½ in.) cellular concrete adds about 9 points to the STC rating when the ceiling is isolated; (3) 19 mm (¾ in.) gypsum cement provides about the same sound insulation performance as 38 mm (1½ in.) cellular concrete; and (4) Mineral wool is acoustically equivalent to glass fiber batt for a given thickness.

Data for Concrete Floating Floors

Figure 7.9 shows a floating floor construction on structural concrete slab with a resiliently suspended ceiling below. The separate gypsum board walls help control the flanking of sound around the floor/ceiling construction. This construction can attain STC 80 with the isolated wall constructions but would be limited to about STC 65 without the "anti-flanking" isolated wall constructions. This construction is called a *room within a room* technique since the walls, floors, and ceilings are double and isolated from one another.

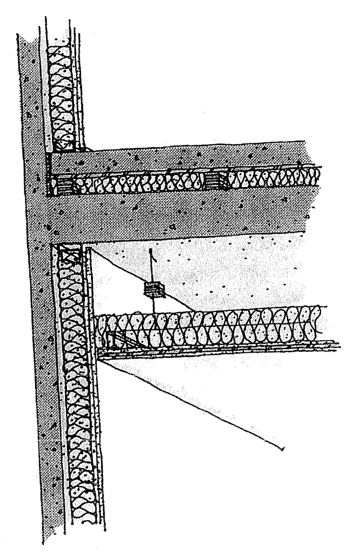


Figure 7.9 Floating floor construction with isolated ceiling and walls.

Data for Impact Insulation

Table 7.3 lists the IIC values for laboratory tests conducted on (1) wood frame and (2) concrete floor/ceiling constructions. Commercial flooring products are available that allow hard-surfaced floors such as ceramic tile and hardwood to achieve IIC values that meet the building code requirements.

, Salter, 1998

2. Concrete slab without ceiling

Floor finish	IIC
None	35
Parquet	50
Sheet vinyl	51
Cushioned vinyl	58
Carpet/pad	80

1. Wood frame

Lightweight concrete	Insulation batts	Resilient channels	Floor finish	IIC
Yes	None	Yes	Sheet vinyl	36
None	None	None	Parquet	39
Yes	None	None	Parquet	40
Yes	None	None	Cushioned vinyl	41
Yes	None	Yes	Parquet	50
Yes	Yes	Yes	Parquet	52
Yes	None	Yes	Cushioned vinyl	55
Yes	None	None	Carpet/pad	61
None	None	None	Carpet/pad	61
Yes	None	Yes	Carpet/pad	76
Yes	Yes	Yes	Carpet/pad	79

Table 7.3 IIC ratings of floor/ceiling constructions. Ceilings are 16 mm (5/8 in.) gypsum board. Batts are 76 mm (3 in.) thick.

10 General Rules about Sound Insulation

1. A doubling in mass is expected to cause a 5 STC point increase.
2. For air spaces greater than 25 mm (1 in.) between panels, every doubling is expected to increase STC by about 5 points if reverberant sound in cavity is controlled.
3. Adding insulation in a construction with direct framing attachment is of limited value—typically about a 2 point improvement.
4. Increasing the number of direct framing attachments results in lower STC.
5. In constructions with rigid framing attachments, the TL values can vary significantly due to subtle differences in connections.
6. STC increases by 5 to 10 points when insulation is added to isolated constructions.
7. Staggered stud construction is acoustically comparable to resilient channel construction.
8. The small air space between the two single stud walls significantly reduces the STC rating as compared to a double stud partition (compare 6d to 6f).
9. Light gauge 0.6 mm (25 ga.) metal studs are acoustically equivalent to wood studs and resilient channels or staggered wood stud construction.
10. It is important to seal both faces of a concrete masonry wall in order to control sound leaks. (Sealing can be achieved by painting, plastering, or gypsum board furring.)

Conclusion

The principles of sound insulation are important when addressing noise control in buildings. They are helpful in understanding the information discussed in Chapter 17, 18, 19, and 21.

Notes

1. NBS results were published in *NBS Building Science Series 77: Acoustical and Thermal Performance of Exterior Residential Walls, Doors and Windows,* November 1975.

2. M. David Egan, *Architectural Acoustics* (McGraw-Hill Book Company, 1988).

3. Data compiled in *Catalog of STC and IIC Ratings for Walls and Floor/Ceiling Assemblies*, California Office of Noise Control, 1981.

Impact and Vibration

Impact and vibration are the two most common sources of structure-borne sounds. Impact is the result of a force that occurs for a short duration. Though an impact force may be repetitive, its repetition is usually not periodic in nature. Vibration, on the other hand, is periodic and continuous.

Walking, jogging and dancing are obvious examples of impact sounds. Other impact sources are playing basketball, bowling, wheeling equipment and furniture, slamming of a door, etc. Vibration is usually produced by machinery and equipment mounted on floors, such as air conditioning equipment, fans, pumps etc. Vibration control is best achieved by mounting the equipment on vibration isolators. Since this is a specialized subject, it is covered separately in Chapter 15.

In this chapter, we shall deal only with impact sound insulation. Although airborne sound insulation is required of all barriers — walls, floor-ceiling assemblies and roofs — impact sound insulation is primarily required of floors, because most impact-producing sources rest on floors. Therefore, this chapter is limited to the sound insulation of floor-ceiling assemblies only.

Insulation and Isolation

In most architectural acoustics literature, the terms "sound insulation" and "sound isolation" are used synonymously, although, there is a subtle difference between the two terms. Sound insulation is similar to thermal insulation, and is the reduction of sound energy as the sound passes through an element from one side to the other.

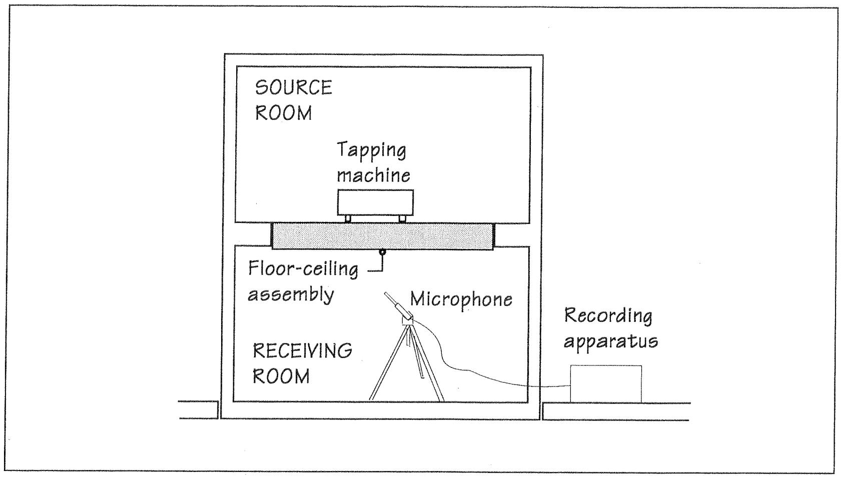
The reduction in sound energy caused by isolating the sound source from the receiver is referred to as sound isolation. Thus, a reduction in the transmission of sound energy obtained through structural discontinuity or break is referred to as sound isolation. Similarly, enclosing a sound source in an enclosure is also a form of sound isolation.

Since the most important factor that affects the transmission of impact sound from one side of the floor to the other is structural isolation, the term "impact isolation" is used interchangeably with "impact insulation".

7.1 IMPACT INSULATION CLASS (IIC)

The structure-borne sound insulation of a floor-ceiling assembly is measured in a two-room set-up, one room above the other. The floor between the two rooms has an opening in which the floor-ceiling assembly, to be tested, is tightly fitted, Figure 7.1. A standard tapping machine, which has five equally spaced hammers, is placed on the test assembly to produce impact at a constant rate. The tapping machine noise transmitted to the lower receiving room is measured in sixteen one-third octave bands, from 100 Hz to 3,150 Hz. The greater the noise level in the receiving room, the lower the sound insulation of floor-ceiling assembly.

Using the above noise level data, a single number rating of structure-borne sound insulation of the assembly is obtained by comparing it with a standard contour, Figure 7.2. The rating so obtained is called the *impact insulation class* (IIC), and the standard contour is referred to as the IIC contour[7.1].



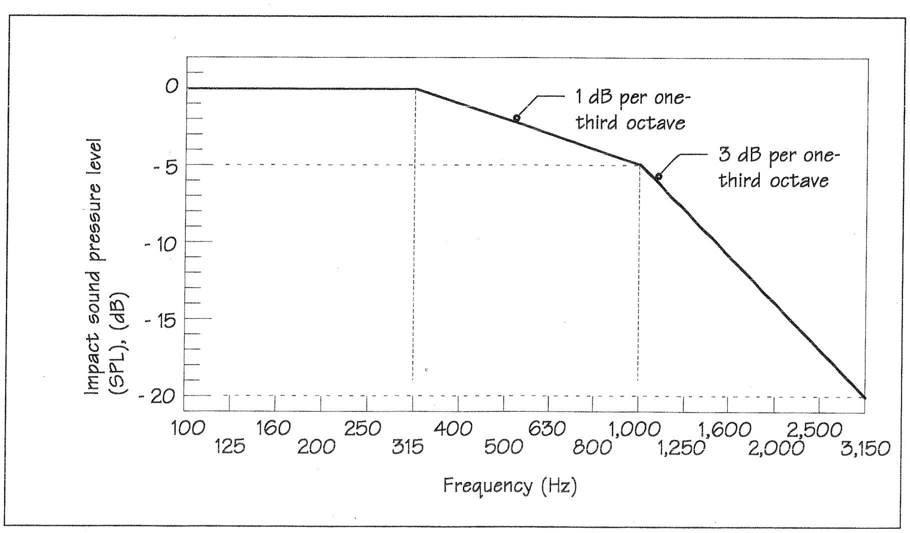
7.1 *Experimental set-up for measuring structure-borne sound insulation of a floor-ceiling assembly.*

The procedure to determine the IIC value is similar to that of determining the STC value of an assembly. The measured noise levels are plotted on a graph paper. Next we overlay the IIC contour on this plot and move the contour vertically as far down as possible until the following two conditions are met.

- The sum of deficiencies at 16 one-third octave bands does not exceed 32 dB.
- The maximum deficiency at any single one-third octave does not exceed 8 dB.

A deficiency is a measurement that lies above the IIC contour, not below the contour (unlike the STC measurement). When both conditions are met, the noise level corresponding to 500 Hz is subtracted from 110 dB. The resulting value is the IIC of the assembly, as further explained at the end of this chapter.

In stating the IIC value, the unit dB is omitted. Therefore, IIC is simply a number, just like the STC. The greater the IIC value, the higher the structure-borne sound insulation of the assembly.



7.2 *Standard IIC contour.*

Note that the shape of IIC contour is reverse of STC contour (see Figure 5.16). The reason is that STC is determined from the transmission loss data — the difference in levels between the source room and the receiving room. The greater the transmission loss, the higher the STC. IIC, on the other hand, is determined from the noise levels in receiving room. The greater these noise levels, the smaller the IIC.

A major criticism of IIC rating is that it does not correlate well with the ear's perception of insulation. It is highly skewed in favor of low frequencies. Consequently, a lightweight floor (e.g., a plywood subfloor on wood floor joists) whose structure-borne sound insulation is worse than a heavy concrete floor, particularly at low frequencies, may have a higher IIC rating than a concrete floor. Despite the criticism, no better single number rating procedure has yet been agreed upon.

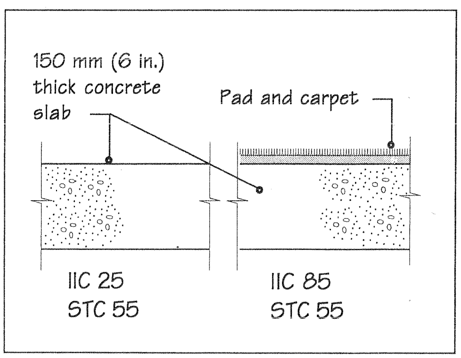
Another criticism of IIC rating is that the massive impacts (people jogging and dropping weights etc.) in modern exercise facilities are not represented by the standard low-mass hammers of the tapping machine.

7.2 STRATEGIES TO INCREASE IMPACT INSULATION

In general, there are four basic strategies available to increase the structure-borne sound insulation of a floor-ceiling assembly, as listed below and discussed in the following sections.

- Soft or resilient floor covering
- Resiliently supported floor — floating floor
- Resiliently supported ceiling
- Structural discontinuity in floor and ceiling — reducing flanking transmission through the structure

7.3 SOFT OR RESILIENT FLOOR COVERING



7.3 *Increase in IIC of a concrete slab by the addition of a pad and a carpet. Adapted primarily from Reference 7.2.*

The best means of insulating a floor against structure-borne sound is to weaken the impact on the floor at the source — before the impact becomes structure-borne. Thus, a soft floor covering, such as a carpet backed by a foam underlayment (pad), is an excellent way of improving the structure-borne sound insulation of a floor.

For example, a 6 in. thick bare concrete slab has an STC rating of nearly 55, but its IIC rating is only 25. The same slab when covered with a pad and a carpet gives an IIC rating of nearly 85 (an improvement of 60 points), but its STC rating remains unchanged at 55, Figure 7.3.

The increase in structure-borne sound insulation due to a carpet is far greater for a hard inflexible floor such as concrete than for a relatively flexible wood floor. For example, a typical residential floor with a plywood subfloor and gypsum board ceiling attached directly to floor joists gives an IIC of 34 and an STC of 38.

If the same floor is covered with a pad and a carpet, its IIC increases to 55 (an improvement of 21 points) and the STC increases to 39, Figure 7.4. The small increase in STC is partially due to the (airborne sound) absorption provided by the carpet and partially due to the covering of joints of the floor by the carpet.

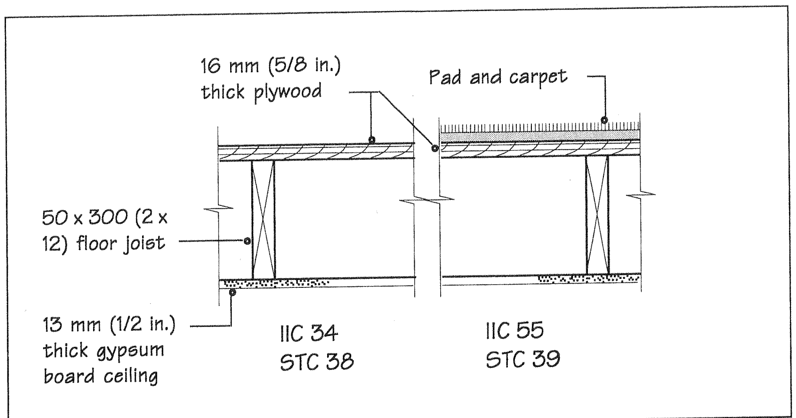
Although a carpet is the best way to improve the structure-borne insulation of a floor, resilient floor coverings such as cork, rubber and vinyl also provide some improvement, Table 7.1.

Table 7.1 Approximate Improvement in IIC for Some Floor Coverings

Floor	Improvement in IIC
Pad and carpet on:	
Wood floor	20
Concrete floor	60
Vinyl, rubber, etc., on:	
Wood floor	5
Concrete floor	7

Adapted from Reference 7.3.

It is important to emphasize that a soft or a resilient floor covering has virtually no effect on airborne sound insulation, except that a carpet, because of its absorption at high frequencies may slightly increase the airborne sound insulation at these frequencies.

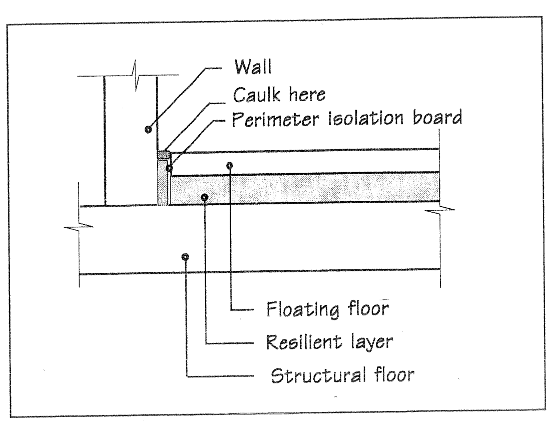


7.4 *Improvement in IIC of a conventional residential wood floor by the addition of a pad and a carpet.*

7.4 FLOATING FLOOR

Although a soft floor covering improves the structure-borne sound insulation of a floor, in many situations a hard concrete or wood surface is required. In such a situation, a floating floor is the answer. Unlike a carpet or a resilient floor covering, a floating floor also increases the airborne sound insulation. Thus, a floating floor is used where high values of both STC and IIC are required.

A floating floor is an additional layer of floor (concrete or wood) supported on a structural floor (concrete or wood) through resilient mounts. To be effective, the floating floor must be isolated at all sides from walls or other building components, so that the impact or vibration from the floor does not flank to other parts of the building through the wall. This isolation is provided by a *perimeter isolation board* (fiberglass board or a plastic foam), Figure 7.5.

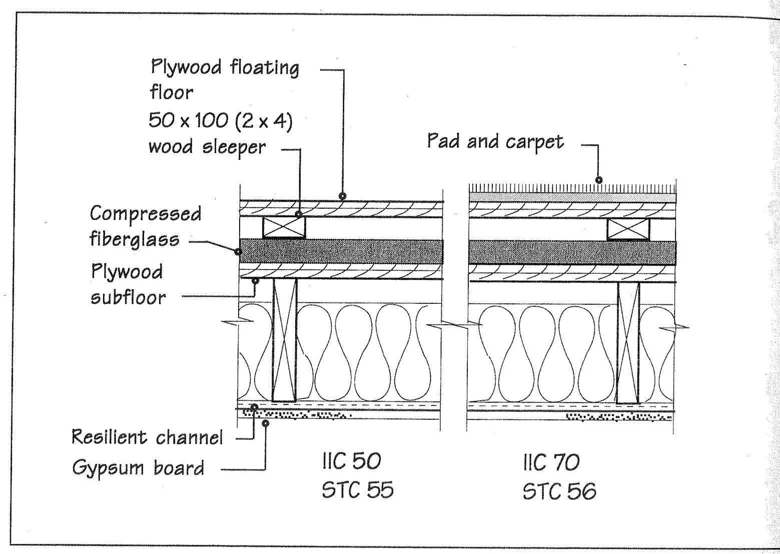


7.5 *Essential elements of a floating floor.*

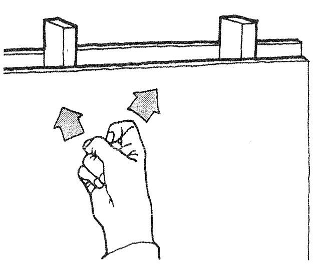
7.4.1 Floating Floor on Conventional Wood Floor

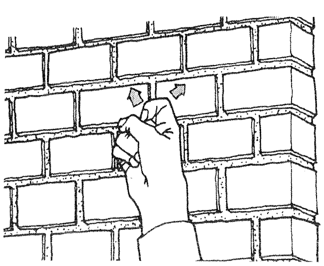
A simple plywood floating floor is shown in Figure 7.6. It consists of plywood panels glued and nailed to 50 x 100 (2 x 4) wood sleepers. The sleepers are laid over 25 to 40 mm (1 to $1^1/_2$ in.) thick compressed fiberglass boards, placed over a conventional plywood subfloor. Note that the sleepers are simply laid over fiberglass boards with no attachment to the structural floor.

Because of its low cost and simple construction, this floor is commonly used for homes and apartments. With a gypsum board ceiling attached to floor joists through resilient channels, this floor-ceiling assembly gives an STC of nearly 55 and an IIC of nearly 50. With a carpet and pad, an IIC of nearly 70 may be achieved.



7.6 *Plywood floating floor on conventional wood floor.*

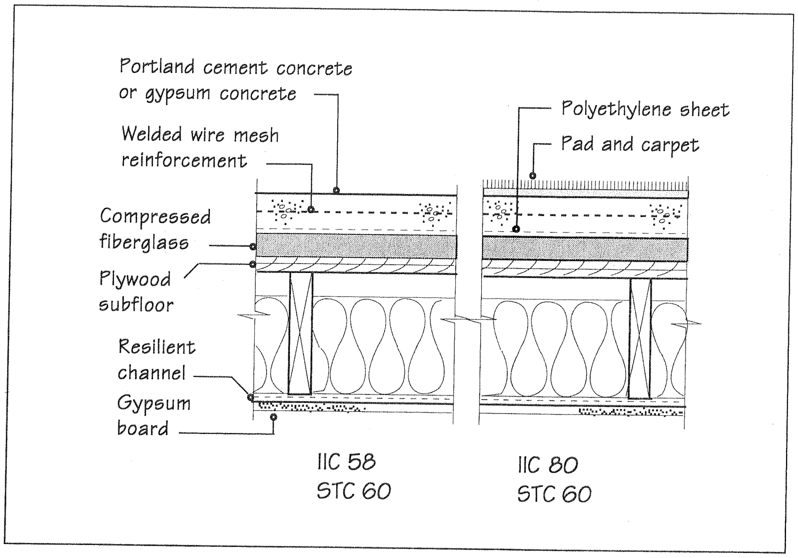




A major disadvantage of such a floor is that, due to its light weight, it transmits low frequency impact noise, which the lower floor occupants perceive as thumps or rattling sound as people walk on the floor above. This fact is not obvious in IIC values since, as stated in Section 7.1, the IIC contour is skewed in favor of low frequencies, which overrates lightweight floors.

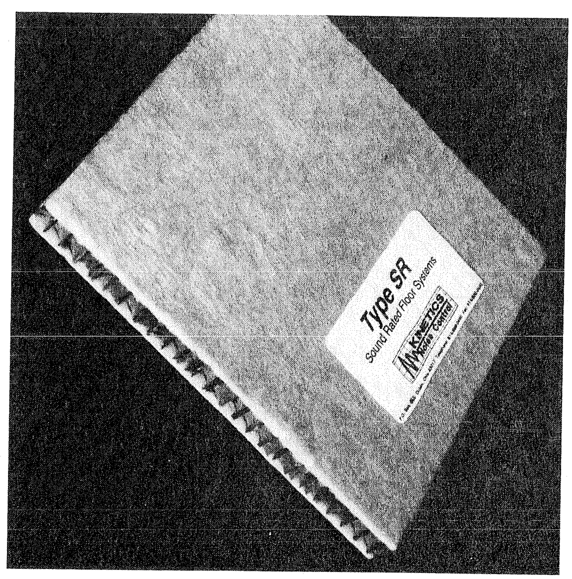
Another disadvantage of a lightweight floor is that it creates more noise within its own space. Tapping on a lightweight wall versus a heavy concrete or masonry wall makes this fact at once obvious.

A layer of portland cement or gypsum concrete in place of plywood provides the necessary weight and improves low frequency insulation, Figure 7.7. In practice, nearly 40 to 50 mm ($1^1/_2$ to 2 in.) thick lightly reinforced cement (or gypsum) concrete layer is used. A polyethylene sheet between compressed fiberglass and concrete provides necessary waterproofing. This assembly gives an IIC of nearly 58 and an STC of nearly 60. With a pad and carpet, an IIC of up to 80 is achieved.



7.7 *Concrete floating floor on conventional wood floor.*

One manufacturer of floating floor system uses a honeycomb floorboard in place of compressed fiberglass. This floor board consists of a thin layer of fiberglass laminated to both sides of a cellulosic honeycomb core, Figure 7.8. With a total thickness of only 16 mm ($^5/_8$ in.), it makes an excellent cost-effective alternative to compressed fiberglass board, and is particularly suitable with concrete-topped floating floors.



