Samuel M. P. Jannotti
Structural
Professor M. Kevin Parfitt

American Eagle Outfitters: Quantum III
Pittsburgh, PA
October 29, 2007

Technical Report II

Executive Summary

American Eagle Outfitters: Quantum III is a steel framed office building located in the South Side Works of Pittsburgh, Pennsylvania. This report analyzes the structure of this building and it's adequacy on the basis of currently accepted national codes, economy, and flexibility.

An introduction to the building and its structural systems is provided by outlining the anomalies in each of its aspects: foundations, floor framing, columns, and lateral load resisting systems. Next, codes used by Atlantic Engineering Services and those utilized in this analysis are described. Building material grades and strengths follow. Next, floor framing is explored in more detail through diagrams and floor plans.

Calculations and details concerning QIII begin in the Building Loads section. Following are descriptions of the five floor framing systems analyzed in this report:

- Composite Metal Deck on Steel Beams
- Concrete Flat Plate Slab
- Waffle Slab
- Slab and Noncomposite Metal Deck on Steel Joists
- Concrete One Way Slab and Beams

Concrete flat plate slab and the steel joist systems can be eliminated from further consideration. The flat plate system is heavy and expensive. Steel joists, though a light and easily constructible system, are deep and require significant work to fireproof. All other systems are open for consideration.

The concrete waffle slab is the best alternative for framing. It is economic and effective structurally and allows for options when it comes to aesthetics and MEP system layouts. Although increasing the structures weight, the floor to floor height increases and mechanical vibrations are absorbed. Details on determination of viable floor framing system solutions are covered on the following pages.

Table of Contents

List of Figures

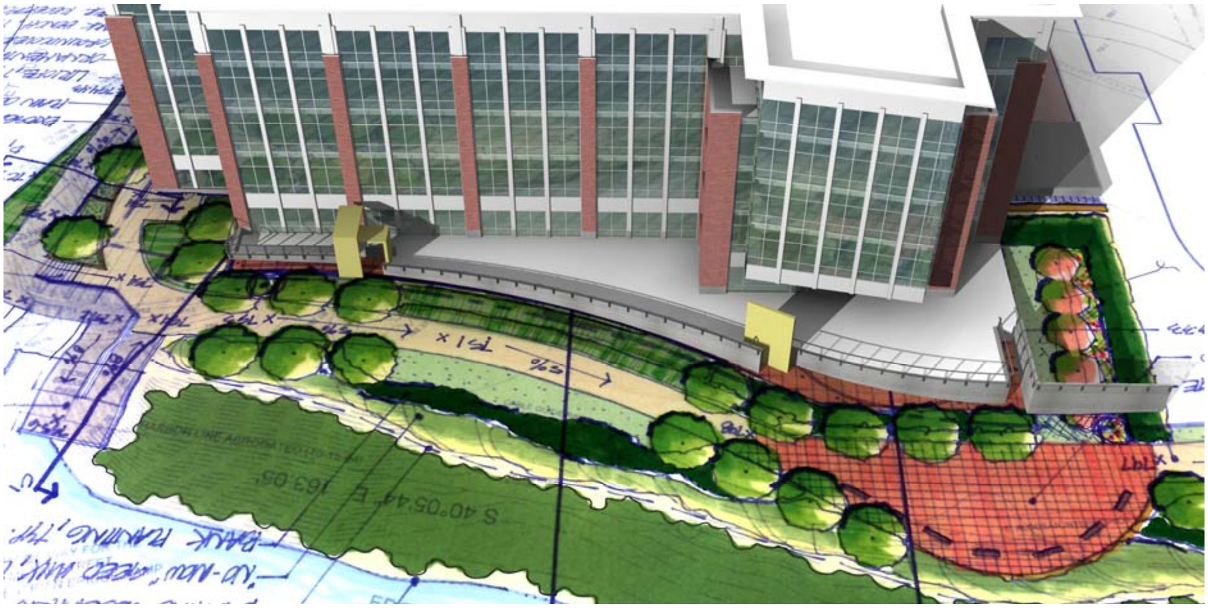
Technical Report II

I. Introduction

American Eagle Outfitters Quantum III: South Side Works is a genuine combination of structural design for flexibility and the blending of the architectural tastes of the developer, The Soffer Organization, with that of the existing South Side of Pittsburgh, PA. The building is 5 stories tall and contains loading, fire pump, and generator rooms on the first floor with the remainder of the first through the fifth floor having open plans for tenant fit-out. The roof holds a mechanical area surrounded by 12' tall windscreens for protection from the environment.