7.8 *Honeycomb resilient floor board. Sample courtesy of Kinetics Noise Control Inc., Dublin, Ohio. Photo by Madan Mehta.*

Table 7.2 Approximate IIC and STC Values for Some Floating Floors

Floating floor	IIC	STC
Wood floating floor on:		
Wood structural floor	52	58
Concrete structural floor	64	62
Concrete floating floor on:		
Wood structural floor	58	60
Concrete structural floor	74	62

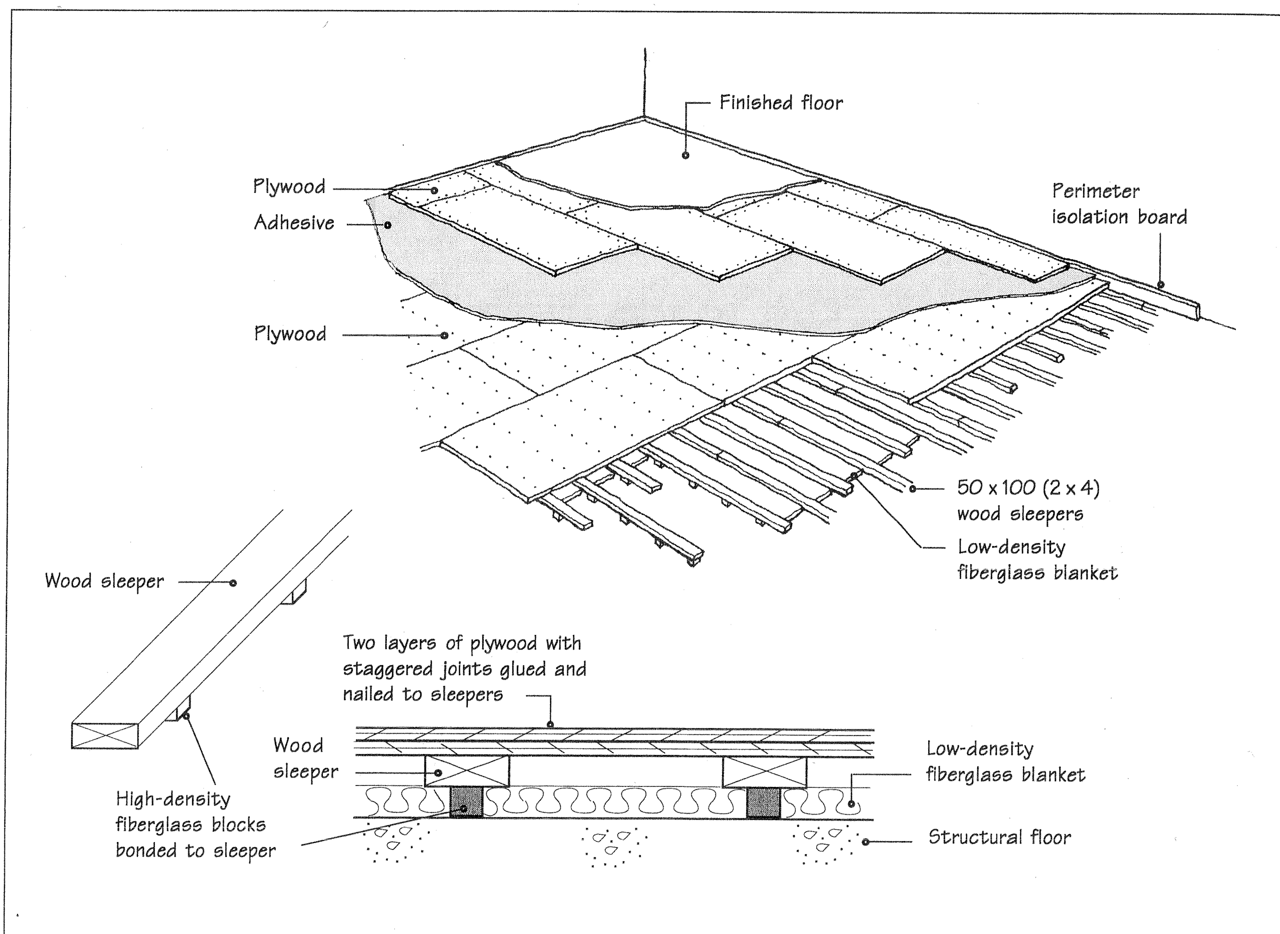
These values are approximate and are provided to compare one type of floating floor with the other. The actual values depend a great deal on the thickness of materials, depth of air cavity, the presence or absence of fiberglass in the cavity, etc. The values represent bare floors with no carpeting.

7.4.2 Wood Floating Floor over Concrete Structural Floor

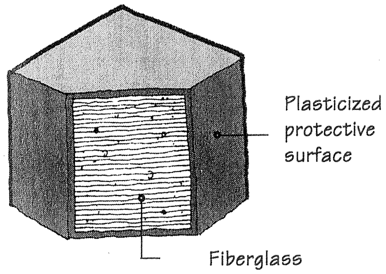
A wood floating floor over a concrete structural floor is ideal for aerobic exercise halls, gymnasiums, dance floors, high-rise apartments, etc., particularly over suspended concrete slabs. Although there are different versions, a typical wood floating floor over a concrete structural floor is shown in Figure 7.9. Impact absorption is provided by high-density fiberglass blocks 50 mm x 50 mm x 50 mm (2 in. x 2 in. x 2 in.).

The fiberglass blocks are bonded to 50 x 100 (2 x 4) wood sleepers at nearly 300 mm (12 in.) on centers. Depending on the load on the floor, the sleepers are simply laid (not attached) on the concrete floor at 300 to 400 mm (12 to 16 in.) on centers.

The space between sleepers is filled with low-density fiberglass. Next a layer of plywood panels is nailed to the sleepers. Finally, a second layer of plywood is adhesively bonded and nailed to the lower plywood, with staggered joints. The STC and IIC values depend on the thickness of the structural floor. A floor covering, such as a hardwood floor, carpet, etc., provides the floor finish. Table 7.2 gives some representative STC and IIC values of floating floors.



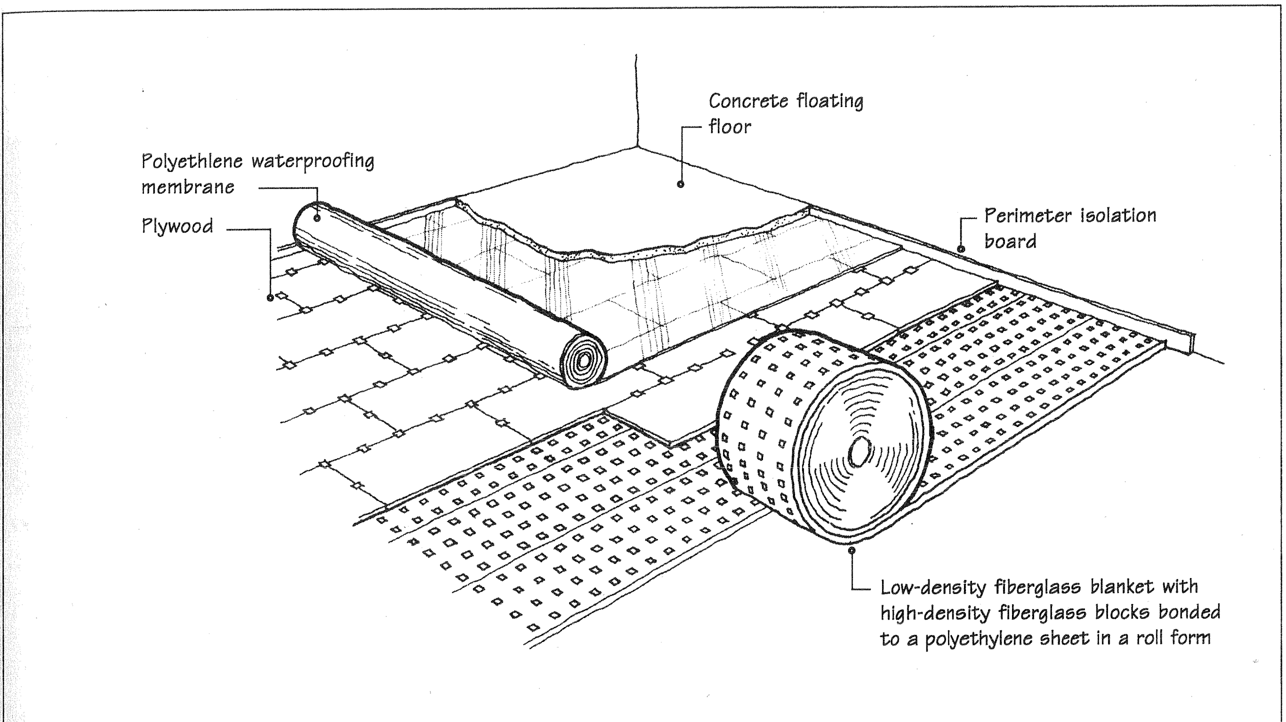
7.9 *Wood floating floor on a reinforced concrete structural floor — a system supplied by Kinetics Noise Control Inc., Dublin, Ohio.*



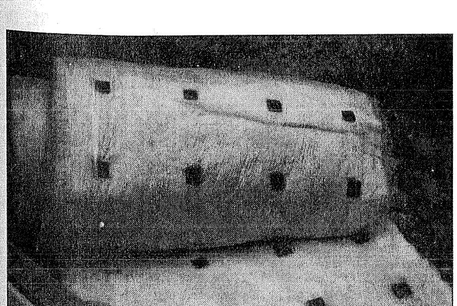
CUTAWAY SECTION THROUGH A
HIGH-DENSITY FIBERGLASS BLOCK

7.4.3 Floating Concrete Slab over Concrete Structural Floor

A concrete topped floating floor is similar to a wood floating floor described previously, and is commonly used in suspended floors for mechanical rooms, squash and racquetball courts, exercise rooms, gymnasiums, etc. A typical concrete floating floor consists of nearly 100 mm (4 in.) thick reinforced concrete slab supported on high-density fiberglass blocks, placed at nearly 300 mm (12 in.) on center over the concrete structural floor, Figure 7.10.



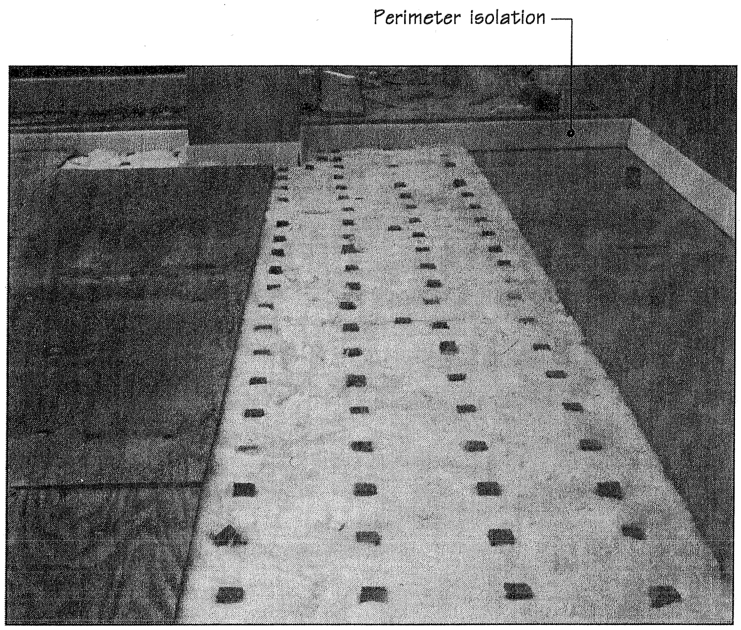
7.10 *Concrete floating floor assembly supplied by Kinetics Noise Control Inc., Dublin, Ohio.*



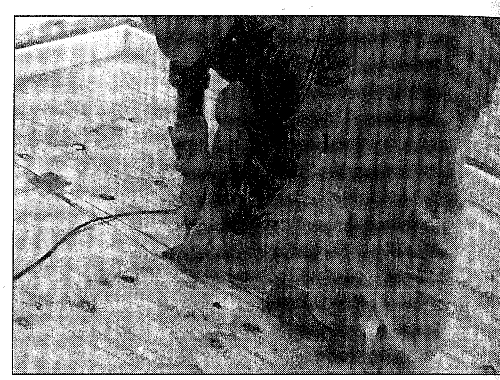
Plywood panels over fiberglass blocks function as a permanent form for the floating concrete slab. The air space between the floating concrete slab and the structural floor is filled with low density fiberglass. In fact, one manufacturer supplies the blocks and low-density fiberglass blanket bonded to a plastic sheet, all packaged in rolls, Figure 7.11.

7.11 *50 mm x 50 mm x 50 mm (2 in. x 2 in. x 2 in.) high-density fiberglass blocks and low-density fiberglass blanket bonded to a plastic sheet — by Kinetics Noise Control Inc., Dublin, Ohio. Photo by Madan Mehta.*

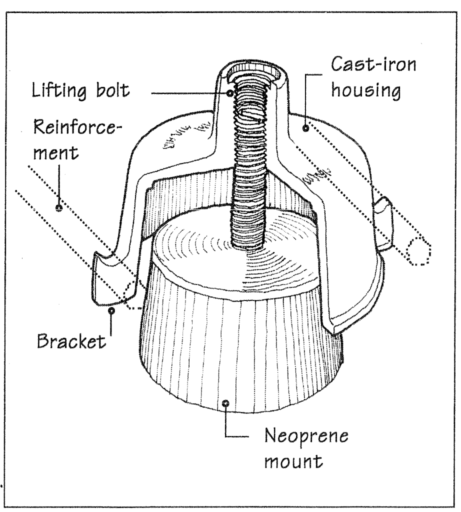
Thus, the low-density fiberglass blanket with high-density fiberglass blocks bonded to it is unrolled over the structural floor and covered with plywood panels, Figure 7.12. The panels are connected together at joints with steel plates, Figure 7.13, and a polyethylene sheet placed over them. Reinforcement is now laid and concrete poured.



7.12 *Plywood form and high-density fiberglass blocks bonded to low-density fiberglass blanket. Photo by Madan Mehta.*



7.13 *Connecting plywood panels together. Photo by Madan Mehta.*



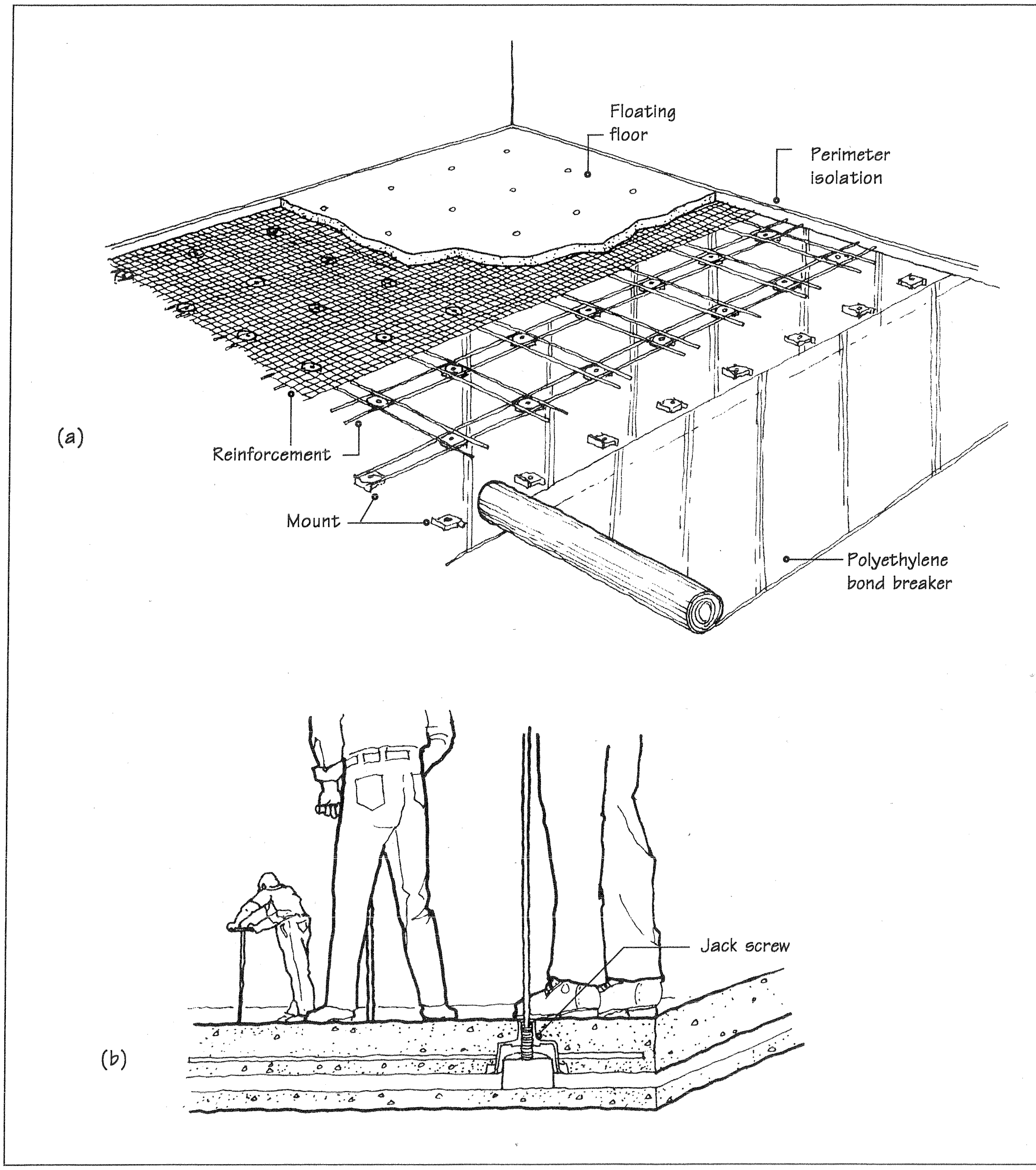
7.14 *Cast-iron housing and neoprene mount.*

7.4.4 Jack-up Floating Concrete Slab

A jack-up concrete floating floor has the same finished appearance as the floor described previously. The difference between the two floors is in the processes of construction and the impact-absorbing mounts. Each mount consists of a neoprene block enclosed in a cast-iron housing, Figure 7.14. The housing is supported on a lifting bolt, which in turn rests on the neoprene block. The cast iron housing has two cantilevered brackets to support reinforcing bars.

The process of construction is shown in Figure 7.15(a). First, a plastic sheet is laid over the structural concrete floor. This sheet works as a bond breaker between the structural floor and the floating slab. Depending on the load on the floor, the mounts are then placed at 600 to 1,200 mm (2 to 4 ft) on centers each way. Reinforcing bars are now placed over the brackets of the mounts. Additional reinforcement is now laid over the previously laid reinforcement, and concrete is poured.

After the slab has cured and attained the necessary strength, it is jacked up with the help of jack screws, Figure 7.15(b). One or two people can lift a large floor little by little, ensuring a uniform lift at all points. The total lift of the floor need be only 25 mm (1 in.), but a greater lift may be specified for a higher insulation. A jack-up floor is particularly suitable for heavily loaded floors, or floors that have an irregular shape.



7.15 *Jack-up floating concrete floor.*

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Table 5.14 ***(Continued)***

Floor/Ceiling Construction

Representative Construction Assemblies	Weight in lb./sq. ft.	STC	IIC
Standard oak flooring with 1/2-in. plywood subfloor on 2 × 10 wood joists, 16-in. o.c.	7.7	25	20
Standard oak flooring with 1/2-in. plywood subfloor on 2 × 10 wood joists, 16-in. o.c., with 5/8-in. gypsum board ceiling	9.7	37	32
Standard oak flooring with 1/2-in. plywood subfloor on 2 × 10 wood joists, 16-in. o.c., with 5/8-in. gypsum board ceiling attached to resilient channels crossing joists @ 24-in. o.c.	10.3	45	39
Standard oak flooring with 1/2-in. plywood subfloor on 2 × 10 wood joists with 3-in. cavity insulation, 16-in. o.c., with 5/8-in. gypsum board ceiling attached to resilient channels crossing joists @ 24-in. o.c.	11.0	49	46
Standard oak flooring on furring strips over 1/2-in. fiberboard on 1/2-in. plywood subfloor on 2 × 10 wood joists, 16-in. o.c. with 3-in. cavity insulation, with 5/8-in. gypsum board ceiling suspended on resilient channels	13.0	53	51
Carpeting with padding on double 5/8-in. plywood with felt between panels, on 2 × 10 wood joists, 16-in. o.c. with 3-in. cavity insulation, with 1/2-in. gypsum plaster ceiling on 3/8-in. gypsum lath suspended on resilient channels	12.0	50	68
2 to 2 1/2-in. concrete slab on cellular metal decking on steel joists with 1/8-in. resilient floor tile and 1/2-in. gypsum board ceiling	41.0	48	35
2 to 2 1/2-in. concrete slab on cellular metal decking on steel joists with carpeting on pad and 1/2-in. gypsum board ceiling	41.0	49	64
4-in. reinforced concrete slab	53.0	44	25
4-in. reinforced concrete slab with 1/8-in. resilient tile	54.0	44	28
4-in. reinforced concrete slab with 1/2-in. oak flooring	55.0	44	45
4-in. reinforced concrete slab with 1/2-in. oak flooring on 1/2-in. fiberboard	56.0	44	45
4-in. reinforced concrete slab with carpeting on padding	54.0	44	80
4-in. reinforced concrete slab with carpeting on padding over 1/2-in. oak flooring	56.0	44	84
6-in. reinforced concrete slab	75.0	55	34
6-in. reinforced concrete slab with 3/4-in. T&G wood flooring on 1 1/2 × 2 wooden battens floated on 1-in. glass fiber	78.0	55	57
6-in. hollow-core concrete panel with 1 1/2-in. lightweight concrete	55.0	50	23
6-in. hollow-core concrete panel with 1 1/2-in. lightweight concrete and carpeting on pad	56.0	51	69
8-in. hollow-core concrete panel with 1 1/2-in. lightweight concrete	67.0	52	24
6-in. hollow-core concrete panel with 1 1/2-in. lightweight concrete and carpeting on padding	68.0	52	74
Heavy carpet laid on pad over 1 5/8-in. concrete slab on 5/8-in. plywood on 18-in. steel joist, 16-in. o.c., with 5/8-in. gypsum board ceiling attached to joists		47	62
2-in. concrete topping on 14-in. precast concrete tees with 2-in. thick slab	75.0	54	24
2-in. concrete topping on 14-in. precast concrete tees with 2-in. thick slab and carpeting on padding	75.0	54	72

Note: This table is compiled from various sources to provide an indication of differences in STC that occurs with different but similar construction. Due to the variation in source, the listed data might not be totally accurate.

to pass through a sound barrier so that the effective maximum transmission loss across the barrier, regardless of its STC rating, would be less than 30 dB. If the opening were 1% of the total area, the effective maximum transmission loss for the barrier would be only 20 dB. This clearly indicates that it makes no sense to choose a partition with a high STC rating unless we are also committed to ensuring that the partition is properly sealed along all edges, such as the ceiling, floor, and adjacent walls, and that there are no holes within the partition, such as back-to-back electric outlets.

While Figure 5.25 can also be used to indicate the transmission loss if there is an opening within the barrier, another graph, Figure 5.27, shows the performance for

APPENDIX C

COST DATA

B1010 Floor Construction

(A) Wide Flange

(B) Pipe

(C) Pipe, Concrete Filled

(D) Square Tube

(E) Square Tube Concrete Filled

(F) Rectangular Tube

(G) Rectangular Tube, Concrete Filled

General: The following pages provide data for seven types of steel columns: wide flange, round pipe, round pipe concrete filled, square tube, square tube concrete filled, rectangular tube and rectangular tube concrete filled.

Design Assumptions: Loads are concentric; wide flange and round pipe bearing capacity is for 36 KSI steel. Square and rectangular tubing bearing capacity is for 46 KSI steel.

The effective length factor K=1.1 is used for determining column values in the tables. K=1.1 is within a frequently used range for pinned connections with cross bracing.

How To Use Tables:
a. Steel columns usually extend through two or more stories to minimize splices. Determine floors with splices.
b. Enter Table No. below with load to column at the splice. Use the unsupported height.
c. Determine the column type desired by price or design.

Cost:
a. Multiply number of columns at the desired level by the total height of the column by the cost/VLF.
b. Repeat the above for all tiers.

Please see the reference section for further design and cost information.

B1010 208 Steel Columns

	LOAD (KIPS)	UNSUPPORTED HEIGHT (FT.)	WEIGHT (P.L.F.)	SIZE (IN.)	TYPE	COST PER V.L.F.		
						MAT.	INST.	TOTAL
1000	25	10	13	4	A	22.50	10.65	33.15
1020	RB1010 -130		7.58	3	B	13.10	10.65	23.75
1040			15	3-1/2	C	16	10.65	26.65
1060			6.87	3	D	11.90	10.65	22.55
1080			15	3	E	15.45	10.65	26.10
1100			8.15	4x3	F	14.10	10.65	24.75
1120			20	4x3	G	18.45	10.65	29.10
1200		16	16	5	A	25.50	8	33.50
1220			10.79	4	B	17.30	8	25.30
1240			36	5-1/2	C	24	8	32
1260			11.97	5	D	19.15	8	27.15
1280			36	5	E	25.50	8	33.50
1300			11.97	6x4	F	19.15	8	27.15
1320			64	8x6	G	37	8	45
1400		20	20	6	A	30.50	8	38.50
1420			14.62	5	B	22	8	30
1440			49	6-5/8	C	29.50	8	37.50
1460			11.97	5	D	18.15	8	26.15
1480			49	6	E	30	8	38
1500			14.53	7x5	F	22	8	30
1520			64	8x6	G	35	8	43
1600	50	10	16	5	A	27.50	10.65	38.15
1620			14.62	5	B	25.50	10.65	36.15
1640			24	4-1/2	C	19.05	10.65	29.70
1660			12.21	4	D	21	10.65	31.65
1680			25	4	E	21.50	10.65	32.15
1700			11.97	6x4	F	20.50	10.65	31.15
1720			28	6x3	G	24.50	10.65	35.15

B1010 Floor Construction

B1010 208 Steel Columns

	LOAD (KIPS)	UNSUPPORTED HEIGHT (FT.)	WEIGHT (P.L.F.)	SIZE (IN.)	TYPE	COST PER V.L.F.		
						MAT.	INST.	TOTAL
1800	50	16	24	8	A	38.50	8	46.50
1820			18.97	6	B	30.50	8	38.50
1840			36	5-1/2	C	24	8	32
1860			14.63	6	D	23.50	8	31.50
1880			36	5	E	25.50	8	33.50
1900			14.53	7x5	F	23.50	8	31.50
1920			64	8x6	G	37	8	45
1940								
2000		20	28	8	A	42.50	8	50.50
2020			18.97	6	B	29	8	37
2040			49	6-5/8	C	29.50	8	37.50
2060			19.02	6	D	29	8	37
2080			49	6	E	30	8	38
2100			22.42	8x6	F	34	8	42
2120			64	8x6	G	35	8	43
2200	75	10	20	6	A	34.50	10.65	45.15
2220			18.97	6	B	33	10.65	43.65
2240			36	4-1/2	C	48	10.65	58.65
2260			14.53	6	D	25	10.65	35.65
2280			28	4	E	21.50	10.65	32.15
2300			14.33	7x5	F	25	10.65	35.65
2320			35	6x4	G	27.50	10.65	38.15
2400		16	31	8	A	49.50	8	57.50
2420			28.55	8	B	45.50	8	53.50
2440			49	6-5/8	C	31.50	8	39.50
2460			17.08	7	D	27.50	8	35.50
2480			36	5	E	25.50	8	33.50
2500			23.34	7x5	F	37.50	8	45.50
2520			64	8x6	G	37	8	45
2600		20	31	8	A	47	8	55
2620			28.55	8	B	43.50	8	51.50
2640			81	8-5/8	C	45	8	53
2660			22.42	7	D	34	8	42
2680			49	6	E	30	8	38
2700			22.42	8x6	F	34	8	42
2720			64	8x6	G	35	8	43
2800	100	10	24	8	A	41.50	10.65	52.15
2820			28.57	6	B	49.50	10.65	60.15
2840			35	4-1/2	C	48	10.65	58.65
2860			17.08	7	D	29.50	10.65	40.15
2880			36	5	E	27.50	10.65	38.15
2900			19.02	7x5	F	33	10.65	43.65
2920			46	8x4	G	33.50	10.65	44.15
3000		16	31	8	A	49.50	8	57.50
3020			28.55	8	B	45.50	8	53.50
3040			56	6-5/8	C	46.50	8	54.50
3060			22.42	7	D	36	8	44
3080			49	6	E	31.50	8	39.50
3100			22.42	8x6	F	36	8	44
3120			64	8x6	G	37	8	45

B1010 Floor Construction

B1010 208 Steel Columns

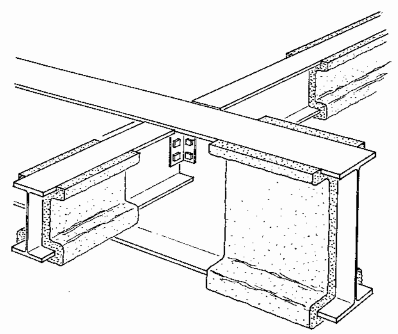
	LOAD (KIPS)	UNSUPPORTED HEIGHT (FT.)	WEIGHT (P.L.F.)	SIZE (IN.)	TYPE	COST PER V.L.F.		
						MAT.	INST.	TOTAL
3200	100	20	40	8	A	60.50	8	68.50
3220			28.55	8	B	43.50	8	51.50
3240			81	8-5/8	C	45	8	53
3260			25.82	8	D	39	8	47
3280			66	7	E	35.50	8	43.50
3300			27.59	8x6	F	42	8	50
3320			70	8x6	G	50.50	8	58.50
3400	125	10	31	8	A	53.50	10.65	64.15
3420			28.57	6	B	49.50	10.65	60.15
3440			81	8	C	51	10.65	61.65
3460			22.42	7	D	39	10.65	49.65
3480			49	6	E	34	10.65	44.65
3500			22.42	8x6	F	39	10.65	49.65
3520			64	8x6	G	40	10.65	50.65
3600		16	40	8	A	64	8	72
3620			28.55	8	B	45.50	8	53.50
3640			81	8	C	47.50	8	55.50
3660			25.82	8	D	41.50	8	49.50
3680			66	7	E	37	8	45
3700			27.59	8x6	F	44	8	52
3720			64	8x6	G	37	8	45
3800		20	48	8	A	73	8	81
3820			40.48	10	B	61.50	8	69.50
3840			81	8	C	45	8	53
3860			25.82	8	D	39	8	47
3880			66	7	E	35.50	8	43.50
3900			37.59	10x6	F	57	8	65
3920			60	8x6	G	50.50	8	58.50
4000	150	10	35	8	A	60.50	10.65	71.15
4020			40.48	10	B	70	10.65	80.65
4040			81	8-5/8	C	51	10.65	61.65
4060			25.82	8	D	44.50	10.65	55.15
4080			66	7	E	40	10.65	50.65
4100			27.48	7x5	F	47.50	10.65	58.15
4120			64	8x6	G	40	10.65	50.65
4200		16	45	10	A	72	8	80
4220			40.48	10	B	65	8	73
4240			81	8-5/8	C	47.50	8	55.50
4260			31.84	8	D	51	8	59
4280			66	7	E	37	8	45
4300			37.69	10x6	F	60.50	8	68.50
4320			70	8x6	G	53.50	8	61.50
4400		20	49	10	A	74.50	8	82.50
4420			40.48	10	B	61.50	8	69.50
4440			123	10-3/4	C	64	8	72
4460			31.84	8	D	48.50	8	56.50
4480			82	8	E	41	8	49
4500			37.69	10x6	F	57	8	65
4520			86	10x6	G	50	8	58

B1010 Floor Construction

B1010 208 Steel Columns

	LOAD (KIPS)	UNSUPPORTED HEIGHT (FT.)	WEIGHT (P.L.F.)	SIZE (IN.)	TYPE	COST PER V.L.F.		
						MAT.	INST.	TOTAL
4600	200	10	45	10	A	78	10.65	88.65
4620			40.48	10	B	70	10.65	80.65
4640			81	8-5/8	C	51	10.65	61.65
4660			31.84	8	D	55	10.65	65.65
4680			82	8	E	46.50	10.65	57.15
4700			37.69	10x6	F	65	10.65	75.65
4720			70	8x6	G	57.50	10.65	68.15
4800		16	49	10	A	78.50	8	86.50
4820			49.56	12	B	79.50	8	87.50
4840			123	10-3/4	C	67	8	75
4860			37.60	8	D	60	8	68
4880			90	8	E	62	8	70
4900			42.79	12x6	F	68.50	8	76.50
4920			85	10x6	G	62	8	70
5000		20	58	12	A	88	8	96
5020			49.56	12	B	75	8	83
5040			123	10-3/4	C	64	8	72
5060			40.35	10	D	61	8	69
5080			90	8	E	58.50	8	66.50
5100			47.90	12x8	F	72.50	8	80.50
5120			93	10x6	G	75.50	8	83.50
5200	300	10	61	14	A	106	10.65	116.65
5220			65.42	12	B	113	10.65	123.65
5240			169	12-3/4	C	89	10.65	99.65
5260			47.90	10	D	83	10.65	93.65
5280			90	8	E	66.50	10.65	77.15
5300			47.90	12x8	F	83	10.65	93.65
5320			86	10x6	G	86	10.65	96.65
5400		16	72	12	A	115	8	123
5420			65.42	12	B	105	8	113
5440			169	12-3/4	C	83	8	91
5460			58.10	12	D	93	8	101
5480			135	10	E	79.50	8	87.50
5500			58.10	14x10	F	93	8	101
5600		20	79	12	A	120	8	128
5620			65.42	12	B	99	8	107
5640			169	12-3/4	C	78.50	8	86.50
5660			58.10	12	D	88	8	96
5680			135	10	E	75	8	83
5700			58.10	14x10	F	88	8	96
5800	400	10	79	12	A	137	10.65	147.65
5840			178	12-3/4	C	117	10.65	127.65
5860			68.31	14	D	118	10.65	128.65
5880			135	10	E	85.50	10.65	96.15
5900			62.46	14x10	F	108	10.65	118.65
6000		16	87	12	A	139	8	147
6040			178	12-3/4	C	108	8	116
6060			68.31	14	D	109	8	117
6080			145	10	E	103	8	111
6100			76.07	14x10	F	122	8	130

B1010 Floor Construction



General: The following table is based upon structural W shape beam and girder framing. Non-composite action is assumed between beams and decking. Deck costs not included.

The deck spans the short direction. The steel beams and girders are fireproofed with sprayed fiber fireproofing.

Design and Pricing Assumptions:
Structural steel is A36, with high strength A325 bolts.

Fireproofing is sprayed fiber (non-asbestos).

Total load includes steel, deck & live load.

Spandrels are assumed the same as interior beams and girders to allow for exterior wall loads and bracing or moment connections. No columns included in price.

See Tables B1010 258 and B1020 128 for metal deck costs.

System Components	QUANTITY	UNIT	COST PER S.F. MAT.	COST PER S.F. INST.	COST PER S.F. TOTAL
SYSTEM B1010 241 1350					
15' X 20' BAY, 40 P.S.F. L.L., 12" DEPTH, .535 P.S.F. FIREPROOF, 50 PSF T.LOAD					
Structural steel	3.200	Lb.	4.67	1.38	6.0
Spray mineral fiber/cement for fire proof., 1" thick on beams	.535	S.F.	.31	.54	.8
TOTAL			4.98	1.92	6.9

B1010 241 W Shape Beams & Girders

	BAY SIZE (FT.) BEAM X GIRD	SUPERIMPOSED LOAD (P.S.F.)	STEEL FRAMING DEPTH (IN.)	FIREPROOFING (S.F. PER S.F.)	TOTAL LOAD (P.S.F.)	COST PER S.F. MAT.	COST PER S.F. INST.	COST PER S.F. TOTAL
1350	15x20	40	12	.535	50	4.98	1.92	6.9
1400		40	16	.65	90	6.50	2.47	8.9
1450		75	18	.694	125	8.60	3.10	11.70
1500		125	24	.796	175	11.85	4.31	16.1
1550		200	24	.89	263	13.40	3.96	17.3
1600	20x15	40	14	.659	50	5.05	2.05	7.10
1650		40	14	.69	90	6.80	2.60	9.40
1700		75	14	.806	125	8.35	3.14	11.49
1800		125	16	.86	175	9.85	3.75	13.60
1900		200	18	1.00	250	11.65	3.51	15.16
2000	20x20	40	12	.55	50	5.60	2.10	7.70
2050		40	14	.579	90	7.65	2.74	10.39
2100		75	16	.672	125	9.15	3.26	12.41
2150		125	16	.714	175	10.90	3.96	14.86
2200		200	24	.841	263	13.65	3.97	17.62
2300	20x20	40	14	.67	50	5.65	2.22	7.87
2400		40	14	.718	90	7.70	2.87	10.57
2500		75	18	.751	125	8.90	3.25	12.15
2550		125	21	.879	175	12.20	4.49	16.69
2600		200	21	.976	250	14.60	4.33	18.93
2650	20x20	40	14	.746	50	5.70	2.29	7.99
2700		40	14	.839	90	7.80	2.99	10.79
2750		75	18	.894	125	9.85	3.66	13.51
2800		125	21	.959	175	13.10	4.84	17.94
2850		200	21	1.10	250	16.10	4.79	20.89
2900	20x25	40	16	.53	50	6.15	2.25	8.40
2950		40	18	.621	96	9.70	3.39	13.09
3000		75	18	.651	131	11.20	3.85	15.05
3050		125	24	.77	200	14.75	5.20	19.95

B1010 Floor Construction

B1010 241 W Shape Beams & Girders

	BAY SIZE (FT.) BEAM X GIRD	SUPERIMPOSED LOAD (P.S.F.)	STEEL FRAMING DEPTH (IN.)	FIREPROOFING (S.F. PER S.F.)	TOTAL LOAD (P.S.F.)	COST PER S.F. MAT.	COST PER S.F. INST.	COST PER S.F. TOTAL
3100	20 x 25	200	27	.855	275	16.80	4.75	21.55
3300	20x25	40	14	.608	50	6.20	2.33	8.53
3350		40	21	.751	90	8.60	3.16	11.76
3400		75	24	.793	125	10.70	3.81	14.51
3450		125	24	.846	175	12.75	4.63	17.38
3500		200	24	.947	256	16	4.63	20.63
3550	20x25	40	14	.72	50	7.15	2.70	9.85
3600		40	21	.802	90	8.65	3.21	11.86
3650		75	24	.924	125	11.05	4.03	15.08
3700		125	24	.964	175	13.40	4.94	18.34
3750		200	27	1.09	250	16.95	4.98	21.93
3800	25x20	40	12	.512	50	6.15	2.24	8.39
3850		40	16	.653	90	8.25	2.99	11.24
3900		75	18	.726	125	10.65	3.74	14.39
4000		125	21	.827	175	13.35	4.79	18.14
4100		200	24	.928	250	16.25	4.67	20.92
4200	25x20	40	12	.65	50	6.20	2.38	8.58
4300		40	18	.702	90	9.15	3.29	12.44
4400		75	21	.829	125	10.70	3.84	14.54
4500		125	24	.914	175	13.10	4.79	17.89
4600		200	24	1.015	250	16.05	4.70	20.75
4700	25x20	40	14	.769	50	6.60	2.59	9.19
4800		40	16	.938	90	9.90	3.70	13.60
4900		75	18	.969	125	11.95	4.33	16.28
5000		125	24	1.136	175	16.70	6.10	22.80
5100		200	24	1.239	250	21.50	6.20	27.70
5200	25x25	40	18	.486	50	6.70	2.39	9.09
5300		40	18	.592	96	10	3.43	13.43
5400		75	21	.668	131	12.05	4.12	16.17
5450		125	24	.738	191	15.90	5.50	21.40
5500		200	30	.861	272	18.50	5.15	23.65
5550	25x25	40	18	.597	50	6.50	2.41	8.91
5600		40	18	.704	90	10.35	3.63	13.98
5650		75	21	.777	125	11.85	4.14	15.99
5700		125	24	.865	175	15.10	5.40	20.50
5750		200	27	.96	250	18.30	5.20	23.50
5800	25x25	40	18	.71	50	7.15	2.69	9.84
5850		40	21	.767	90	10.35	3.70	14.05
5900		75	24	.887	125	12.50	4.43	16.93
5950		125	24	.972	175	15.75	5.65	21.40
6000		200	30	1.10	250	19.25	5.55	24.80
6050	25x30	40	24	.547	50	8.50	2.95	11.45
6100		40	24	.629	103	12.05	4.07	16.12
6150		75	30	.726	138	14.45	4.85	19.30
6200		125	30	.751	206	17.10	5.90	23
6250		200	33	.868	281	20.50	5.65	26.15
6300	25x30	40	21	.568	50	7.65	2.73	10.38
6350		40	21	.694	90	10.35	3.62	13.97
6400		75	24	.776	125	13.30	4.57	17.87
6450		125	30	.904	175	16	5.70	21.70
6500		200	33	1.008	263	19.15	5.45	24.60

B1010 Floor Construction

B1010 241 W Shape Beams & Girders

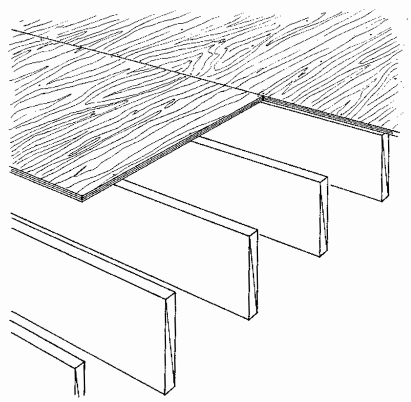
	BAY SIZE (FT.) BEAM X GIRD	SUPERIMPOSED LOAD (P.S.F.)	STEEL FRAMING DEPTH (IN.)	FIREPROOFING (S.F. PER S.F.)	TOTAL LOAD (P.S.F.)	COST PER S.F. MAT.	INST.	TOTA
6550	25x30	40	16	.632	50	7.95	2.88	1
6600		40	21	.76	90	10.95	3.87	1
6650		75	24	.857	125	13.05	4.56	17
6700		125	30	.983	175	16.35	5.85	2
6750		200	33	1.11	250	20.50	5.90	2
6800	30x25	40	16	.532	50	7.30	2.59	[illegible]
6850		40	21	.672	96	11.20	3.87	15
6900		75	24	.702	131	13.25	4.49	17
6950		125	27	1.020	175	17.25	5.95	23
7000		200	30	1.160	250	22	7.45	29
7100	30x25	40	18	.569	50	7.65	2.73	10
7150		40	24	.740	90	10.65	3.75	14
7200		75	24	.787	125	13.30	4.58	17
7300		125	24	.874	175	16.55	5.85	22
7400		200	30	1.013	250	20.50	5.70	26
7450	30x25	40	16	.637	50	7.95	2.88	10
7500		40	24	.839	90	11.30	4.03	15
7550		75	24	.919	125	13.65	4.80	18
7600		125	27	1.02	175	17.25	6.15	23
7650		200	30	1.160	250	21.50	6.15	27
7700	30x30	40	21	.52	50	8.20	2.85	11
7750		40	24	.629	103	12.60	4.25	16
7800		75	30	.715	138	15	5	20
7850		125	36	.822	206	19.75	6.75	26.
7900		200	36	.878	281	22	6	28
7950	30x30	40	24	.619	50	8.55	3.02	11.
8000		40	24	.706	90	11.50	3.97	15.
8020		75	27	.818	125	13.60	4.69	18.
8040		125	30	.910	175	17.45	6.15	23.6
8060		200	33	.999	263	21.50	5.95	27.4
8080	30x30	40	18	.631	50	9.15	3.21	12.3
8100		40	24	.805	90	12.45	4.34	16.7
8120		75	27	.899	125	14.85	5.10	19.9
8150		125	30	1.010	175	18.40	6.50	24.9
8200		200	36	1.148	250	22	6.20	28.2
8250	30x35	40	21	.508	50	9.35	3.18	12.5
8300		40	24	.651	109	13.80	4.62	18.4
8350		75	33	.732	150	16.75	5.55	22.3
8400		125	36	.802	225	21	7.10	28.10
8450		200	36	.888	300	27.50	7.30	34.80
8500	30x35	40	24	.554	50	8.20	2.89	11.0
8520		40	24	.655	90	12.05	4.11	16.16
8540		75	30	.751	125	15.05	5.05	20.10
8600		125	33	.845	175	18.30	6.35	24.65
8650		200	36	.936	263	24	6.55	30.55
8700	30x35	40	21	.644	50	8.85	3.14	11.99
8720		40	24	.733	90	12.70	4.36	17.06
8740		75	30	.833	125	15.95	5.40	21.35
8760		125	36	.941	175	18.35	6.45	24.80
8780		200	36	1.03	250	24.50	6.65	31.15

B1010 Floor Construction

B1010 241 W Shape Beams & Girders

	BAY SIZE (FT.) BEAM X GIRD	SUPERIMPOSED LOAD (P.S.F.)	STEEL FRAMING DEPTH (IN.)	FIREPROOFING (S.F. PER S.F.)	TOTAL LOAD (P.S.F.)	COST PER S.F. MAT.	INST.	TOTAL
8800	35x30	40	24	.540	50	9.05	3.12	12.17
8850		40	30	.670	103	13.55	4.55	18.10
8900		75	33	.748	138	16.50	5.50	22
8950		125	36	.824	206	20.50	6.95	27.45
8980		200	36	.874	281	24.50	6.60	31.10
9000	35x30	40	24	.619	50	8.85	3.11	11.96
9050		40	24	.754	90	13	4.46	17.46
9100		75	27	.844	125	15.40	5.25	20.65
9200		125	30	.856	175	18.90	6.50	25.40
9250		200	33	.953	263	21	5.80	26.80
9300	35x30	40	24	.705	50	9.45	3.38	12.83
9350		40	24	.833	90	13.35	4.62	17.97
9400		75	30	.963	125	16.35	5.60	21.95
9450		125	33	1.078	175	20.50	7.20	27.70
9500		200	36	1.172	250	24.50	6.90	31.40
9550	35x35	40	27	.560	50	9.65	3.33	12.98
9600		40	36	.706	109	17.65	5.80	23.45
9650		75	36	.750	150	18.25	6	24.25
9820		125	36	.797	225	24.50	8.20	32.70
9840		200	36	.914	300	29	7.70	36.70
9860	35x35	40	24	.580	50	8.80	3.08	11.88
9880		40	30	.705	90	13.55	4.58	18.13
9890		75	33	.794	125	16.50	5.55	22.05
9900		125	36	.878	175	20.50	7	27.50
9920		200	36	.950	263	25	6.80	31.80
9930	35x35	40	24	.689	50	9.45	3.37	12.82
9940		40	30	.787	90	13.90	4.76	18.66
9960		75	33	.871	125	17.75	5.95	23.70
9970		125	36	.949	175	19.55	6.80	26.35
9980		200	36	1.060	250	27	7.35	34.35

B1010 Floor Construction



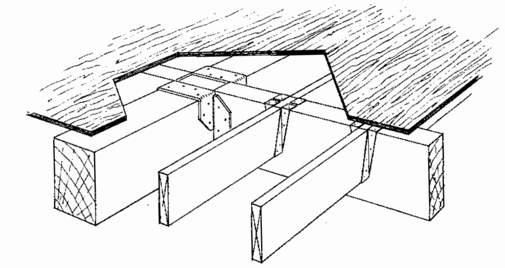
Description: Table below lists the S.F. costs for wood joists and a minimum thickness plywood subfloor.