The structural system reflects the need for flexibility with 30'x30' bays and a superimposed 20 psf partition load over all office spaces. Although only a 50 psf live load is required for office areas, 80 psf was used by Atlantic Engineering Services to account for the unpredictability of corridor locations on each floor. The 80 psf combines the required live and partition loads with an added factor of safety. Vertical trusses are placed at either the core of the building—the mechanical spaces, stairwells, and elevators; or the shell to limit interference with the open plan architecture.

Following is an analysis to create a foundation from which to expand understanding of the existing structure of Quantum III. Four unique floor framing systems are analyzed as replacements to the existing floor framing, and are studied as preliminary designs. On the subsequent pages, these four systems are analyzed, designed, and compared. The report concludes with a closing statement on the most economical and quality system available.



II. Structural Systems

Foundations and Geotechnical Concerns

The foundation of Quantum III will be constructed on abandoned steel industry facility foundations with fills consisting of silty sand, cinder and slag. With the unpredictability of the subgrade to the deeper bedrock, and the Monongahela River directly adjacent to the building, shallow foundations cannot be used. The fill located deeper in the subgrade has a higher bearing capacity than the aforementioned soils. Therefore, Geo-Mechanics Inc. insisted on 16” diameter auger cast piles with an ultimate load capacity of 300 kips, and design load capacity of 120 kips. Bedrock is located roughly 85 feet below the surface. With the water table resting at 730 ft above sea level—slab on grade is proposed to be at 753’.

Since the building includes no plans for a basement, slab on grade connects with pile caps and grade beams to make up the foundation of QIII. Grade beams line the exterior of the building and connect pile caps where lateral frames are located. Interior gravity columns typically have four piles with a single, separate pile cap, while columns on the exterior wall tie in with grade beams and three- to four-pile configurations.

Floor Framing

All floor framing and steel deck is composite. A lightweight concrete slab on 3” galvanized steel deck was incorporated. Shear studs are 4” long and ¾” diameter in 2.5” lightweight concrete topping. The total slab and deck thickness is 5.5”. Typical roof framing consists of 3” metal roof deck, except the mechanical unit area. 2” deck with 3” lightweight concrete provides added support and dampens mechanical vibrations here. Typical girders are W24x55 with 28 studs. Infill beams are W18x35’s spaced at 10’ center to center with 16 studs. Refer to Figures 2 and 3 for the floor framing layout. All exceptions are explained in Technical Report I, available online at Sam Jannotti’s CPEP website.

Columns

American Eagle Outfitters: Quantum III has a wide range of column sizes, ranging from W10’s to W14’s. Gravity columns range from a W10x33 to a W12x72. Moment frame columns run from W14x74’s to W14x193’s. Floor to floor heights are typically 13’-8”. Column splices for both gravity and lateral resistance are on the third and fifth floors with all roof framing columns being less than one floor height high. Unbraced length is not an issue in Quantum III since columns are braced at each floor.

Lateral Load Resisting System

Five vertical trusses are arranged throughout the building core and exterior. Three of the five trusses are forms of a Chevron truss, with one x braced frame and the last being a single strut truss. Only one truss is on the exterior and is an excellent display of structure—a curtain wall provides a view of it from the exterior of the building. The remaining four trusses are interior and border stairs, elevators, or mechanical shafts. One of the interior trusses is eccentric to avoid a conflict with stair access doors on the easternmost corner of the building. Refer to Technical Report I for diagrams showing truss locations and elevations with an in depth description of lateral load resisting systems.

III. Codes and Material Properties

Codes and Referenced Standards

American Eagle Outfitters Quantum III uses the 2003 International Building Code (IBC) as amended by the City of Pittsburgh Building Department. The 2003 IBC references ASCE 7 – 02 and ACI 318-02. All analysis and design was performed by Atlantic Engineering Services using Allowable Stress Design (ASD) as opposed to Load and Resistance Factor Design (LRFD), which is used throughout this technical report. These design methods are prescribed in the AISC Steel Construction Manual, 13th edition.

Codes used for this analysis are IBC 2006 without any Pittsburgh amendments, ASCE 7 – 05 and ACI 318 – 05.