Design Assumptions: 10% allowance has been added to framing quantities for overlaps, waste, double joists at openings or under partitions, etc. 5% added to subfloor for waste.

System Components	QUANTITY	UNIT	COST PER S.F. MAT.	COST PER S.F. INST.	COST PER S.F. TOTAL
SYSTEM B1010 261 2500					
WOOD JOISTS 2" X 6", 12" O.C.					
Framing joists, fir, 2"x6"	1.100	B.F.	.68	.97	1.[illegible]
Subfloor plywood CDX 1/2"	1.050	S.F.	.67	.78	1.[illegible]
TOTAL			1.35	1.75	3.[illegible]

B1010 261	Wood Joist	COST PER S.F. MAT.	COST PER S.F. INST.	COST PER S.F. TOTAL
2500	Wood joists, 2"x6", 12" O.C.	1.35	1.75	3.[illegible]
2550	16" O.C.	1.18	1.51	2.[illegible]
2600	24" O.C.	1.23	1.42	2.[illegible]
2900	2"x8", 12" O.C.	1.62	1.89	3.[illegible]
2950	16" O.C.	1.39	1.62	3.0[illegible]
3000	24" O.C.	1.37	1.49	2.8[illegible]
3300	2"x10", 12" O.C.	1.99	2.15	4.[illegible]
3350	16" O.C.	1.66	1.81	3.4[illegible]
3400	24" O.C.	1.54	1.61	3.1[illegible]
3700	2"x12", 12" O.C.	2.28	2.17	4.4[illegible]
3750	16" O.C.	1.87	1.82	3.6[illegible]
3800	24" O.C.	1.69	1.62	3.3[illegible]
4100	2"x14", 12" O.C.	2.76	2.37	5.1[illegible]
4150	16" O.C.	2.24	1.98	4.2[illegible]
4200	24" O.C.	1.94	1.73	3.67
4500	3"x6", 12" O.C.	2.31	2.09	4.40
4550	16" O.C.	1.90	1.77	3.67
4600	24" O.C.	1.72	1.59	3.31
4900	3"x8", 12" O.C.	3.37	2.06	5.43
4950	16" O.C.	2.69	1.74	4.43
5000	24" O.C.	2.24	1.57	3.81
5300	3"x10", 12" O.C.	4.04	2.33	6.37
5350	16" O.C.	3.21	1.95	5.16
5400	24" O.C.	2.58	1.71	4.29
5700	3"x12", 12" O.C.	4.04	2.03	6.07
5750	16" O.C.	3.71	2.31	6.02
5800	24" O.C.	2.91	1.94	4.85
6100	4"x6", 12" O.C.	3.37	2.13	5.50
6150	16" O.C.	2.69	1.79	4.48
6200	24" O.C.	2.24	1.61	3.85

B1010 Floor Construction



Description: Table lists the S.F. costs, total load, and member sizes, for various bay sizes and loading conditions.

Design Assumptions: Dead load = girder, beams, and joist weight plus 3/4" plywood floor.

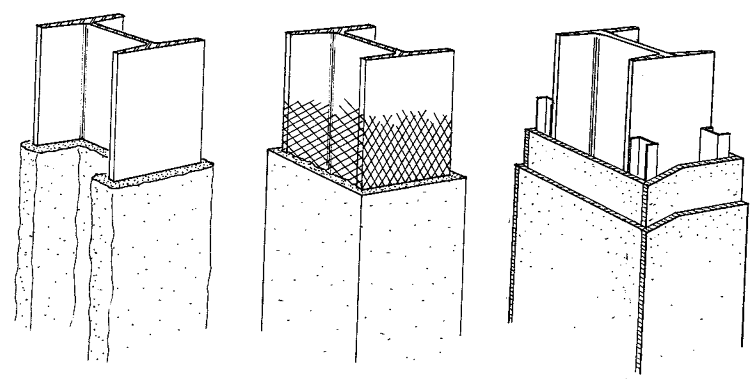
Maximum deflection is 1/360 of the clear span.

Lumber is stress grade f(w) = 1,800 PSI

System Components	QUANTITY	UNIT	COST PER S.F. MAT.	COST PER S.F. INST.	COST PER S.F. TOTAL
SYSTEM B1010 264 2000					
15' X 15' BAY, S. LOAD 40 P.S.F.					
Beams and girders, structural grade, 8" x 12"	.730	B.F.	1.71	.23	1.94
Framing joists, fir 4" x 12"	.660	B.F.	.92	.41	1.33
Framing joists, 2" x 6"	.840	B.F.	.52	.74	1.26
Beam to girder saddles	.510	Lb.	3.54	.73	4.27
Column caps	.510	Lb.	.95	.10	1.05
Drilling, bolt holes	.510	Lb.		.35	.35
Machine bolts	.510	Lb.	.15	.16	.31
Joist hangers 18 ga.	.213	Ea.	.30	.71	1.01
Subfloor plywood CDX 3/4"	1.050	S.F.	.89	.93	1.82
TOTAL			8.98	4.36	13.34

B1010 264	Wood Beam & Joist						
	BAY SIZE (FT.)	SUPERIMPOSED LOAD (P.S.F.)	GIRDER BEAM (IN.)	JOISTS (IN.)	TOTAL LOAD (P.S.F.)	COST PER S.F. MAT.	COST PER S.F. INST.	COST PER S.F. TOTAL
2000	15x15	40	8 x 12 4 x 12	2 x 6 @ 16	53	9	4.36	13.36
2050	RB1010 -100	75	8 x 16 4 x 16	2 x 8 @ 16	90	11.90	4.77	16.67
2100		125	12 x 16 6 x 16	2 x 8 @ 12	144	18.45	6.10	24.55
2150		200	14 x 22 12 x 16	2 x 10 @ 12	227	37	9.35	46.35
2500	15x20	40	10 x 16 8 x 12	2 x 6 @ 16	58	11.60	4.45	16.05
2550		75	12 x 14 8 x 14	2 x 8 @ 16	96	15	5.15	20.15
2600		125	10 x 18 12 x 14	2 x 8 @ 12	152	22	6.90	28.90
2650		200	14 x 20 14 x 16	2 x 10 @ 12	234	32	8.50	40.50
3000	20x20	40	10 x 14 10 x 12	2 x 8 @ 16	63	11.05	4.39	15.44
3050		75	12 x 16 8 x 16	2 x 10 @ 16	102	15.80	4.92	20.72
3100		125	14 x 22 12 x 16	2 x 10 @ 12	163	31	7.80	38.80

B1010 Floor Construction



Listed below are costs per V.L.F. for fireproofing by material, column size, thickness and fire rating. Weights listed are for the fireproofing material only.

System Components	QUANTITY	UNIT	COST PER V.L.F. MAT.	INST.	TOTAL
SYSTEM B1010 720 3000					
CONCRETE FIREPROOFING, 8" STEEL COLUMN, 1" THICK, 1 HR. FIRE RATING					
Forms in place, columns, plywood, 4 uses	3.330	SFCA	2.93	27.97	[illegible]
Welded wire fabric, 2 x 2 #14 galv. 21 lb./C.S.F., column wrap	2.700	S.F.	1.24	5.24	[illegible]
Concrete ready mix, regular weight, 3000 psi	.621	C.F.	2.46		[illegible]
Place and vibrate concrete, 12" sq./round columns, pumped	.621	C.F.		1.76	[illegible]
TOTAL			6.63	34.97	[illegible]

B1010 720 Steel Column Fireproofing

	ENCASEMENT SYSTEM	COLUMN SIZE (IN.)	THICKNESS (IN.)	FIRE RATING (HRS.)	WEIGHT (P.L.F.)	COST PER V.L.F. MAT.	INST.	TOTAL
3000	Concrete	8	1	1	110	6.65	35	[illegible]
3050			1-1/2	2	133	7.60	39	[illegible]
3100			2	3	145	8.55	42	[illegible]
3150		10	1	1	145	8.65	43.50	[illegible]
3200			1-1/2	2	168	9.60	46.50	[illegible]
3250			2	3	196	10.65	49.50	[illegible]
3300		14	1	1	258	10.90	51	[illegible]
3350			1-1/2	2	294	11.85	54	[illegible]
3400			2	3	325	13	58	[illegible]
3450	Gypsum board	8	1/2	2	8	3.25	21.50	[illegible]
3500	1/2" fire rated	10	1/2	2	11	3.40	22.50	[illegible]
3550	1 layer	14	1/2	2	18	3.48	23	[illegible]
3600	Gypsum board	8	1	3	14	4.33	27.50	[illegible]
3650	1/2" fire rated	10	1	3	17	4.61	29	[illegible]
3700	2 layers	14	1	3	22	4.76	30	[illegible]
3750	Gypsum board	8	1-1/2	3	23	5.60	34.50	[illegible]
3800	1/2" fire rated	10	1-1/2	3	27	6.25	38	[illegible]
3850	3 layers	14	1-1/2	3	35	6.90	42	[illegible]
3900	Sprayed fiber	8	1-1/2	2	6.3	3.93	6.85	[illegible]
3950	Direct application		2	3	8.3	5.40	9.45	[illegible]
4000			2-1/2	4	10.4	7	12.20	[illegible]
4050		10	1-1/2	2	7.9	4.75	8.25	[illegible]
4100			2	3	10.5	6.50	11.30	[illegible]
4150			2-1/2	4	13.1	8.40	14.60	[illegible]

B1010 Floor Construction

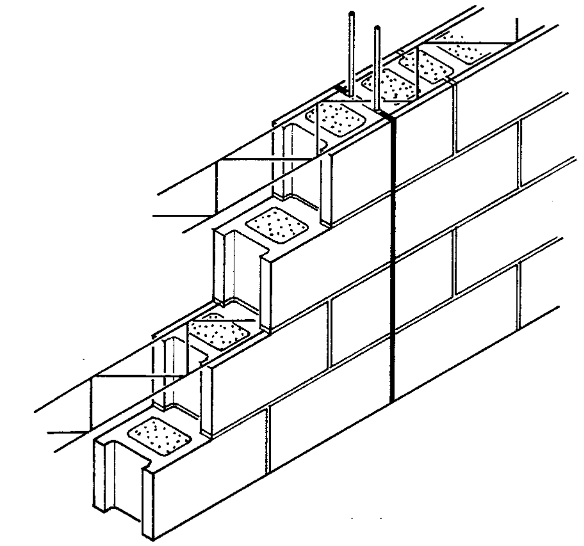
B1010 720 Steel Column Fireproofing

	ENCASEMENT SYSTEM	COLUMN SIZE (IN.)	THICKNESS (IN.)	FIRE RATING (HRS.)	WEIGHT (P.L.F.)	COST PER V.L.F. MAT.	INST.	TOTAL
4200	Sprayed fiber	14	1-1/2	2	10.8	5.90	10.25	16.15
4250	Direct application		2	3	14.5	8.05	14.05	22.10
4300			2-1/2	4	18	10.30	17.95	28.25
4350	3/4" gypsum plaster	8	3/4	1	23	6.70	27.50	34.20
4400	On metal lath	10	3/4	1	28	7.70	31	38.70
4450		14	3/4	1	38	9.35	39	48.35
4500	Perlite plaster	8	1	2	18	7.60	30.50	38.10
4550	On metal lath		1-3/8	3	23	8.30	34	42.30
4600			1-3/4	4	35	9.85	41	50.85
4650	Perlite plaster	10	1	2	21	8.75	35.50	44.25
4700			1-3/8	3	27	9.90	40.50	50.40
4750			1-3/4	4	41	11.15	46.50	57.65
4800		14	1	2	29	11	44.50	55.50
4850			1-3/8	3	35	12.40	51	63.40
4900			1-3/4	4	53	12.85	53	65.85
4950	1/2 gypsum plaster	8	7/8	1	13	6.10	23	29.10
5000	On 3/8" gypsum lath	10	7/8	1	16	7.30	27	34.30
5050		14	7/8	1	21	8.95	33	41.95
5100	5/8" gypsum plaster	8	1	1-1/2	20	6.15	25	31.15
5150	On 3/8" gypsum lath	10	1	1-1/2	24	7.30	29.50	36.80
5200		14	1	1-1/2	33	8.95	36.50	45.45
5250	1"perlite plaster	8	1-3/8	2	23	6.05	26	32.05
5300	On 3/8" gypsum lath	10	1-3/8	2	28	6.90	30	36.90
5350		14	1-3/8	2	37	8.60	38	46.60
5400	1-3/8" perlite plaster	8	1-3/4	3	27	7.50	29.50	37
5450	On 3/8" gypsum lath	10	1-3/4	3	33	8.60	34	42.60
5500		14	1-3/4	3	43	10.85	43	53.85
5550	Concrete masonry	8	4-3/4	4	126	10.30	32	42.30
5600	Units 4" thick	10	4-3/4	4	166	12.90	40	52.90
5650	75% solid	14	4-3/4	4	262	15.45	48	63.45

B2010 Exterior Walls

B2010 106	Tilt-Up Concrete Panel	COST PER S.F.	
		MAT.	INST.
4500	8" thick, 3000 PSI	6.45	6.75
4550	5000 PSI	6.65	6.60
4600	Exposed aggregate & vert. rustication 5-1/2" thick, 3000 PSI	6.65	7.65
4650	5000 PSI	6.75	7.55
4700	6" thick, 3000 PSI	7.05	7.80
4750	5000 PSI	7.15	7.70
4800	7-1/2" thick, 3000 PSI	8.25	8
4850	5000 PSI	8.45	7.90
4900	8" thick, 3000 PSI	8.70	8.15
4950	5000 PSI	8.85	8.05
5000	Vertical rib & light sandblast, 5-1/2" thick, 3000 PSI	6.65	10
5050	5000 PSI	6.75	9.90
5100	6" thick, 3000 PSI	7.10	10.15
5150	5000 PSI	7.20	10.05
5200	7-1/2" thick, 3000 PSI	8.30	10.40
5250	5000 PSI	8.45	10.30
5300	8" thick, 3000 PSI	8.70	10.55
5350	5000 PSI	8.90	10.45
6000	Broom finish w/2" polystyrene insulation, 6" thick, 3000 PSI	3.84	7.45
6050	5000 PSI	3.99	7.45
6100	Broom finish 2" fiberplank insulation, 6" thick, 3000 PSI	4.33	7.35
6150	5000 PSI	4.48	7.35
6200	Exposed aggregate w/2" polystyrene insulation, 6" thick, 3000 PSI	4.11	7.45
6250	5000 PSI	4.26	7.45
6300	Exposed aggregate 2" fiberplank insulation, 6" thick, 3000 PSI	4.60	7.35
6350	5000 PSI	4.75	7.35

B2010 Exterior Walls



Exterior concrete block walls are defined in the following terms; structural reinforcement, weight, percent solid, size, strength and insulation. Within each of these categories, two to four variations are shown. No costs are included for brick shelf or relieving angles.

System Components	QUANTITY	UNIT	COST PER S.F. MAT.	INST.	TOTAL
SYSTEM B2010 109 1400					
UNREINFORCED CONCRETE BLOCK WALL, 8" X 8" X 16", PERLITE CORE FILL					
Concrete block wall, 8" thick	1.000	S.F.	2.50	6.65	9.15
Perlite insulation	1.000	S.F.	1.70	.41	2.11
Horizontal joint reinforcing, alternate courses	.800	S.F.	.16	.17	.33
Control joint	.050	L.F.	.07	.07	.14
TOTAL			4.43	7.30	11.73

B2010 109	Concrete Block Wall - Regular Weight						
	TYPE	SIZE (IN.)	STRENGTH (P.S.I.)	CORE FILL	COST PER S.F. MAT.	INST.	TOTAL
1200	Hollow	4x8x16	2,000	none	1.85	6	7.85
1250			4,500	none	2.25	6	8.25
1300	RB2010 -200	6x8x16	2,000	perlite	3.70	6.80	10.50
1310				styrofoam	3.80	6.45	10.25
1340				none	2.55	6.45	9
1350			4,500	perlite	3.92	6.80	10.72
1360				styrofoam	4.02	6.45	10.47
1390				none	2.77	6.45	9.22
1400		8x8x16	2,000	perlite	4.43	7.30	11.73
1410				styrofoam	3.98	6.90	10.88
1440				none	2.73	6.90	9.63
1450			4,500	perlite	5.10	7.30	12.40
1460				styrofoam	4.63	6.90	11.53
1490				none	3.38	6.90	10.28
1500		12x8x16	2,000	perlite	6.85	9.75	16.60
1510				styrofoam	6.25	8.95	15.20
1540				none	4.07	8.95	13.02
1550			4,500	perlite	7.25	9.75	17
1560				styrofoam	6.65	8.95	15.60
1590				none	4.47	8.95	13.42
2000	75% solid	4x8x16	2,000	none	2.23	6.10	8.33
2050			4,500	none	2.76	6.10	8.86

B2010 Exterior Walls

B2010 111 Reinforced Concrete Block Wall - Regular Weight

	TYPE	SIZE (IN.)	STRENGTH (P.S.I.)	VERT. REINF & GROUT SPACING		COST PER S.F. MAT.	INST.	TO[TAL]
5400	Hollow	8x8x16	2,000	#4 @ 48"		3.11	7.60	
5430				#5 @ 32"		3.28	8	
5440				#5 @ 16"		3.82	9.15	
5450		8x8x16	4,500	#4 @ 48"		3.69	7.70	
5480				#5 @ 32"		3.93	8	
5490				#5 @ 16"		4.47	9.15	
5500		12x8x16	2,000	#4 @ 48"		4.51	9.80	
5530				#5 @ 32"		4.82	10.10	
5540				#5 @ 16"		5.55	11.30	
5550			4,500	#4 @ 48"		4.91	9.80	
5580				#5 @ 32"		5.20	10.10	
5590				#5 @ 16"		5.95	11.30	
6100	75% solid	6x8x16	2,000	#4 @ 48"		3.23	7.10	
6130				#5 @ 32"		3.39	7.35	
6140				#5 @ 16"		3.68	8.10	
6150			4,500	#4 @ 48"		3.52	7.10	
6180				#5 @ 32"		3.68	7.35	
6190				#5 @ 16"		3.97	8.10	
6200		8x8x16	2,000	#4 @ 48"		3.43	7.65	
6230				#5 @ 32"		3.60	7.90	
6240				#5 @ 16"		3.91	8.85	
6250			4,500	#4 @ 48"		4.28	7.65	
6280				#5 @ 32"		4.45	7.90	
6290				#5 @ 16"		4.76	8.85	
6300		12x8x16	2,000	#4 @ 48"		5.20	9.75	
6330				#5 @ 32"		5.40	10	
6340				#5 @ 16"		5.85	10.95	
6350			4,500	#4 @ 48"		5.70	9.75	
6380				#4 @ 32"		5.95	10	
6390				#5 @ 16"		6.40	10.95	
6500	Solid-double Wythe	2-4x8x16	2,000	#4 @ 48" E.W.		5.10	14.05	
6530				#5 @ 16" E.W.		5.80	14.95	
6550			4,500	#4 @ 48" E.W.		7.05	13.95	
6580				#5 @ 16" E.W.		7.80	14.85	
6600		2-6x8x16	2,000	#4 @ 48" E.W.		5.10	15.10	
6630				#5 @ 16" E.W.		5.85	16	
6650			4,000	#4 @ 48" E.W.		8.40	14.90	
6680				#5 @ 16" E.W.		9.15	15.80	

B2010 112 Reinforced Concrete Block Wall - Lightweight

	TYPE	SIZE (IN.)	WEIGHT (P.C.F.)	VERT REINF. & GROUT SPACING		COST PER S.F. MAT.	INST.	TOTA[L]
7100	Hollow	8x4x16	105	#4 @ 48"		2.88	7.30	
7130				#5 @ 32"		3.12	7.60	
7140				#5 @ 16"		3.66	8.75	
7150			85	#4 @ 48"		4.15	7.15	
7180				#5 @ 32"		4.39	7.45	
7190				#5 @ 16"		4.93	8.60	
7200		4x8x16	105	#4 @ 48"		2.15	6.55	
7250			85	#4 @ 48"		2.63	6.40	

B2010 Exterior Walls

B2010 112 Reinforced Concrete Block Wall - Lightweight

	TYPE	SIZE (IN.)	WEIGHT (P.C.F.)	VERT REINF. & GROUT SPACING		COST PER S.F. MAT.	INST.	TOTAL
7300	Hollow	6x8x16	105	#4 @ 48"		3.07	7	10.07
7330				#5 @ 32"		3.28	7.25	10.53
7340				#5 @ 16"		3.75	8.20	11.95
7350			85	#4 @ 48"		3.71	6.85	10.56
7380				#5 @ 32"		3.92	7.10	11.02
7390				#5 @ 16"		4.39	8.05	12.44
7400		8x8x16	105	#4 @ 48"		3.69	7.55	11.24
7430				#5 @ 32"		3.93	7.85	11.78
7440				#5 @ 16"		4.47	9	13.47
7450		8x8x16	85	#4 @ 48"		3.96	7.40	11.36
7480				#5 @ 32"		4.20	7.70	11.90
7490				#5 @ 16"		4.74	8.85	13.59
7510		12x8x16	105	#4 @ 48"		4.67	9.55	14.22
7530				#5 @ 32"		4.98	9.85	14.83
7540				#5 @ 16"		5.70	11.05	16.75
7550			85	#4 @ 48"		5.95	9.30	15.25
7580				#5 @ 32"		6.25	9.60	15.85
7590				#5 @ 16"		7	10.80	17.80
7600		4x8x24	105	#4 @ 48"		1.67	7.25	8.92
7650			85	#4 @ 48"		3.69	6.15	9.84
7700		6x8x24	105	#4 @ 48"		2.35	7.55	9.90
7730				#5 @ 32"		2.56	7.80	10.36
7740				#5 @ 16"		3.03	8.75	11.78
7750			85	#4 @ 48"		5.30	6.45	11.75
7780				#5 @ 32"		5.50	6.70	12.20
7790				#5 @ 16"		6	7.65	13.65
7800		8x8x24	105	#4 @ 48"		2.85	8.10	10.95
7840				#5 @ 16"		3.63	9.55	13.18
7850			85	#4 @ 48"		6.40	6.95	13.35
7880				#5 @ 32"		6.65	7.25	13.90
7890				#5 @ 16"		7.15	8.40	15.55
7900		12x8x24	105	#4 @ 48"		3.63	9.20	12.83
7930				#5 @ 32"		3.94	9.50	13.44
7940				#5 @ 16"		4.67	10.70	15.37
7950			85	#4 @ 48"		8.05	9	17.05
7980				#5 @ 32"		8.35	9.30	17.65
7990				#5 @ 16"		9.10	10.50	19.60
8100	75% solid	6x8x16	105	#4 @ 48"		4.24	6.90	11.14
8130				#5 @ 32"		4.40	7.15	11.55
8140				#5 @ 16"		4.69	7.90	12.59
8150			85	#4 @ 48"		4.41	6.75	11.16
8180				#5 @ 32"		4.57	7	11.57
8190				#5 @ 16"		4.86	7.75	12.61
8200		8x8x16	105	#4 @ 48"		5.05	7.50	12.55
8230				#5 @ 32"		5.25	7.75	13
8240				#5 @ 16"		5.55	8.70	14.25
8250			85	#4 @ 48"		4.63	7.30	11.93
8280				#5 @ 32"		4.80	7.55	12.35
8290				#5 @ 16"		5.10	8.50	13.60

06 16 23 – Subflooring

06 16 23.10 Subfloor

		Crew	Daily Output	Labor-Hours	Unit	2013 Bare Costs Material	Labor	Equipment	Total
0010	**SUBFLOOR**								
0011	Plywood, CDX, 1/2" thick	2 Carp	1500	.011	SF Flr.	.58	.48		1.06
0017	Pneumatic nailed		1860	.009		.58	.39		.97
0102	5/8" thick		1350	.012		.73	.53		1.26
0107	Pneumatic nailed		1674	.010		.73	.43		1.16
0202	3/4" thick		1250	.013		.77	.57		1.34
0207	Pneumatic nailed		1550	.010		.77	.46		1.23
0302	1-1/8" thick, 2-4-1 including underlayment		1050	.015		1.53	.68		2.21
0440	With boards, 1" x 6", S4S, laid regular		900	.018		1.80	.80		2.60
0452	1" x 8", laid regular		1000	.016		1.81	.72		2.53
0462	Laid diagonal		850	.019		1.81	.85		2.66
0502	1" x 10", laid regular		1100	.015		1.84	.65		2.49
0602	Laid diagonal		900	.018		1.84	.80		2.64
8990	Subfloor adhesive, 3/8" bead	1 Carp	2300	.003	L.F.	.12	.16		.28
9000	Minimum labor/equipment charge	"	4	2	Job		90		90

06 16 26 – Underlayment

06 16 26.10 Wood Product Underlayment

		Crew	Daily Output	Labor-Hours	Unit	2013 Bare Costs Material	Labor	Equipment	Total
0010	**WOOD PRODUCT UNDERLAYMENT** R061636-20								
0030	Plywood, underlayment grade, 3/8" thick	2 Carp	1500	.011	SF Flr.	.81	.48		1.29
0080	Pneumatic nailed		1860	.009		.81	.39		1.20
0102	1/2" thick		1450	.011		.94	.50		1.44
0107	Pneumatic nailed		1798	.009		.94	.40		1.34
0202	5/8" thick		1400	.011		1.09	.51		1.60
0207	Pneumatic nailed		1736	.009		1.09	.41		1.50
0302	3/4" thick		1300	.012		1.24	.55		1.79
0306	Pneumatic nailed		1612	.010		1.24	.45		1.69
0502	Particle board, 3/8" thick		1500	.011		.37	.48		.85
0507	Pneumatic nailed		1860	.009		.37	.39		.76
0602	1/2" thick		1450	.011		.41	.50		.91
0607	Pneumatic nailed		1798	.009		.41	.40		.81
0802	5/8" thick		1400	.011		.50	.51		1.01
0807	Pneumatic nailed		1736	.009		.50	.41		.91
0902	3/4" thick		1300	.012		.68	.55		1.23
0907	Pneumatic nailed		1612	.010		.68	.45		1.13
0955	Particleboard, 100% recycled straw/wheat, 4' x 8' x 1/4" G		1450	.011	S.F.	.28	.50		.78
0960	4' x 8' x 3/8" G		1450	.011		.41	.50		.91
0965	4' x 8' x 1/2" G		1350	.012		.57	.53		1.10
0970	4' x 8' x 5/8" G		1300	.012		.69	.55		1.24
0975	4' x 8' x 3/4" G		1250	.013		.79	.57		1.36
0980	4' x 8' x 1" G		1150	.014		1.05	.62		1.67
0985	4' x 8' x 1-1/4" G		1100	.015		1.20	.65		1.85
1100	Hardboard, underlayment grade, 4' x 4', .215" thick		1500	.011	SF Flr.	.57	.48		1.05
9000	Minimum labor/equipment charge	1 Carp	4	2	Job		90		90

06 16 36 – Wood Panel Product Sheathing

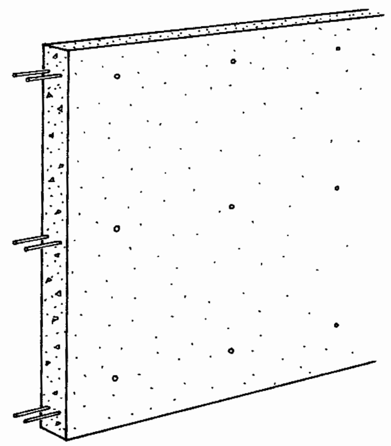
06 16 36.10 Sheathing

		Crew	Daily Output	Labor-Hours	Unit	2013 Bare Costs Material	Labor	Equipment	Total
0010	**SHEATHING** R061636-20								
0012	Plywood on roofs, CDX								
0032	5/16" thick	2 Carp	1600	.010	S.F.	.55	.45		1
0037	Pneumatic nailed R061110-30		1952	.008		.55	.37		.92
0052	3/8" thick		1525	.010		.51	.47		.98
0057	Pneumatic nailed		1860	.009		.51	.39		.90
0102	1/2" thick		1400	.011		.58	.51		1.09

06 16 36.10 Sheathing

		Crew	Daily Output	Labor-Hours	Unit	2013 Bare Costs Material	Labor	Equipment	Total	Total Incl O&P
0103	Pneumatic nailed	2 Carp	1708	.009	S.F.	.58	.42		1	1.33
0202	5/8" thick		1300	.012		.73	.55		1.28	1.71
0207	Pneumatic nailed		1586	.010		.73	.45		1.18	1.54
0302	3/4" thick		1200	.013		.77	.60		1.37	1.83
0307	Pneumatic nailed		1464	.011		.77	.49		1.26	1.66
0502	Plywood on walls with exterior CDX, 3/8" thick		1200	.013		.51	.60		1.11	1.54
0507	Pneumatic nailed		1488	.011		.51	.48		.99	1.35
0602	1/2" thick		1125	.014		.58	.64		1.22	1.69
0607	Pneumatic nailed		1395	.011		.58	.52		1.10	1.48
0702	5/8" thick		1050	.015		.73	.68		1.41	1.92
0707	Pneumatic nailed		1302	.012		.73	.55		1.28	1.71
0802	3/4" thick		975	.016		.77	.74		1.51	2.06
0807	Pneumatic nailed		1209	.013		.77	.59		1.36	1.82
0840	Oriented strand board, 7/16" thick G		1400	.011		.37	.51		.88	1.25
0845	Pneumatic nailed G		1736	.009		.37	.41		.78	1.09
0846	1/2" thick G		1325	.012		.37	.54		.91	1.30
0847	Pneumatic nailed G		1643	.010		.37	.44		.81	1.13
0852	5/8" thick G		1250	.013		.47	.57		1.04	1.46
0857	Pneumatic nailed G		1550	.010		.47	.46		.93	1.28
1000	For shear wall construction, add						20%			
1200	For structural 1 exterior plywood, add				S.F.	10%				
1402	With boards, on roof 1" x 6" boards, laid horizontal	2 Carp	725	.022		1.80	.99		2.79	3.61
1502	Laid diagonal		650	.025		1.80	1.11		2.91	3.79
1702	1" x 8" boards, laid horizontal		875	.018		1.81	.82		2.63	3.34
1802	Laid diagonal		725	.022		1.81	.99		2.80	3.62
2000	For steep roofs, add						40%			
2200	For dormers, hips and valleys, add					5%	50%			
2402	Boards on walls, 1" x 6" boards, laid regular	2 Carp	650	.025		1.80	1.11		2.91	3.79
2502	Laid diagonal		585	.027		1.80	1.23		3.03	3.99
2702	1" x 8" boards, laid regular		765	.021		1.81	.94		2.75	3.53
2802	Laid diagonal		650	.025		1.81	1.11		2.92	3.80
2852	Gypsum, weatherproof, 1/2" thick		1050	.015		.41	.68		1.09	1.57
2900	With embedded glass mats		1100	.015		.72	.65		1.37	1.86
3000	Wood fiber, regular, no vapor barrier, 1/2" thick		1200	.013		.56	.60		1.16	1.60
3100	5/8" thick		1200	.013		.71	.60		1.31	1.76
3300	No vapor barrier, in colors, 1/2" thick		1200	.013		.68	.60		1.28	1.73
3400	5/8" thick		1200	.013		.72	.60		1.32	1.77
3600	With vapor barrier one side, white, 1/2" thick		1200	.013		.55	.60		1.15	1.59
3700	Vapor barrier 2 sides, 1/2" thick		1200	.013		.77	.60		1.37	1.83
3800	Asphalt impregnated, 25/32" thick		1200	.013		.30	.60		.90	1.31
3850	Intermediate, 1/2" thick		1200	.013		.22	.60		.82	1.22
9000	Minimum labor/equipment charge	1 Carp	2	4	Job		180		180	295

B2010 Exterior Walls



The table below describes a concrete wall system for exterior closure. There are several types of wall finishes priced from plain finish to a finish with 3/4″ rustication strip.

Design Assumptions:
Conc. f'c = 3000 to 5000 psi
Reinf. fy = 60,000 psi

System Components	QUANTITY	UNIT	COST PER S.F. MAT.	COST PER S.F. INST.	COST PER S.F. TOTAL
SYSTEM B2010 101 2100					
CONC. WALL, REINFORCED, 8′ HIGH, 6″ THICK, PLAIN FINISH, 3,000 PSI					
Forms in place, wall, job built plyform to 8′ high, 4 uses	2.000	SFCA	2.12	12.80	
Reinforcing in place, walls, #3 to #7	.752	Lb.	.43	.32	
Concrete ready mix, regular weight, 3000 psi	.018	C.Y.	1.93		
Place and vibrate concrete, walls 6″ thick, pump	.018	C.Y.		.83	
Finish wall, break ties, patch voids	2.000	S.F.	.08	1.88	
TOTAL			4.56	15.83	

B2010 101	Cast In Place Concrete	COST PER S.F. MAT.	COST PER S.F. INST.	COST PER S.F. TOTAL
2100	Conc wall reinforced, 8′ high, 6″ thick, plain finish, 3000 PSI	4.56	15.85	
2200	4000 PSI	4.65	15.85	
2300	5000 PSI	4.77	15.85	
2400	Rub concrete 1 side, 3000 PSI	4.56	18.75	
2500	4000 PSI	4.65	18.75	
2600	5000 PSI	4.77	18.75	
2700	Aged wood liner, 3000 PSI	5.75	18	
2800	4000 PSI	5.85	18	
2900	5000 PSI	5.95	18	
3000	Sand blast light 1 side, 3000 PSI	5.40	18.05	
3100	4000 PSI	5.45	18.05	
3300	5000 PSI	5.60	18.05	
3400	Sand blast heavy 1 side, 3000 PSI	6.20	22.50	
3500	4000 PSI	6.30	22.50	
3600	5000 PSI	6.40	22.50	
3700	3/4″ bevel rustication strip, 3000 PSI	4.73	16.80	
3800	4000 PSI	4.82	16.80	
3900	5000 PSI	4.94	16.80	
4000	8″ thick, plain finish, 3000 PSI	5.40	16.25	
4100	4000 PSI	5.50	16.25	
4200	5000 PSI	5.65	16.25	
4300	Rub concrete 1 side, 3000 PSI	5.40	19.15	
4400	4000 PSI	5.50	19.15	
4500	5000 PSI	5.65	19.15	
4550	8″ thick, aged wood liner, 3000 PSI	6.55	18.40	
4600	4000 PSI	6.70	18.40	

B2010 Exterior Walls

B2010 101	Cast In Place Concrete	COST PER S.F. MAT.	COST PER S.F. INST.	COST PER S.F. TOTAL
4700	5000 PSI	6.85	18.40	25.25
4750	Sand blast light 1 side, 3000 PSI	6.20	18.45	24.65
4800	4000 PSI	6.30	18.45	24.75
4900	5000 PSI	6.50	18.45	24.95
5000	Sand blast heavy 1 side, 3000 PSI	7	22.50	29.50
5100	4000 PSI	7.15	22.50	29.65
5200	5000 PSI	7.30	22.50	29.80
5300	3/4″ bevel rustication strip, 3000 PSI	5.55	17.20	22.75
5400	4000 PSI	5.65	17.20	22.85
5500	5000 PSI	5.85	17.20	23.05
5600	10″ thick, plain finish, 3000 PSI	6.15	16.60	22.75
5700	4000 PSI	6.30	16.60	22.90
5800	5000 PSI	6.55	16.60	23.15
5900	Rub concrete 1 side, 3000 PSI	6.15	19.50	25.65
6000	4000 PSI	6.30	19.50	25.80
6100	5000 PSI	6.55	19.50	26.05
6200	Aged wood liner, 3000 PSI	7.35	18.80	26.15
6300	4000 PSI	7.50	18.80	26.30
6400	5000 PSI	7.70	18.80	26.50
6500	Sand blast light 1 side, 3000 PSI	7	18.80	25.80
6600	4000 PSI	7.15	18.80	25.95
6700	5000 PSI	7.35	18.80	26.15
6800	Sand blast heavy 1 side, 3000 PSI	7.80	23	30.80
6900	4000 PSI	7.95	23	30.95
7000	5000 PSI	8.15	23	31.15
7100	3/4″ bevel rustication strip, 3000 PSI	6.35	17.55	23.90
7200	4000 PSI	6.50	17.55	24.05
7300	5000 PSI	6.70	17.55	24.25
7400	12″ thick, plain finish, 3000 PSI	7.10	17.05	24.15
7500	4000 PSI	7.30	17.05	24.35
7600	5000 PSI	7.55	17.05	24.60
7700	Rub concrete 1 side, 3000 PSI	7.10	19.95	27.05
7800	4000 PSI	7.30	19.95	27.25
7900	5000 PSI	7.55	19.95	27.50
8000	Aged wood liner, 3000 PSI	8.30	19.25	27.55
8100	4000 PSI	8.45	19.25	27.70
8200	5000 PSI	8.75	19.25	28
8300	Sand blast light 1 side, 3000 PSI	7.95	19.25	27.20
8400	4000 PSI	8.10	19.25	27.35
8500	5000 PSI	8.35	19.25	27.60
8600	Sand blast heavy 1 side, 3000 PSI	8.75	23.50	32.25
8700	4000 PSI	8.95	23.50	32.45
8800	5000 PSI	9.20	23.50	32.70
8900	3/4″ bevel rustication strip, 3000 PSI	7.30	18	25.30
9000	4000 PSI	7.45	18	25.45
9500	5000 PSI	7.70	18	25.70

B1010 Floor Construction

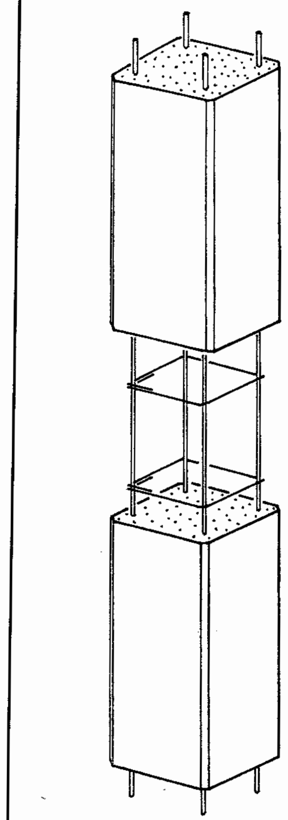
B1010 201 C.I.P. Column - Round Tied

	LOAD (KIPS)	STORY HEIGHT (FT.)	COLUMN SIZE (IN.)	COLUMN WEIGHT (P.L.F.)	CONCRETE STRENGTH (PSI)	COST PER V.L.F. MAT.	INST.	TOTAL
1940	900	10	24	439	6000	46.50	58.50	[illegible]
1945		12	24	445	6000	47.50	60	[illegible]
1970	1000	10	26	517	6000	55.50	63.50	[illegible]
1980		12	26	524	6000	56.50	65	[illegible]
1995		14	26	528	6000	57.50	66.50	[illegible]

B1010 202 C.I.P. Columns, Round Tied - Minimum Reinforcing

	LOAD (KIPS)	STORY HEIGHT (FT.)	COLUMN SIZE (IN.)	COLUMN WEIGHT (P.L.F.)	CONCRETE STRENGTH (PSI)	COST PER V.L.F. MAT.	INST.	TOTAL
2500	100	10-14	12	107	4000	9.55	24.50	34.[illegible]
2510	200	10-14	16	190	4000	16.70	31	47.[illegible]
2520	400	10-14	20	295	4000	26.50	39.50	66
2530	600	10-14	24	425	4000	37	48.50	85.5[illegible]
2540	800	10-14	28	580	4000	51	59.50	110.5[illegible]
2550	1100	10-14	32	755	4000	65.50	69	134.5[illegible]
2560	1400	10-14	36	960	4000	78	81	159
2570								

B1010 Floor Construction



CONCRETE COLUMNS

General: It is desirable for purposes of consistency and simplicity to maintain constant column sizes throughout the building height. To do this, concrete strength may be varied (higher strength concrete at lower stories and lower strength concrete at upper stories), as well as varying the amount of reinforcing.

The first portion of the table provides probable minimum column sizes with related costs and weights per lineal foot of story height for bottom level columns.

The second portion of the table provides costs by column size for top level columns with minimum code reinforcement. Probable maximum loads for these columns are also given.

How to Use Table:

1. Enter the second portion (minimum reinforcing) of the table with the minimum allowable column size from the selected cast in place floor system.

   If the total load on the column does not exceed the allowable working load shown, use the cost per L.F. multiplied by the length of columns required to obtain the column cost.

2. If the total load on the column exceeds the allowable working load shown in the second portion of the table, enter the first portion of the table with the total load on the column and the minimum allowable column size from the selected cast in place floor system.

   Select a cost per L.F. for bottom level columns by total load or minimum allowable column size.

   Select a cost per L.F. for top level columns using the column size required for bottom level columns from the second portion of the table.

$$\frac{\text{Btm. + Top Col. Costs/L.F.}}{2} = \text{Avg. Col. Cost/L.F.}$$

Column Cost = Average Col. Cost/L.F. x Length of Cols. Required.

See reference section in back of book to determine total loads.

Design and Pricing Assumptions:
Normal wt. concrete, f'c = 4 or 6 KSI, placed by pump.
Steel, fy = 60 KSI, spliced every other level.
Minimum design eccentricity of 0.1t.
Assumed load level depth is 8" (weights prorated to full story basis).
Gravity loads only (no frame or lateral loads included).

Please see the reference section for further design and cost information.

System Components	QUANTITY	UNIT	COST PER V.L.F. MAT.	INST.	TOTAL
SYSTEM B1010 203 0640					
SQUARE COLUMNS, 100K LOAD, 10' STORY, 10" SQUARE					
Forms in place, columns, plywood, 10" x 10", 4 uses	3.323	SFCA	3.27	31	34.27
Chamfer strip,wood, 3/4" wide	4.000	L.F.	1.04	4.20	5.24
Reinforcing in place, column ties	1.405	Lb.	3.88	5.71	9.59
Concrete ready mix, regular weight, 4000 psi	.026	C.Y.	2.91		2.91
Placing concrete, incl. vibrating, 12" sq./round columns, pumped	.026	C.Y.		1.98	1.98
Finish, break ties, patch voids, burlap rub w/grout	3.323	S.F.	.13	3.77	3.90
TOTAL			11.23	46.66	57.89

B1010 203 C.I.P. Column, Square Tied

	LOAD (KIPS)	STORY HEIGHT (FT.)	COLUMN SIZE (IN.)	COLUMN WEIGHT (P.L.F.)	CONCRETE STRENGTH (PSI)	COST PER V.L.F. MAT.	INST.	TOTAL
0640	100	10	10	96	4000	11.25	47	58.25
0680	RB1010 -112	12	10	97	4000	11.40	47	58.40
0700		14	12	142	4000	14.85	57	71.85
0710								

B1010 Floor Construction

B1010 203 — C.I.P. Column, Square Tied

	LOAD (KIPS)	STORY HEIGHT (FT.)	COLUMN SIZE (IN.)	COLUMN WEIGHT (P.L.F.)	CONCRETE STRENGTH (PSI)	COST PER V.L.F. MAT.	INST.	TOTAL
0740	150	10	10	96	4000	13.15	49.50	62.65
0780		12	12	142	4000	15.40	58	73.40
0800		14	12	143	4000	15.70	58	73.70
0840	200	10	12	140	4000	16.25	59	75.25
0860		12	12	142	4000	16.50	59.50	76
0900		14	14	196	4000	19.05	66	85.05
0920	300	10	14	192	4000	20	67.50	87.50
0960		12	14	194	4000	20.50	68	88.50
0980		14	16	253	4000	23.50	75.50	99
1020	400	10	16	248	4000	25	77.50	102.50
1060		12	16	251	4000	25.50	78.50	104
1080		14	16	253	4000	26	79	105
1200	500	10	18	315	4000	29.50	86.50	116
1250		12	20	394	4000	35.50	98.50	134
1300		14	20	397	4000	36	100	136
1350	600	10	20	388	4000	37	101	138
1400		12	20	394	4000	38	102	140
1600		14	20	397	4000	38.50	103	141.50
1900	700	10	20	388	4000	42.50	111	153.50
2100		12	22	474	4000	42.50	112	154.50
2300		14	22	478	4000	43.50	113	156.50
2600	800	10	22	388	4000	44.50	115	159.50
2900		12	22	474	4000	45.50	116	161.50
3200		14	22	478	4000	46.50	117	163.50
3400	900	10	24	560	4000	50	125	175
3800		12	24	567	4000	51	127	178
4000		14	24	571	4000	52	128	180
4250	1000	10	24	560	4000	54.50	132	186.50
4500		12	26	667	4000	57.50	138	195.50
4750		14	26	673	4000	58.50	140	198.50
5600	100	10	10	96	6000	11.80	46.50	58.30
5800		12	10	97	6000	12	47	59
6000		14	12	142	6000	15.70	57	72.70
6200	150	10	10	96	6000	13.75	49.50	63.25
6400		12	12	98	6000	16.25	58	74.25
6600		14	12	143	6000	16.55	58	74.55
6800	200	10	12	140	6000	17.10	59	76.10
7000		12	12	142	6000	17.40	59.50	76.90
7100		14	14	196	6000	20	66	86
7300	300	10	14	192	6000	21	67	88
7500		12	14	194	6000	21.50	67.50	89
7600		14	14	196	6000	21.50	68	89.50
7700	400	10	14	192	6000	22.50	69.50	92
7800		12	14	194	6000	23	70	93
7900		14	16	253	6000	25.50	75.50	101
8000	500	10	16	248	6000	26.50	77.50	104
8050		12	16	251	6000	27	78.50	105.50
8100		14	16	253	6000	27.50	79	106.50
8200	600	10	18	315	6000	31	87.50	118.50
8300		12	18	319	6000	31.50	88.50	120
8400		14	18	321	6000	32	89	121

B1010 Floor Construction

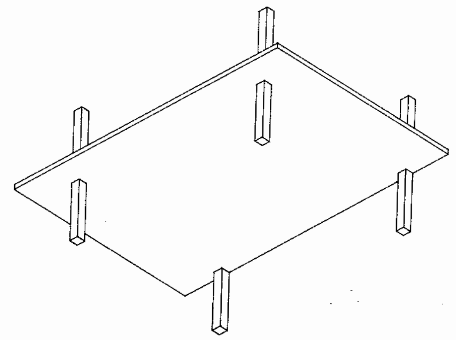
B1010 203 — C.I.P. Column, Square Tied

	LOAD (KIPS)	STORY HEIGHT (FT.)	COLUMN SIZE (IN.)	COLUMN WEIGHT (P.L.F.)	CONCRETE STRENGTH (PSI)	COST PER V.L.F. MAT.	INST.	TOTAL
8500	700	10	18	315	6000	32.50	90	122.50
8600		12	18	319	6000	33.50	91	124.50
8700		14	18	321	6000	34	92	126
8800	800	10	20	388	6000	38	98.50	136.50
8900		12	20	394	6000	38.50	100	138.50
9000		14	20	397	6000	39.50	101	140.50
9100	900	10	20	388	6000	41	103	144
9300		12	20	394	6000	41.50	104	145.50
9600		14	20	397	6000	42.50	106	148.50
9800	1000	10	22	469	6000	46.50	113	159.50
9840		12	22	474	6000	47.50	115	162.50
9900		14	22	478	6000	48.50	116	164.50

B1010 204 — C.I.P. Column, Square Tied-Minimum Reinforcing

	LOAD (KIPS)	STORY HEIGHT (FT.)	COLUMN SIZE (IN.)	COLUMN WEIGHT (P.L.F.)	CONCRETE STRENGTH (PSI)	COST PER V.L.F. MAT.	INST.	TOTAL
9913	150	10-14	12	135	4000	13.45	55	68.45
9918	300	10-14	16	240	4000	21	72	93
9924	500	10-14	20	375	4000	31.50	93	124.50
9930	700	10-14	24	540	4000	43	115	158
9936	1000	10-14	28	740	4000	56.50	141	197.50
9942	1400	10-14	32	965	4000	70	159	229
9948	1800	10-14	36	1220	4000	87	185	272
9954	2300	10-14	40	1505	4000	106	214	320

B1010 Floor Construction



General: Flat Plates: Solid uniform depth concrete two-way slab without drops or interior beams. Primary design limit is shear at columns.