Material Properties

Concrete

Foundations	3000 psi
Terrace Walls	4000 psi
Interior Slabs	4000 psi
Exterior Slabs	4000 psi
Site Access Canopy Walls	5000 psi
Auger Pile Grout	5000 psi
Reinforcing Steel (Yld)	60 ksi
Headed Concrete Anchors (Yld) ASTM A108 Grades 1015-1020	60 ksi

Steel

Structural Steel

W Shapes	ASTM A992	50 ksi
M, S, HP Shapes	ASTM A572 Grade 50	50 ksi
Channels	ASTM A572 Grade 50	50 ksi
Steel Tubes (HSS Shapes)	ASTM A500 Grade B	46 ksi
Steel Pipes (Round HSS)	ASTM A500 Grade B	42 ksi
Angles	ASTM A36	36 ksi
Plates	ASTM A36	36 ksi

Galvanized Structural Steel

Structural Shapes and Rods	ASTM A123	Zinc coating, Strength of base
Bolts, Fasteners, and Hardware	ASTM A153	Zinc coating, Strength of base
Metal Decking (Yield Strength)		33 ksi
Light Gage Studs, 12-16 Gage	ASTM A653 Grade D	50 ksi
Light Gage Studs, 18-20 Gage	ASTM A653 Grade A	33 ksi

Masonry

Mortar (Prism Strength)	ASTM C270	F'm = 2500 psi
Grout	ASTM C476	F'c = 3000 psi
Masonry (Prism Strength, 28-day)		F'm = 1500 psi

IV. Framing Plans

Typical Floor Plan

Quantum III is designed for flexibility to allow individual tenants to lay out each floor as they please. It utilizes 30’ by 30’ bays with two ‘cores’ containing elevators, stairs, mechanical openings and bathrooms. Since the extent of the work of the firms stated (Atlantic Engineering Services, The Design Alliance Architects, etc.) was core and shell—the exact placement of partitions is not addressed in the architectural plans as seen in Figure 1.

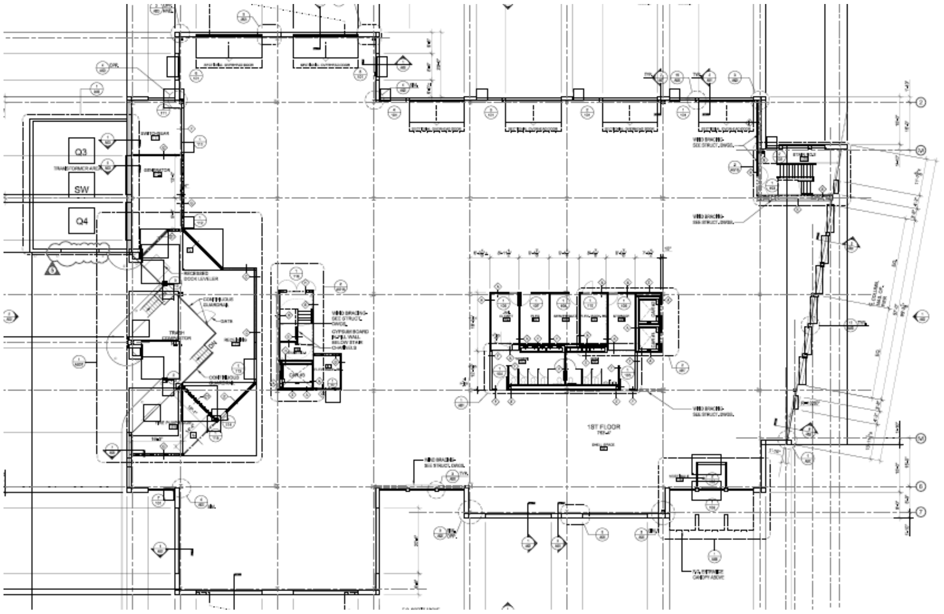


Figure 1 – Typical Architectural Floor Plan

As you can see from the architectural plan, no partitions are even considered in this stage of the building development. To expand upon the structural system, typical bays for the second through fifth floors are shown on the next page in Figure 2.

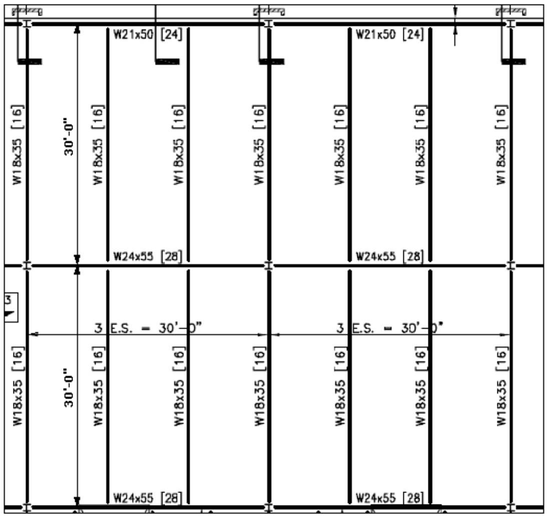


Figure 2 – Typical Bay

The W24x55 girders are 30’ on center, with W18x35’s at 10’ on center. American Eagle Outfitters Quantum III has two bays to the north of the building cores as discussed earlier, and one set of bays to the south as seen in Figure 3.