Design and Pricing Assumptions:
Concrete f'c to 4 KSI, placed by concrete pump.
Reinforcement, fy = 60 KSI.
Forms, four use.
Finish, steel trowel.
Curing, spray on membrane.
Based on 4 bay x 4 bay structure.

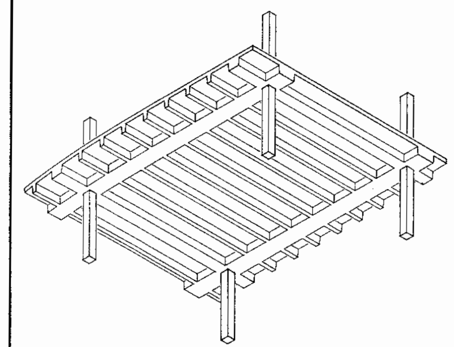
System Components

System Components	QUANTITY	UNIT	COST PER S.F. MAT.	COST PER S.F. INST.	COST PER S.F. TOTAL
SYSTEM B1010 223 2000					
15' X 15' BAY, 40 PSF S. LOAD, 12" MIN. COL.					
Forms in place, flat plate to 15' high, 4 uses	.992	S.F.	1.26	5.70	6.96
Edge forms to 6" high on elevated slab, 4 uses	.065	L.F.	.01	.27	.28
Reinforcing in place, elevated slabs #4 to #7	1.706	Lb.	.97	.73	1.70
Concrete, ready mix, regular weight, 3000 psi	.459	C.F.	1.82		1.82
Place and vibrate concrete, elevated slab less than 6", pump	.459	C.F.		.70	.70
Finish floor, monolithic steel trowel finish for finish floor	1.000	S.F.		.88	.88
Cure with sprayed membrane curing compound	.010	C.S.F.	.09	.09	.18
TOTAL			4.15	8.37	12.52

B1010 223 Cast in Place Flat Plate

B1010 223	BAY SIZE (FT.)	SUPERIMPOSED LOAD (P.S.F.)	MINIMUM COL. SIZE (IN.)	SLAB THICKNESS (IN.)	TOTAL LOAD (P.S.F.)	COST PER S.F. MAT.	COST PER S.F. INST.	COST PER S.F. TOTAL
2000	15 x 15	40	12	5-1/2	109	4.15	8.35	12.50
2200	RB1010 -010	75	14	5-1/2	144	4.18	8.35	12.53
2400		125	20	5-1/2	194	4.38	8.45	12.83
2600		175	22	5-1/2	244	4.49	8.50	12.99
3000	15 x 20	40	14	7	127	4.81	8.50	13.31
3400	RB1010 -100	75	16	7-1/2	169	5.15	8.65	13.80
3600		125	22	8-1/2	231	5.70	8.90	14.60
3800		175	24	8-1/2	281	5.75	8.90	14.65
4200	20 x 20	40	16	7	127	4.83	8.50	13.33
4400		75	20	7-1/2	175	5.20	8.65	13.85
4600		125	24	8-1/2	231	5.70	8.85	14.55
5000		175	24	8-1/2	281	5.75	8.90	14.65
5600	20 x 25	40	18	8-1/2	146	5.65	8.90	14.55
6000		75	20	9	188	5.85	8.95	14.80
6400		125	26	9-1/2	244	6.35	9.25	15.60
6600		175	30	10	300	6.60	9.35	15.95
7000	25 x 25	40	20	9	152	5.85	8.95	14.80
7400		75	24	9-1/2	194	6.20	9.20	15.40
7600		125	30	10	250	6.65	9.40	16.05
8000								

B1010 Floor Construction



General: Combination of thin concrete slab and monolithic ribs at uniform spacing to reduce dead weight and increase rigidity. The ribs (or joists) are arranged parallel in one direction between supports.

Square end joists simplify forming. Tapered ends can increase span or provide for heavy load.

Costs for multiple span joists are provided in this section. Single span joist costs are not provided here.

Design and Pricing Assumptions:
Concrete f'c = 4 KSI, normal weight placed by concrete pump.
Reinforcement, fy = 60 KSI.
Forms, four use.
4-1/2" slab.
30" pans, sq. ends (except for shear req.).
6" rib thickness.
Distribution ribs as required.
Finish, steel trowel.
Curing, spray on membrane.
Based on 4 bay x 4 bay structure.

System Components

System Components	QUANTITY	UNIT	COST PER S.F. MAT.	COST PER S.F. INST.	COST PER S.F. TOTAL
SYSTEM B1010 226 2000					
15' X 15' BAY, 40 PSF S. LOAD, 12" MIN. COLUMN					
Forms in place, floor slab, with 1-way joist pans, 4 use	.905	S.F.	3.06	5.84	8.90
Forms in place, exterior spandrel, 12" wide, 4 uses	.170	SFCA	.18	1.77	1.95
Forms in place, interior beam. 12" wide, 4 uses	.095	SFCA	.12	.81	.93
Edge forms, 7"-12" high on elevated slab, 4 uses	.010	L.F.	.01	.07	.08
Reinforcing in place, elevated slabs #4 to #7	.628	Lb.	.36	.27	.63
Concrete, ready mix, regular weight, 4000 psi	.555	C.F.	2.30		2.30
Place and vibrate concrete, elevated slab, 6" to 10" pump	.555	C.F.		.73	.73
Finish floor, monolithic steel trowel finish for finish floor	1.000	S.F.		.88	.88
Cure with sprayed membrane curing compound	.010	S.F.	.09	.09	.18
TOTAL			6.12	10.46	16.58

B1010 226 Cast in Place Multispan Joist Slab

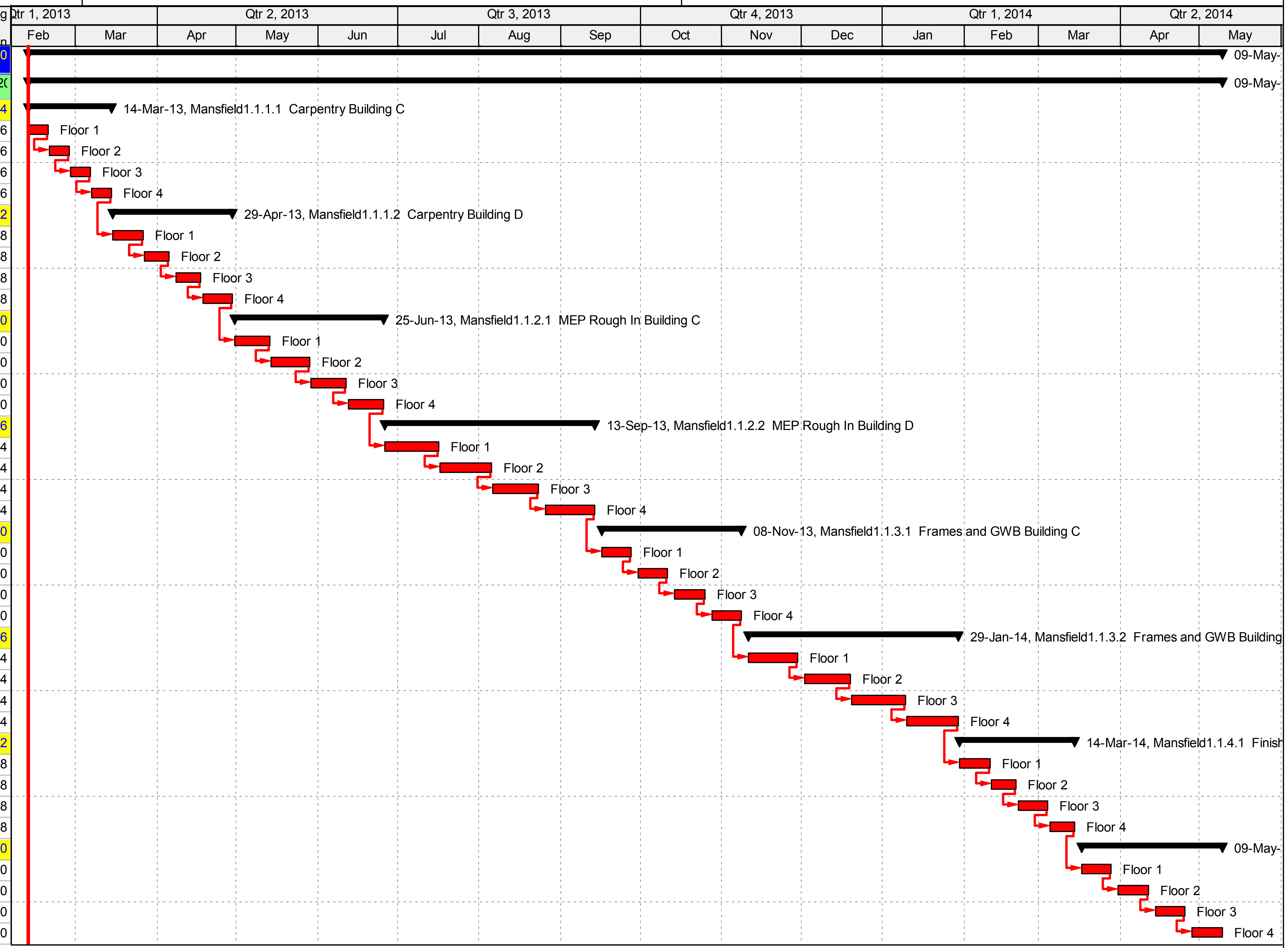
B1010 226	BAY SIZE (FT.)	SUPERIMPOSED LOAD (P.S.F.)	MINIMUM COL. SIZE (IN.)	RIB DEPTH (IN.)	TOTAL LOAD (P.S.F.)	COST PER S.F. MAT.	COST PER S.F. INST.	COST PER S.F. TOTAL
2000	15 x 15	40	12	8	115	6.10	10.45	16.55
2100	RB1010 -010	75	12	8	150	6.15	10.45	16.60
2200		125	12	8	200	6.30	10.55	16.85
2300		200	14	8	275	6.45	10.95	17.40
2600	15 x 20	40	12	8	115	6.25	10.40	16.65
2800	RB1010 -100	75	12	8	150	6.35	11.05	17.40
3000		125	14	8	200	6.60	11.20	17.80
3300		200	16	8	275	6.90	11.40	18.30
3600	20 x 20	40	12	10	120	6.40	10.30	16.70
3900		75	14	10	155	6.65	10.90	17.55
4000		125	16	10	205	6.70	11.10	17.80
4100		200	18	10	280	7.05	11.60	18.65
4300	20 x 25	40	12	10	120	6.35	10.45	16.80
4400		75	14	10	155	6.65	11	17.65
4500		125	16	10	205	7.05	11.55	18.60
4600		200	18	12	280	7.35	12.10	19.45
4700	25 x 25	40	12	12	125	6.45	10.20	16.65
4800		75	16	12	160	6.85	10.75	17.60
4900		125	18	12	210	7.60	11.80	19.40
5000		200	20	14	291	8	12.05	20.05

APPENDIX D

STICK BUILT CORE SCHEDULE

Mansfield Dormitories	Stick Built Non-Staggered Schedule	Depth 2

Activity ID	Activity Name	iginal ation	Start	Finish	ing ion
Mansfield1	Mansfield Dormitc	320	11-Feb-13	09-May-14	320
Mansfield1.1	Non-Staggered (	320	11-Feb-13	09-May-14	32(
Mansfield1.1.1.1	Carpentry Buildin	24	11-Feb-13	14-Mar-13	24
A1000	Floor 1	6	11-Feb-13	18-Feb-13	6
A1010	Floor 2	6	19-Feb-13	26-Feb-13	6
A1020	Floor 3	6	27-Feb-13	06-Mar-13	6
A1030	Floor 4	6	07-Mar-13	14-Mar-13	6
Mansfield1.1.1.2	Carpentry Buildin	32	15-Mar-13	29-Apr-13	32
A1040	Floor 1	8	15-Mar-13	26-Mar-13	8
A1050	Floor 2	8	27-Mar-13	05-Apr-13	8
A1060	Floor 3	8	08-Apr-13	17-Apr-13	8
A1070	Floor 4	8	18-Apr-13	29-Apr-13	8
Mansfield1.1.2.1	MEP Rough In Bui	40	30-Apr-13	25-Jun-13	40
A1080	Floor 1	10	30-Apr-13	13-May-13	10
A1090	Floor 2	10	14-May-13	28-May-13	10
A1100	Floor 3	10	29-May-13	11-Jun-13	10
A1110	Floor 4	10	12-Jun-13	25-Jun-13	10
Mansfield1.1.2.2	MEP Rough In Bui	56	26-Jun-13	13-Sep-13	56
A1120	Floor 1	14	26-Jun-13	16-Jul-13	14
A1130	Floor 2	14	17-Jul-13	05-Aug-13	14
A1140	Floor 3	14	06-Aug-13	23-Aug-13	14
A1150	Floor 4	14	26-Aug-13	13-Sep-13	14
Mansfield1.1.3.1	Frames and GWB	40	16-Sep-13	08-Nov-13	40
A1160	Floor 1	10	16-Sep-13	27-Sep-13	10
A1170	Floor 2	10	30-Sep-13	11-Oct-13	10
A1180	Floor 3	10	14-Oct-13	25-Oct-13	10
A1190	Floor 4	10	28-Oct-13	08-Nov-13	10
Mansfield1.1.3.2	Frames and GWB	56	11-Nov-13	29-Jan-14	56
A1200	Floor 1	14	11-Nov-13	29-Nov-13	14
A1210	Floor 2	14	02-Dec-13	19-Dec-13	14
A1220	Floor 3	14	20-Dec-13	09-Jan-14	14
A1230	Floor 4	14	10-Jan-14	29-Jan-14	14
Mansfield1.1.4.1	Finishes Building	32	30-Jan-14	14-Mar-14	32
A1240	Floor 1	8	30-Jan-14	10-Feb-14	8
A1250	Floor 2	8	11-Feb-14	20-Feb-14	8
A1260	Floor 3	8	21-Feb-14	04-Mar-14	8
A1270	Floor 4	8	05-Mar-14	14-Mar-14	8
Mansfield1.1.4.2	Finishes Building	40	17-Mar-14	09-May-14	40
A1280	Floor 1	10	17-Mar-14	28-Mar-14	10
A1290	Floor 2	10	31-Mar-14	11-Apr-14	10
A1300	Floor 3	10	14-Apr-14	25-Apr-14	10
A1310	Floor 4	10	28-Apr-14	09-May-14	10

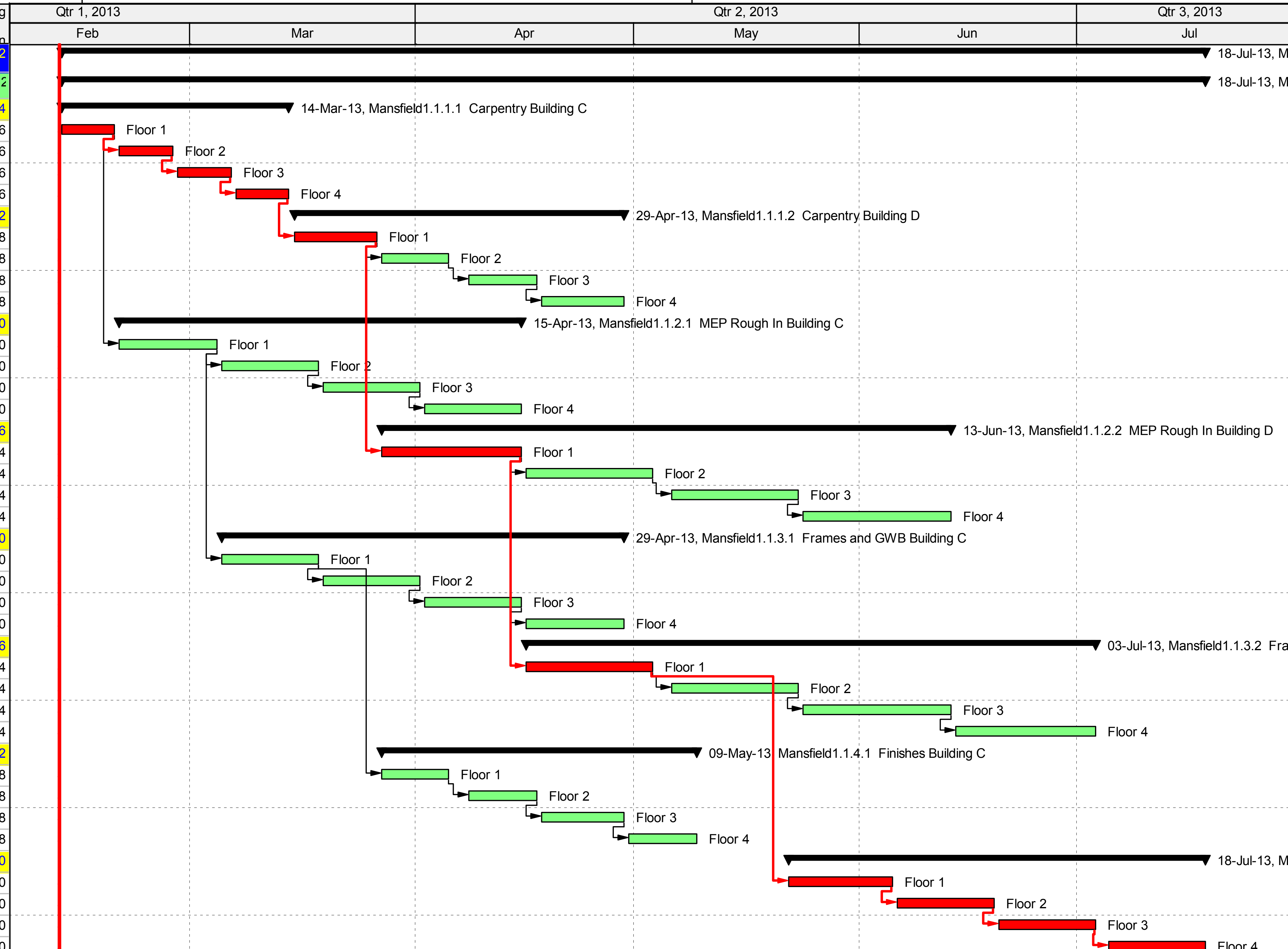


Actual Level of Effort — Remaining Work — Milestone
Actual Work — Critical Remaining Work — summary

TASK filter: All Activities

Mansfield Dormitories | Stick Built Schedule | Depth 2

Activity ID	Activity Name	iginal ation	Start	Finish	ing ion
Mansfield1	**Mansfield Dormitc**	112	11-Feb-13	18-Jul-13	112
Mansfield1.1	**Non-Staggered (**	112	11-Feb-13	18-Jul-13	112
Mansfield1.1.1.1	**Carpentry Buildin**	24	11-Feb-13	14-Mar-13	24
A1000	Floor 1	6	11-Feb-13	18-Feb-13	6
A1010	Floor 2	6	19-Feb-13	26-Feb-13	6
A1020	Floor 3	6	27-Feb-13	06-Mar-13	6
A1030	Floor 4	6	07-Mar-13	14-Mar-13	6
Mansfield1.1.1.2	**Carpentry Buildin**	32	15-Mar-13	29-Apr-13	32
A1040	Floor 1	8	15-Mar-13	26-Mar-13	8
A1050	Floor 2	8	27-Mar-13	05-Apr-13	8
A1060	Floor 3	8	08-Apr-13	17-Apr-13	8
A1070	Floor 4	8	18-Apr-13	29-Apr-13	8
Mansfield1.1.2.1	**MEP Rough In Bui**	40	19-Feb-13	15-Apr-13	40
A1080	Floor 1	10	19-Feb-13	04-Mar-13	10
A1090	Floor 2	10	05-Mar-13	18-Mar-13	10
A1100	Floor 3	10	19-Mar-13	01-Apr-13	10
A1110	Floor 4	10	02-Apr-13	15-Apr-13	10
Mansfield1.1.2.2	**MEP Rough In Bui**	56	27-Mar-13	13-Jun-13	56
A1120	Floor 1	14	27-Mar-13	15-Apr-13	14
A1130	Floor 2	14	16-Apr-13	03-May-13	14
A1140	Floor 3	14	06-May-13	23-May-13	14
A1150	Floor 4	14	24-May-13	13-Jun-13	14
Mansfield1.1.3.1	**Frames and GWB**	40	05-Mar-13	29-Apr-13	40
A1160	Floor 1	10	05-Mar-13	18-Mar-13	10
A1170	Floor 2	10	19-Mar-13	01-Apr-13	10
A1180	Floor 3	10	02-Apr-13	15-Apr-13	10
A1190	Floor 4	10	16-Apr-13	29-Apr-13	10
Mansfield1.1.3.2	**Frames and GWB**	56	16-Apr-13	03-Jul-13	56
A1200	Floor 1	14	16-Apr-13	03-May-13	14
A1210	Floor 2	14	06-May-13	23-May-13	14
A1220	Floor 3	14	24-May-13	13-Jun-13	14
A1230	Floor 4	14	14-Jun-13	03-Jul-13	14
Mansfield1.1.4.1	**Finishes Building**	32	27-Mar-13	09-May-13	32
A1240	Floor 1	8	27-Mar-13	05-Apr-13	8
A1250	Floor 2	8	08-Apr-13	17-Apr-13	8
A1260	Floor 3	8	18-Apr-13	29-Apr-13	8
A1270	Floor 4	8	30-Apr-13	09-May-13	8
Mansfield1.1.4.2	**Finishes Building**	40	22-May-13	18-Jul-13	40
A1280	Floor 1	10	22-May-13	05-Jun-13	10
A1290	Floor 2	10	06-Jun-13	19-Jun-13	10
A1300	Floor 3	10	20-Jun-13	03-Jul-13	10
A1310	Floor 4	10	05-Jul-13	18-Jul-13	10