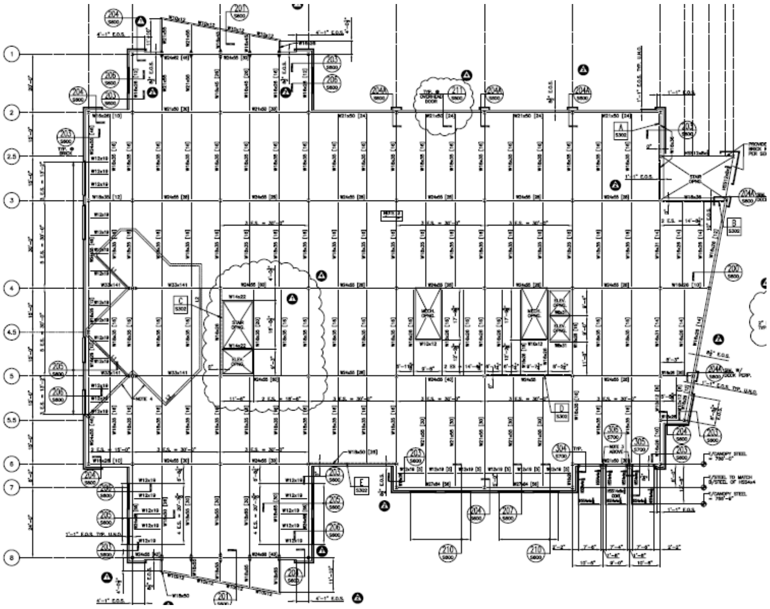


Figure 3 – Typical Floor Framing

V. Building Loads

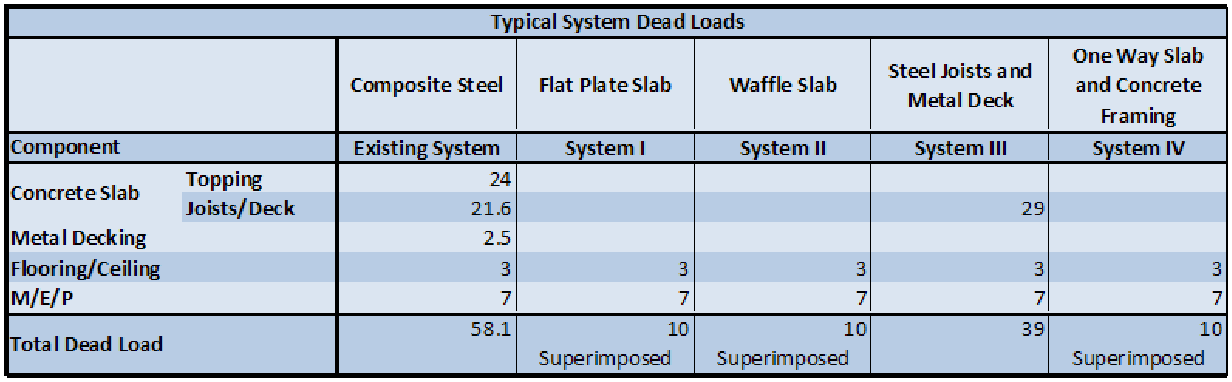
Live Loads

The typical bay for the roof has the same dimensions as that for the typical floor, so all reduced live loads are based on the bays and spacing outlined in Section IV. Refer to Framing Plans in Figure 2, page 9.

Location	Live Load (psf)	Description
Roof	20 **18**	A_t = 10' x 30' = 300 ft^2 $\therefore R_1 = 1.2 - 0.001A_t = 1.2 - 0.001 * (300\ ft^2) = 0.9$ F = 0, the roof pitch is small enough to be negligible $\therefore R_2 = 1$ $\therefore L_r = R_1 * R_2 * L = 0.9 \times 1.0 * 20 =$ **18 psf**
Offices and corridors above the first floor	80 **54.6** **48.3**	Offices require only 50 psf but since the building is designed to be flexible for tenant fit out, the location of corridors is not currently known, and the conservative corridor load is applied over the entire plan K_{LL} = 4 : Interior Beams $A_{t,\ beam}$ = 300 ft^2 $A_{t,\ girder}$ = 15 ft x 30 ft = 450 ft^2 $L = L_o \times \left(0.25 + \frac{15}{(K_{LL} \times A_t)^{0.5}}\right) =$ $= 80 \times \left(0.25 + \frac{15}{(4 \times 300\ ft^2)^{0.5}}\right) =$ **54.6 psf** $L = L_o \times \left(0.25 + \frac{15}{(K_{LL} \times A_t)^{0.5}}\right) =$ $= 80 \times \left(0.25 + \frac{15}{(4 \times 450\ ft^2)^{0.5}}\right) =$ **48.3 psf**
Lobbies and first floor corridors	100	Irreducible per ASCE 7-05 Section 4.8.2
Stairs	100	

Dead Loads

Unit weights and dead loads are taken from the AISC Steel Manual, 13th Edition. Wall weights are supplied in the structural documents of American Eagle Outfitters: Quantum III. Finally, all supporting calculations are available on page 25.