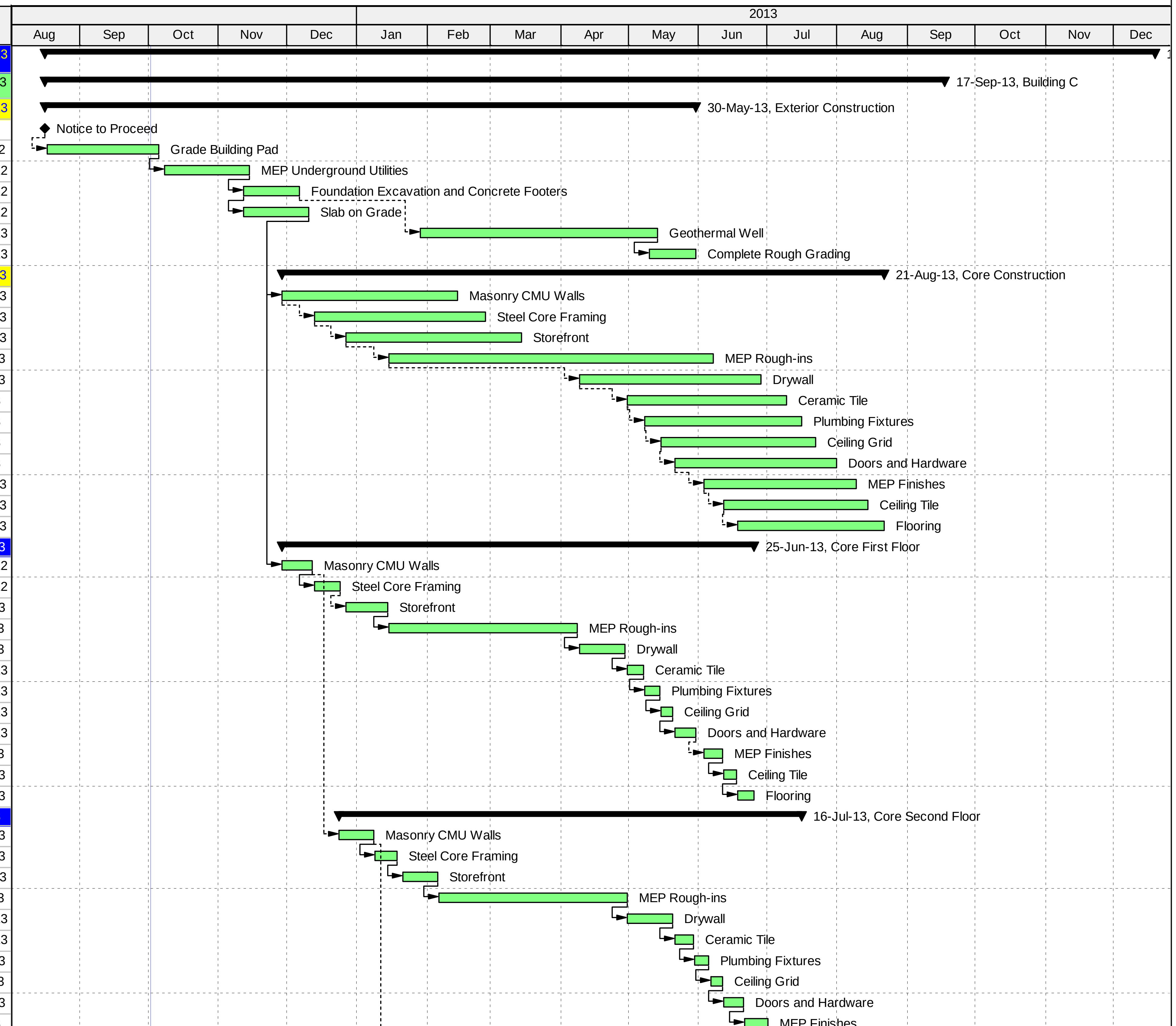
Actual Level of Effort | Remaining Work | Milestone
Actual Work | Critical Remaining Work | summary

TASK filter: All Activities

Michael Mahoney - Tech 2

Mansfield University Building C and D

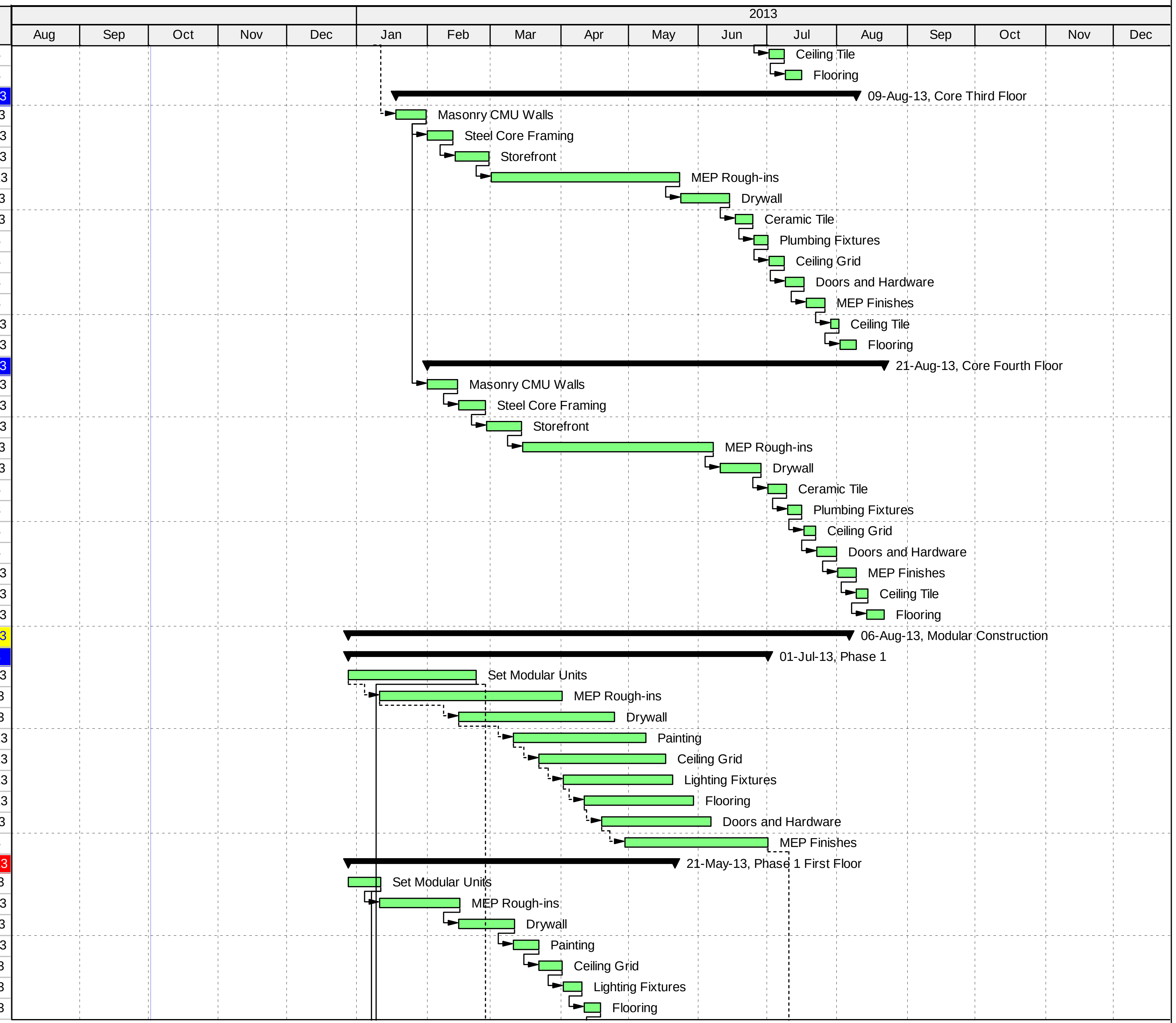
Activity ID	Activity Name	Original Duration	Start	Finish
Detailed Project Schedule1		343	16-Aug-12	19-Dec-13
Building C		277	16-Aug-12	17-Sep-13
Exterior Construction		201	16-Aug-12	30-May-13
E-000	Notice to Proceed	0	16-Aug-12	
E-001	Grade Building Pad	35	17-Aug-12	05-Oct-12
E-002	MEP Underground Utilities	28	08-Oct-1	14-Nov-12
E-003	Foundation Excavation and Concrete Foote	18	12-Nov-1	06-Dec-12
E-004	Slab on Grade	20	12-Nov-1	10-Dec-12
E-005	Geothermal Well	75	29-Jan-1	13-May-13
E-006	Complete Rough Grading	14	10-May-1	30-May-13
Core Construction		186	29-Nov-12	21-Aug-13
C-001	Masonry CMU Walls	54	29-Nov-1	14-Feb-13
C-002	Steel Core Framing	52	13-Dec-1	26-Feb-13
C-003	Storefront	55	27-Dec-1	14-Mar-13
C-004	MEP Rough-ins	103	15-Jan-1	07-Jun-13
C-005	Drywall	58	09-Apr-1	28-Jun-13
C-006	Ceramic Tile	49	30-Apr-1	09-Jul-13
C-007	Plumbing Fixtures	48	08-May-1	16-Jul-13
C-008	Ceiling Grid	47	15-May-1	22-Jul-13
C-009	Doors and Hardware	50	21-May-1	31-Jul-13
C-010	MEP Finishes	49	03-Jun-1	09-Aug-13
C-011	Ceiling Tile	45	12-Jun-1	14-Aug-13
C-012	Flooring	46	18-Jun-1	21-Aug-13
Core First Floor		146	29-Nov-12	25-Jun-13
C1-001	Masonry CMU Walls	10	29-Nov-1	12-Dec-12
C1-002	Steel Core Framing	8	13-Dec-1	24-Dec-12
C1-003	Storefront	12	27-Dec-1	14-Jan-13
C1-004	MEP Rough-ins	60	15-Jan-1	08-Apr-13
C1-005	Drywall	15	09-Apr-1	29-Apr-13
C1-006	Ceramic Tile	6	30-Apr-1	07-May-13
C1-007	Plumbing Fixtures	5	08-May-1	14-May-13
C1-008	Ceiling Grid	4	15-May-1	20-May-13
C1-009	Doors and Hardware	7	21-May-1	30-May-13
C1-010	MEP Finishes	7	03-Jun-1	11-Jun-13
C1-011	Ceiling Tile	4	12-Jun-1	17-Jun-13
C1-012	Flooring	6	18-Jun-1	25-Jun-13
Core Second Floor		143	24-Dec-12	16-Jul-13
C2-001	Masonry CMU Walls	10	24-Dec-1	08-Jan-13
C2-002	Steel Core Framing	8	09-Jan-1	18-Jan-13
C2-003	Storefront	12	21-Jan-1	05-Feb-13
C2-004	MEP Rough-ins	60	06-Feb-1	30-Apr-13
C2-005	Drywall	15	30-Apr-1	20-May-13
C2-006	Ceramic Tile	6	21-May-1	29-May-13
C2-007	Plumbing Fixtures	5	30-May-1	05-Jun-13
C2-008	Ceiling Grid	4	06-Jun-1	11-Jun-13
C2-009	Doors and Hardware	7	12-Jun-1	20-Jun-13
C2-010	MEP Finishes	7	21-Jun-1	01-Jul-13



Actual Work | Critical Remaining Work | Summary | Remaining Work | Milestone

TASK filter: All Activities

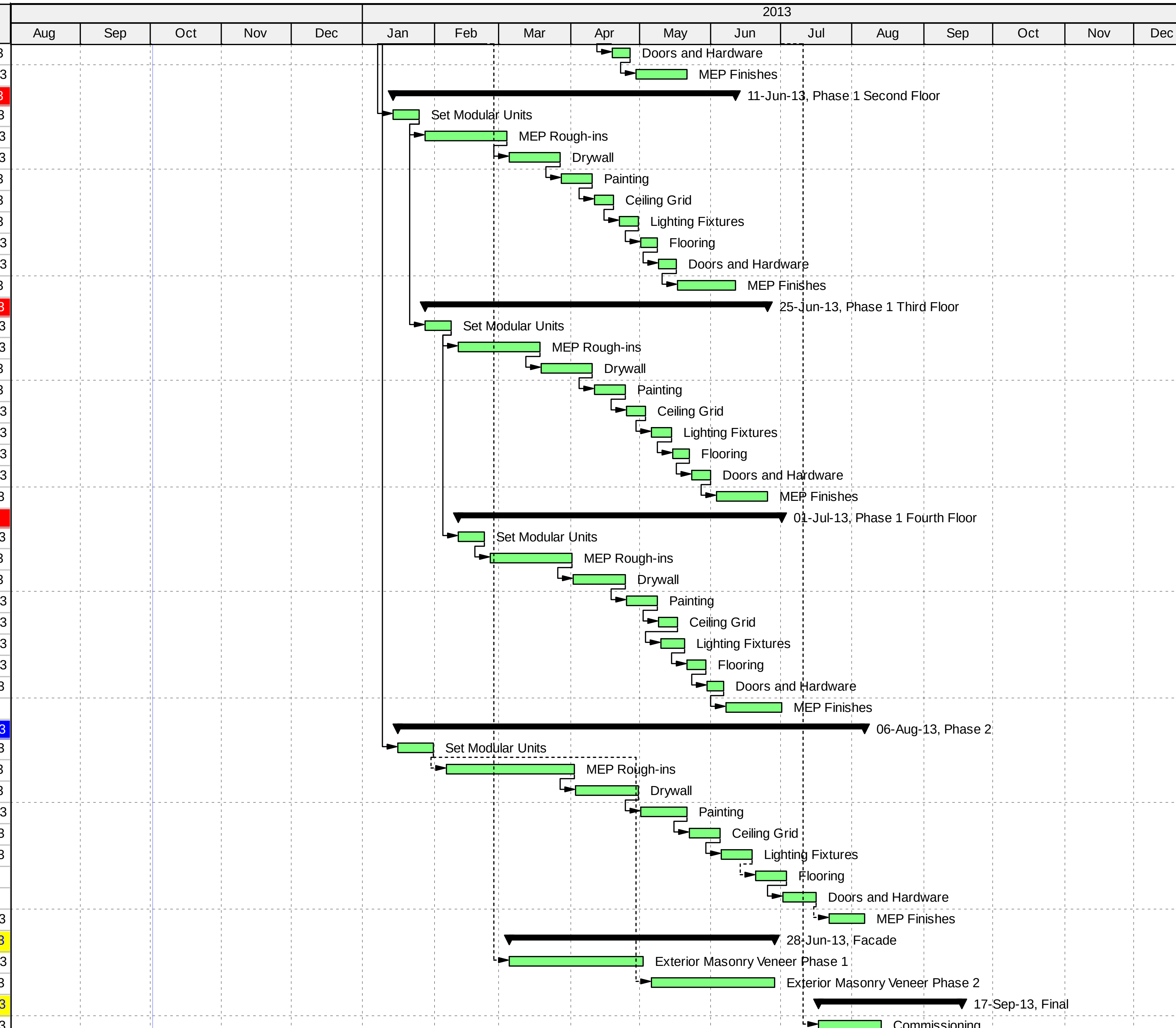
Activity ID	Activity Name	Original Duration	Start	Finish
C2-011	Ceiling Tile	4	02-Jul-13*	08-Jul-13
C2-012	Flooring	6	09-Jul-13*	16-Jul-13
Core Third Floor		**144**	**18-Jan-13**	**09-Aug-13**
C3-001	Masonry CMU Walls	10	18-Jan-1	31-Jan-13
C3-002	Steel Core Framing	8	01-Feb-1	12-Feb-13
C3-003	Storefront	12	13-Feb-1	28-Feb-13
C3-004	MEP Rough-ins	60	01-Mar-1	23-May-13
C3-005	Drywall	15	24-May-1	14-Jun-13
C3-006	Ceramic Tile	6	17-Jun-1	24-Jun-13
C3-007	Plumbing Fixtures	5	25-Jun-1	01-Jul-13
C3-008	Ceiling Grid	4	02-Jul-13*	08-Jul-13
C3-009	Doors and Hardware	7	09-Jul-13*	17-Jul-13
C3-010	MEP Finishes	7	18-Jul-13*	26-Jul-13
C3-011	Ceiling Tile	4	29-Jul-13*	01-Aug-13
C3-012	Flooring	6	02-Aug-1	09-Aug-13
Core Fourth Floor		**142**	**01-Feb-13**	**21-Aug-13**
C4-001	Masonry CMU Walls	10	01-Feb-1	14-Feb-13
C4-002	Steel Core Framing	8	15-Feb-1	26-Feb-13
C4-003	Storefront	12	27-Feb-1	14-Mar-13
C4-004	MEP Rough-ins	60	15-Mar-1	07-Jun-13
C4-005	Drywall	15	10-Jun-1	28-Jun-13
C4-006	Ceramic Tile	6	01-Jul-13*	09-Jul-13
C4-007	Plumbing Fixtures	5	10-Jul-13*	16-Jul-13
C4-008	Ceiling Grid	4	17-Jul-13*	22-Jul-13
C4-009	Doors and Hardware	7	23-Jul-13*	31-Jul-13
C4-010	MEP Finishes	7	01-Aug-1	09-Aug-13
C4-011	Ceiling Tile	4	09-Aug-1	14-Aug-13
C4-012	Flooring	6	14-Aug-1	21-Aug-13
Modular Construction		**155**	**28-Dec-12**	**06-Aug-13**
Phase 1		**130**	**28-Dec-12**	**01-Jul-13**
M-1001	Set Modular Units	40	28-Dec-1	22-Feb-13
M-1002	MEP Rough-ins	57	11-Jan-1	01-Apr-13
M-1003	Drywall	49	15-Feb-1	24-Apr-13
M-1004	Painting	43	11-Mar-1	08-May-13
M-1005	Ceiling Grid	41	22-Mar-1	17-May-13
M-1006	Lighting Fixtures	35	02-Apr-1	20-May-13
M-1007	Flooring	34	11-Apr-1	29-May-13
M-1008	Doors and Hardware	34	19-Apr-1	06-Jun-13
M-1009	MEP Finishes	45	29-Apr-1	01-Jul-13
Phase 1 First Floor		**102**	**28-Dec-12**	**21-May-13**
M1-001	Set Modular Units	10	28-Dec-1	11-Jan-13
M1-002	MEP Rough-ins	26	11-Jan-1	15-Feb-13
M1-003	Drywall	17	15-Feb-1	11-Mar-13
M1-004	Painting	10	11-Mar-1	22-Mar-13
M1-005	Ceiling Grid	7	22-Mar-1	01-Apr-13
M1-006	Lighting Fixtures	7	02-Apr-1	10-Apr-13
M1-007	Flooring	6	11-Apr-1	18-Apr-13



Actual Work | Critical Remaining Work | Summary
Remaining Work | Milestone

TASK filter: All Activities

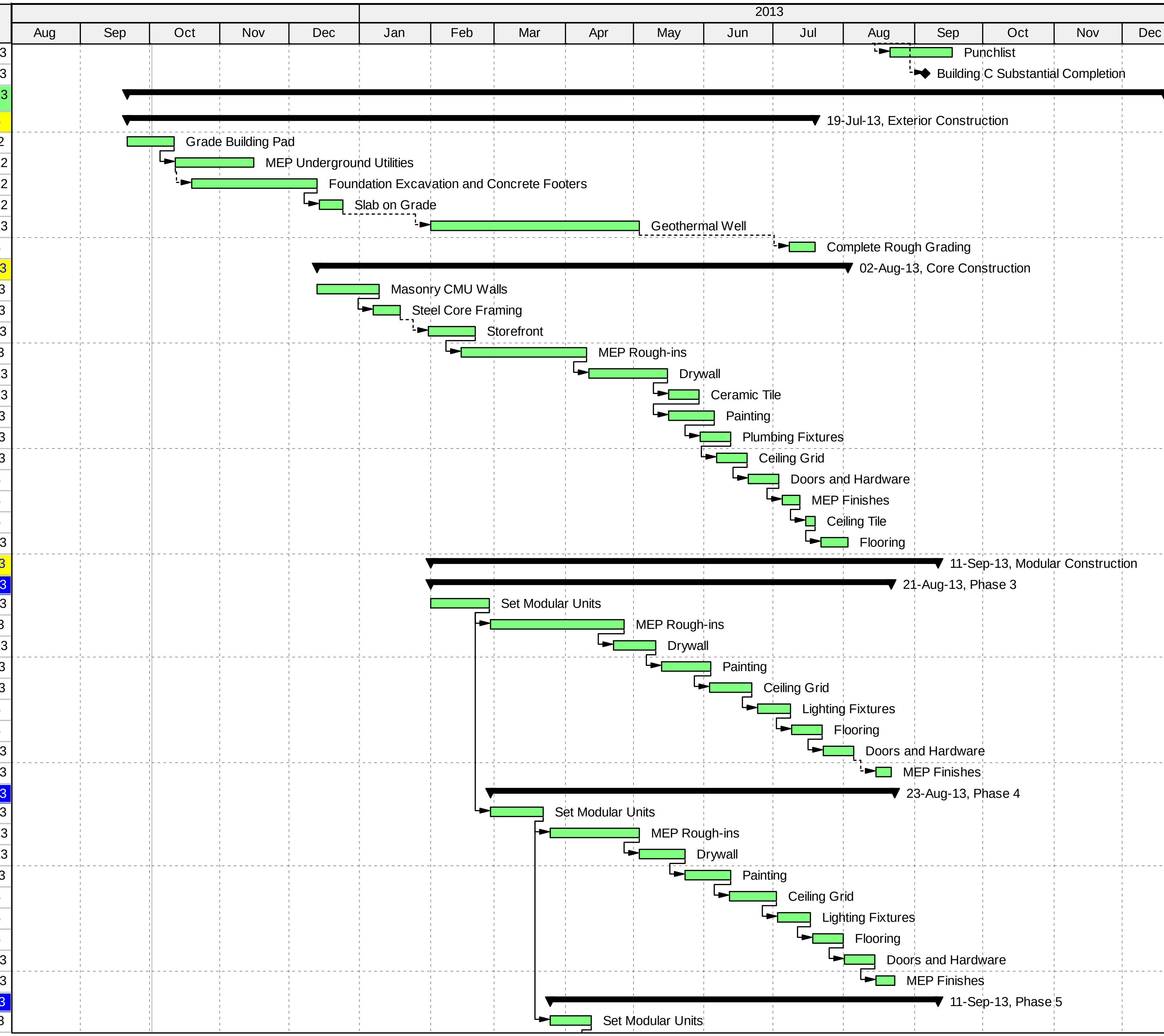
Activity ID	Activity Name	Original Duration	Start	Finish
M1-008	Doors and Hardware	6	19-Apr-1	26-Apr-13
M1-009	MEP Finishes	17	29-Apr-1	21-May-13
Phase 1 Second Floor		106	14-Jan-13	11-Jun-13
M2-001	Set Modular Units	10	14-Jan-1	25-Jan-13
M2-002	MEP Rough-ins	26	28-Jan-1	04-Mar-13
M2-003	Drywall	17	05-Mar-1	27-Mar-13
M2-004	Painting	10	28-Mar-1	10-Apr-13
M2-005	Ceiling Grid	7	11-Apr-1:	19-Apr-13
M2-006	Lighting Fixtures	7	22-Apr-1	30-Apr-13
M2-007	Flooring	6	01-May-1	08-May-13
M2-008	Doors and Hardware	6	09-May-1	16-May-13
M2-009	MEP Finishes	17	17-May-1	11-Jun-13
Phase 1 Third Floor		106	28-Jan-13	25-Jun-13
M3-001	Set Modular Units	10	28-Jan-1	08-Feb-13
M3-002	MEP Rough-ins	26	11-Feb-1	18-Mar-13
M3-003	Drywall	17	19-Mar-1	10-Apr-13
M3-004	Painting	10	11-Apr-1:	24-Apr-13
M3-005	Ceiling Grid	7	25-Apr-1	03-May-13
M3-006	Lighting Fixtures	7	06-May-1	14-May-13
M3-007	Flooring	6	15-May-1	22-May-13
M3-008	Doors and Hardware	6	23-May-1	31-May-13
M3-009	MEP Finishes	17	03-Jun-1	25-Jun-13
Phase 1 Fourth Floor		100	11-Feb-13	01-Jul-13
M4-001	Set Modular Units	10	11-Feb-1	22-Feb-13
M4-002	MEP Rough-ins	26	25-Feb-1	01-Apr-13
M4-003	Drywall	17	02-Apr-1	24-Apr-13
M4-004	Painting	10	25-Apr-1	08-May-13
M4-005	Ceiling Grid	7	09-May-1	17-May-13
M4-006	Lighting Fixtures	7	10-May-1	20-May-13
M4-007	Flooring	6	21-May-1	29-May-13
M4-008	Doors and Hardware	6	30-May-1	06-Jun-13
M4-009	MEP Finishes	17	07-Jun-1	01-Jul-13
Phase 2		143	16-Jan-13	06-Aug-13
M-2001	Set Modular Units	12	16-Jan-1	31-Jan-13
M-2002	MEP Rough-ins	40	06-Feb-1	02-Apr-13
M-2003	Drywall	20	03-Apr-1	30-Apr-13
M-2004	Painting	15	01-May-1	21-May-13
M-2005	Ceiling Grid	9	22-May-1	04-Jun-13
M-2006	Lighting Fixtures	10	05-Jun-1	18-Jun-13
M-2007	Flooring	10	20-Jun-1	03-Jul-13
M-2008	Doors and Hardware	10	02-Jul-13*	16-Jul-13
M-2009	MEP Finishes	12	22-Jul-13*	06-Aug-13
Facade		83	05-Mar-13	28-Jun-13
F-0001	Exterior Masonry Veneer Phase 1	43	05-Mar-1	02-May-13
F-0002	Exterior Masonry Veneer Phase 2	39	06-May-1	28-Jun-13
Final		44	17-Jul-13	17-Sep-13
F-1001	Commissioning	20	17-Jul-13*	13-Aug-13



Actual Work | Critical Remaining Work | Summary | Remaining Work | Milestone

TASK filter: All Activities

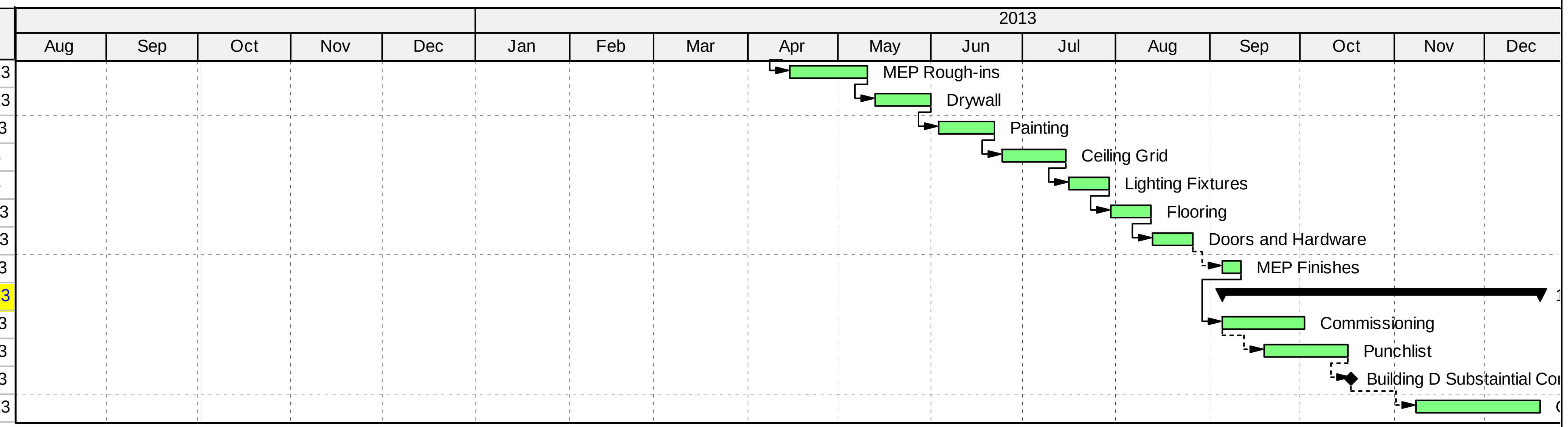
Activity ID	Activity Name	Original Duration	Start	Finish
F-1002	Punchlist	19	21-Aug-1	17-Sep-13
F-1003	Building C Substantial Completion	0		05-Sep-13
Building D		318	21-Sep-12	19-Dec-13
Exterior Construction		211	21-Sep-12	19-Jul-13
E-1001	Grade Building Pad	15	21-Sep-12	11-Oct-12
E-1002	MEP Underground Utilities	25	12-Oct-1	15-Nov-12
E-1003	Foundation Excavation and Concrete Foote	39	19-Oct-1	13-Dec-12
E-1004	Slab on Grade	7	14-Dec-1	24-Dec-12
E-1005	Geothermal Well	66	01-Feb-1	03-May-13
E-1006	Complete Rough Grading	10	08-Jul-13*	19-Jul-13
Core Construction		163	13-Dec-12	02-Aug-13
C-1001	Masonry CMU Walls	18	13-Dec-1	09-Jan-13
C-1002	Steel Core Framing	10	07-Jan-1	18-Jan-13
C-1003	Storefront	15	31-Jan-1	20-Feb-13
C-1004	MEP Rough-ins	40	14-Feb-1	10-Apr-13
C-1005	Drywall	25	11-Apr-1	15-May-13
C-1006	Ceramic Tile	9	16-May-1	29-May-13
C-1007	Painting	14	16-May-1	05-Jun-13
C-1008	Plumbing Fixtures	10	30-May-1	12-Jun-13
C-1009	Ceiling Grid	10	06-Jun-1	19-Jun-13
C-1010	Doors and Hardware	10	20-Jun-1	03-Jul-13
C-1011	MEP Finishes	6	05-Jul-13*	12-Jul-13
C-1012	Ceiling Tile	5	15-Jul-13*	19-Jul-13
C-1013	Flooring	10	22-Jul-13*	02-Aug-13
Modular Construction		156	01-Feb-13	11-Sep-13
Phase 3		142	01-Feb-13	21-Aug-13
M-3001	Set Modular Units	18	01-Feb-1	26-Feb-13
M-3002	MEP Rough-ins	43	27-Feb-1	26-Apr-13
M-3003	Drywall	15	22-Apr-1	10-May-13
M-3004	Painting	15	13-May-1	03-Jun-13
M-3005	Ceiling Grid	15	03-Jun-1	21-Jun-13
M-3006	Lighting Fixtures	10	24-Jun-1	08-Jul-13
M-3007	Flooring	10	09-Jul-13*	22-Jul-13
M-3008	Doors and Hardware	10	23-Jul-13*	05-Aug-13
M-3009	MEP Finishes	5	15-Aug-1	21-Aug-13
Phase 4		126	27-Feb-13	23-Aug-13
M-4001	Set Modular Units	18	27-Feb-1	22-Mar-13
M-4002	MEP Rough-ins	30	25-Mar-1	03-May-13
M-4003	Drywall	15	03-May-1	23-May-13
M-4004	Painting	14	23-May-1	12-Jun-13
M-4005	Ceiling Grid	15	12-Jun-1	02-Jul-13
M-4006	Lighting Fixtures	10	03-Jul-13*	17-Jul-13
M-4007	Flooring	10	18-Jul-13*	31-Jul-13
M-4008	Doors and Hardware	10	01-Aug-1	14-Aug-13
M-4009	MEP Finishes	7	15-Aug-1	23-Aug-13
Phase 5		120	25-Mar-13	11-Sep-13
M-5001	Set Modular Units	15	25-Mar-1	12-Apr-13



Actual Work | Critical Remaining Work | Summary | Remaining Work | Milestone

TASK filter: All Activities

Activity ID	Activity Name	Original Duration	Start	Finish
M-5002	MEP Rough-ins	20	15-Apr-1	10-May-13
M-5003	Drywall	14	13-May-1	31-May-13
M-5004	Painting	15	03-Jun-1	21-Jun-13
M-5005	Ceiling Grid	15	24-Jun-1	15-Jul-13
M-5006	Lighting Fixtures	10	16-Jul-13*	29-Jul-13
M-5007	Flooring	10	30-Jul-13*	12-Aug-13
M-5008	Doors and Hardware	10	13-Aug-1	26-Aug-13
M-5009	MEP Finishes	5	05-Sep-1	11-Sep-13
Final		75	05-Sep-13	19-Dec-13
A1860	Commissioning	20	05-Sep-1	02-Oct-13
A1870	Punchlist	20	19-Sep-1	16-Oct-13
A1880	Building D Substaintial Completion	0		17-Oct-13
A1890	Close Out	29	08-Nov-1	19-Dec-13



Actual Work | Critical Remaining Work | Summary
Remaining Work | Milestone

TASK filter: All Activities

APPENDIX E

TAKE OFFS

APPENDIX E

DEPTH 1: FLOORING SYSTEM ANALYSIS

Steel Beams and Girders			Length		Weight	Tons
W 8	x	18	116	LF	2088	1.04
W 10	x	22	868	LF	19096	9.55
W 10	x	68	225	LF	15300	7.65
W 14	x	22	18	LF	396	0.20
W 14	x	43	22	LF	946	0.47
W 14	x	53	34	LF	1802	0.90
W 14	x	74	27	LF	1998	1.00
W 14	x	132	62	LF	8184	4.09
W 14	x	145	31	LF	4495	2.25
W 14	x	193	28	LF	5404	2.70
						29.85

2x10 Wood Joists			
Board Ft	Price/Ft	Cost/flr	Cost
1329	$ 0.77	$ 1,023.33	$ 4,093.32

Flooring		
3/4"OSB	2040	sqft
1/2" Cementitious Backer Board	2040	sqft
3/4" Floor Sheathing	2040	sqft
6" Batt Insulation	2040	sqft

Masonry Wall					
220	LF/floor	13	ft tall	2860	sq ft/floor

Columns				
Steel	Weight	Length		Weight
HSS6x6x3/8	27.4	1640	LF	44942
HSS6x6x5/8	42.1	192.2	LF	8092
W 10 x 68	68	389.7	LF	26500
				79534

Concrete											
								For 4 Floors		Total Concrete	
Flat Plate	2040	sqft	10	" thick	1700	ft^3		6800	ft^3	252	CY
Columns	(2) - 2' x 2'		13	ft tall	104	ft^3		416	ft^3	15	CY
Wall	220	LF	13	ft tall	2383	ft^2		9533.333	ft^3	353	CY

Formwork	Area		Amount		Total Area	
2x2 Columns	104	SFCA/col	8	Columns	832	SFCA
Flat Plate	2040	SF/Floor	4	flrs	8160	SF
Walls	2383	SFCA/flr	4	flrs	9532	SFCA

Steel per Floor			Sum (ft)	Weight
8	x	18	28.62	515.16
10	x	22	211.48	4652.56
10	x	68	90	6120
				11287.72

	Wood	Concrete
125	31	45
160	34	48
200	37	51
250	40	54
315	43	57
400	46	60
500	47	61
530	48	62
800	49	63
1000	50	64
1250	51	65
1600	51	65
2000	51	65
2500	51	65
3150	51	65
4000	51	65

Brick					
Building D					
Total Area		Small Windows	Large Windows	Area of Brick	
North Wing					
West Face					
3631	Sq Ft	34	5	2965	Sq Ft
North Face					
294	Sq Ft	0	0	294	Sq Ft
292	Sq Ft	0	0	292	Sq Ft
East Face					
3674	Sq Ft	34	6	2987	Sq Ft
				6538	Sq Ft
Center Wing					
West Face					
2869	Sq Ft	34	0	2308	Sq Ft
South Face					
540	Sq Ft	6	0	441	Sq Ft
307	Sq Ft	0	0	307	Sq Ft
East Face					
3606	Sq Ft	34	6	2919	Sq Ft
				5975	Sq Ft
South Wing					
North Face					
760	Sq Ft	8	0	628	Sq Ft
480	Sq Ft	0	0	480	Sq Ft
West Face					
5550	Sq Ft	48	8	4590	Sq Ft
South Face					
454	Sq Ft	0	0	454	Sq Ft
294	Sq Ft	0	0	294	Sq Ft
East Face					
3238	Sq Ft	26	5	2704	Sq Ft
				9150	Sq Ft

Stone						
Building D						
Total Area		Small Windows	Large Windows	Doors	Area of Stone	
North Wing						
West Face						
2283	Sq Ft	20	1	3	1860	Sq Ft
North Face						
218	Sq Ft	0	0	0	218	Sq Ft
210	Sq Ft	0	0	0	210	Sq Ft
East Face						
1650	Sq Ft	16	2	0	1344	Sq Ft
					3632	Sq Ft
Center Wing						
West Face						
2902	Sq Ft	0	0	0	2902	Sq Ft
South Face						
202	Sq Ft	2	0	0	169	Sq Ft
206	Sq Ft	0	0	0	206	Sq Ft
East Face						
1666	Sq Ft	15	2	1	1352.5	Sq Ft
					4629.5	Sq Ft
South Wing						
North Face						
180	Sq Ft	0	0	0	180	Sq Ft
230	Sq Ft	2	0	0	197	Sq Ft
West Face						
2190	Sq Ft	16	1	1	1881	Sq Ft
South Face						
810	Sq Ft	0	0	0	810	Sq Ft
East Face						
1824	Sq Ft	12	1	2	1557	Sq Ft
					4625	Sq Ft

Brick					
Building C					
Total Area		Small Windows	Large Windows	Area of Brick	
North Wing					
West Face					
3631	Sq Ft	34	5	2965	Sq Ft
North Face					
294	Sq Ft	0	0	294	Sq Ft
292	Sq Ft	0	0	292	Sq Ft
East Face					
3674	Sq Ft	34	6	2987	Sq Ft
				6538	Sq Ft
South Wing					
West Face					
2869	Sq Ft	34	0	2308	Sq Ft
South Face					
540	Sq Ft	6	0	441	Sq Ft
307	Sq Ft	0	0	307	Sq Ft
East Face					
3606	Sq Ft	34	6	2919	Sq Ft
				5975	Sq Ft

Stone						
Building C						
Total Area		Small Windows	Large Windows	Doors	Area of Stone	
North Wing						
West Face						
2283	Sq Ft	20	1	3	1860	Sq Ft
North Face						
218	Sq Ft				218	Sq Ft
210	Sq Ft				210	Sq Ft
East Face						
1650	Sq Ft	16	2		1344	Sq Ft
					3632	Sq Ft
South Wing						
West Face						
2902	Sq Ft				2902	Sq Ft
South Face						
202	Sq Ft	2			169	Sq Ft
206	Sq Ft				206	Sq Ft
East Face						
1666	Sq Ft	15	2	1	1352.5	Sq Ft
					4629.5	Sq Ft

Panel Type	Size (SF)	Total Number	Total Area (SF)
Thin Brick			
A	165	111	18,315
B	148	16	2,368
C	250	40	10,000
D	162	20	3,240
E	280	10	2,800
			36,723
Precast			
Z	380	24	9,120
Y	270	36	9,720
X	170	16	2,720
W	215	40	8,600
			30,160

			Building C							
			Wing and Elevation							
Panel Types	Size (SF)		North - N	North - W	South - W	South - S	South - E	North - E	Total	Area
Thin Brick										
A	165		0	10	8	0	8	10	36	5940
B	148		0	2	2	0	2	2	8	1184
C	250		0	6	2	0	2	6	16	4000
D	162		0	2	1	1	1	2	7	1134
E	280		2	0	0	1	0	0	3	840
Precast Concrete										13098
Z	380		0	6	8	0	2	0	16	6080
Y	270		0	6	2	0	2	6	16	4320
X	170		3	0	1	5	0	0	9	1530
W	215		0	0	0	0	3	5	8	1720
										13650

			Building D										
			Wing and Elevation										
Panel Types	Size (SF)		North - N	North - W	Center - W	South - N	South - W	South - S	South - E	Center - S	Center - E	North - E	Total	Area
Thin Brick														
A	165		0	10	10	4	16	0	13	2	10	10	75	12375
B	148		0	2	0	0	0	0	2	0	2	2	8	1184
C	250		0	5	5	0	4	0	2	0	3	5	24	6000
D	162		0	1	1	0	8	0	0	1	1	1	13	2106
E	280		2	0	0	1.5	0	2.5	0	1	0	0	7	1960
Precast Concrete														23625
Z	380		0	1	5	2	0	0	0	0	0	0	8	3040
Y	270		0	3	3	0	2	0	2	0	5	5	20	5400
X	170		2	0	0	1	0	3	0	1	0	0	7	1190
W	215		0	6	0	0	8	0	7	1	5	5	32	6880
														16510

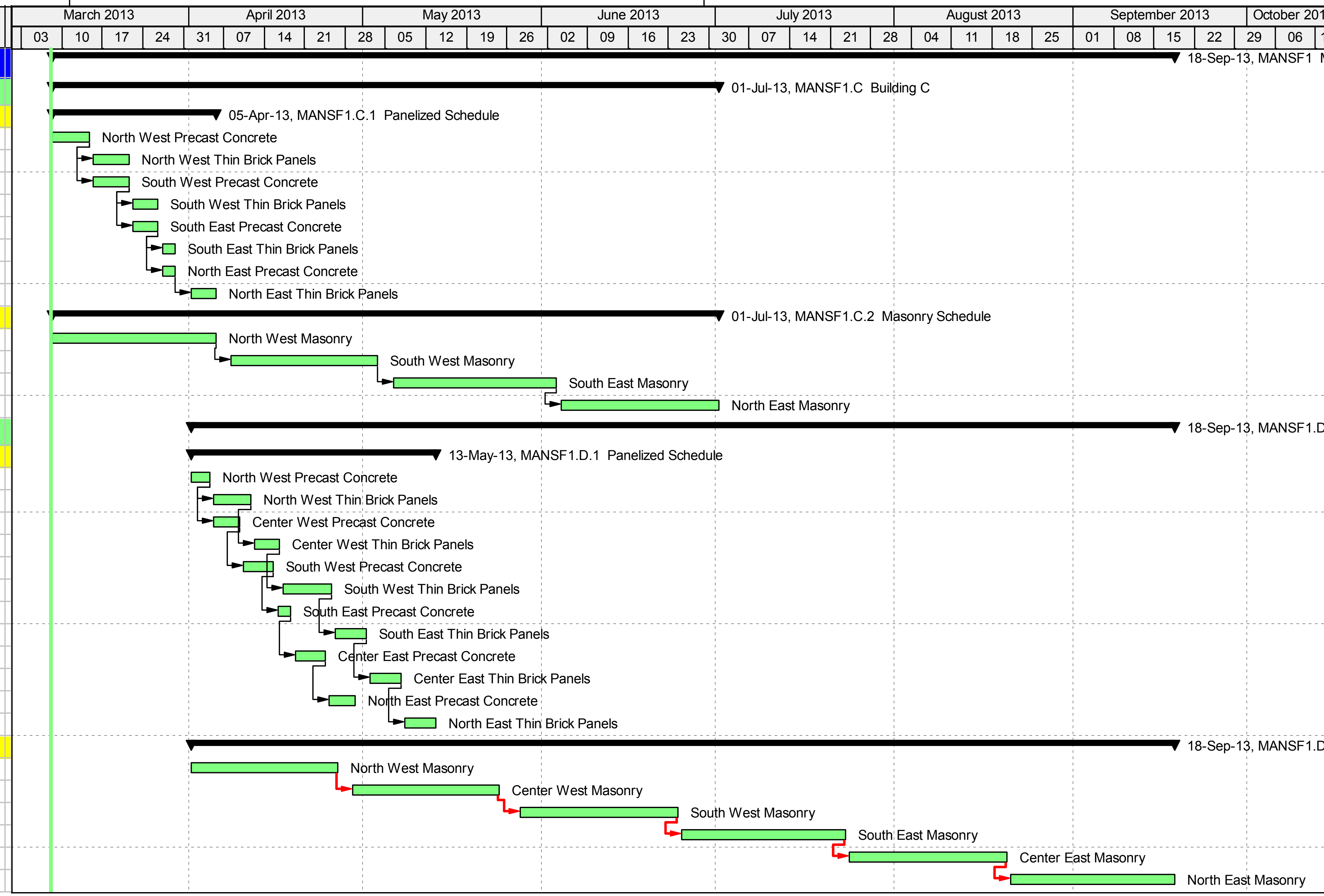
APPENDIX F

PANELIZED VS MASONRY FAÇADE SCHEDULE

Mike Mahoney

Mansfield Exterior Facade Schedule

Activity ID	Activity Name	Original Duration	Start	Finish
MANSF1	Mansfield Facade S	136	08-Mar-13	18-Sep-13
MANSF1.C	Building C	81	08-Mar-13	01-Jul-13
MANSF1.C.1	Panelized Schedule	21	08-Mar-13	05-Apr-13
A1000	North West Precast Concre	5	08-Mar-13	14-Mar-13
A1010	North West Thin Brick Pan	5	15-Mar-13	21-Mar-13
A1020	South West Precast Concr	5	15-Mar-13	21-Mar-13
A1030	South West Thin Brick Pan	3	22-Mar-13	26-Mar-13
A1040	South East Precast Concre	3	22-Mar-13	26-Mar-13
A1050	South East Thin Brick Pane	3	27-Mar-13	29-Mar-13
A1060	North East Precast Concre	3	27-Mar-13	29-Mar-13
A1070	North East Thin Brick Pane	5	01-Apr-13	05-Apr-13
MANSF1.C.2	Masonry Schedule	81	08-Mar-13	01-Jul-13
A1080	North West Masonry	21	08-Mar-13	05-Apr-13
A1090	South West Masonry	20	08-Apr-13	03-May-13
A1100	South East Masonry	20	06-May-13	03-Jun-13
A1110	North East Masonry	20	04-Jun-13	01-Jul-13
MANSF1.D	Building D	120	01-Apr-13	18-Sep-13
MANSF1.D.1	Panelized Schedule	31	01-Apr-13	13-May-13
A1120	North West Precast Concre	4	01-Apr-13*	04-Apr-13
A1130	North West Thin Brick Pan	5	05-Apr-13	11-Apr-13
A1140	Center West Precast Conc	3	05-Apr-13	09-Apr-13
A1150	Center West Thin Brick Pa	3	12-Apr-13	16-Apr-13
A1160	South West Precast Concr	4	10-Apr-13	15-Apr-13
A1170	South West Thin Brick Pan	7	17-Apr-13	25-Apr-13
A1180	South East Precast Concre	3	16-Apr-13	18-Apr-13
A1190	South East Thin Brick Pane	4	26-Apr-13	01-May-13
A1200	Center East Precast Concr	4	19-Apr-13	24-Apr-13
A1210	Center East Thin Brick Pan	4	02-May-13	07-May-13
A1220	North East Precast Concre	3	25-Apr-13	29-Apr-13
A1230	North East Thin Brick Pane	4	08-May-13	13-May-13
MANSF1.D.2	Masonry Schedule	120	01-Apr-13	18-Sep-13
A1240	North West Masonry	20	01-Apr-13*	26-Apr-13
A1250	Center West Masonry	20	29-Apr-13	24-May-13
A1260	South West Masonry	20	28-May-13	24-Jun-13
A1270	South East Masonry	20	25-Jun-13	23-Jul-13
A1280	Center East Masonry	20	24-Jul-13	20-Aug-13
A1290	North East Masonry	20	21-Aug-13	18-Sep-13



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

TASK filter: All Activities