Typical System Dead Loads

		Composite Steel	Flat Plate Slab	Waffle Slab	Steel Joists and Metal Deck	One Way Slab and Concrete Framing
Component		**Existing System**	**System I**	**System II**	**System III**	**System IV**
Concrete Slab	**Topping**	24				
	Joists/Deck	21.6			29	
Metal Decking		2.5				
Flooring/Ceiling		3	3	3	3	3
M/E/P		7	7	7	7	7
Total Dead Load		58.1	10 Superimposed	10 Superimposed	39	10 Superimposed

Figure 4 – System Dead Loads

Wall Loads

Curtain Walls………………………………...20 psf
8” CMU, grout/rein. 24” cc……………...…..51 psf
Partitions……………………………………..20 psf

VI. Existing Frame: Composite Steel

Framing Plan and General Parameters

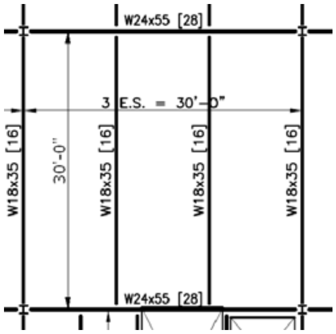


Figure 5 – Typical Bay

Each floor of QIII has nearly identical framing plans, and all are based on the 30’x30’ grid shown at left. An 80 psf live load is typical for these bays considering the unpredictability of partition placement. Deck runs perpendicular to the W18x35 beams. The parameters of this design are outlined below.

2.5" LW Concrete Slab
3" 20-Gage Steel Deck
f'_c = 4000 psi
f_y = 50 ksi
Beams: W18x35, A_s = 10.3 in^2, d = 17.7 in
Girders: W24x55, A_s = 16.2 in^2, d = 23.6 in
3/4" Diameter, 4" Long Studs
Proposed Fire Rating: 0 hrs

System Effectiveness

Structural
This is a very effective floor system for American Eagle Outfitters: Quantum III. The overall system thickness is 29.1” which limits the usable floor to floor height to 11’-2.9”. Although this system is deep, the existing floor to floor heights are large enough to limit interference with other building systems. The proposed fire rating was 0 hrs. Since American Eagle Outfitters: Quantum III is a shell and core project, fireproofing is not specified for the typical open floor. This leads to the assumption that fireproofing must be provided by the tenant leasing the space.

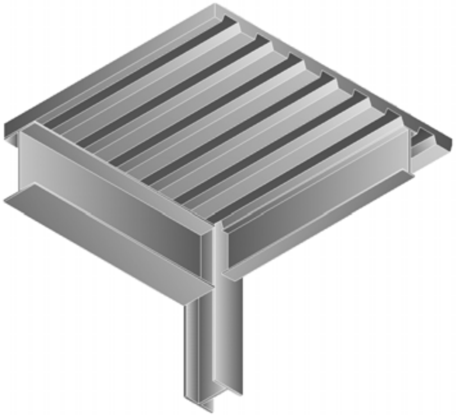


Figure 6 – Existing System

Construction and Cost
Composite steel and deck meets the constructability and economic requirements of QIII. No shoring is needed for the short deck spans. Forms aren’t needed. Deck does not need to be cut due to the few and regular floor openings. Connections and details are easy and fast to construct. With proper planning, multiple systems can be installed simultaneously throughout the building.

Architectural and Mechanical Issues
The large system depth limits the floor to floor height. Due to the large height between stories, this has minimal impact on American Eagle Outfitters’ architecture. Mechanical equipment can easily fit underneath the beams and allow a comfortable ceiling height. The open plan is kept intact and sound transmission through the system is dampened.

System Advantages

- Easy constructability
- System maintains large bay spacing
- Fast erection time
- Cost effective
- Easy construction sequencing
- Handles large live load

System Disadvantages

- Thick system that provides only 11’-2.9” clear height
- Heavy steel members are required
- More lead time required
- Stud welding increases cost

VII. System I: Flat Plate Slab

Framing Plan and General Parameters

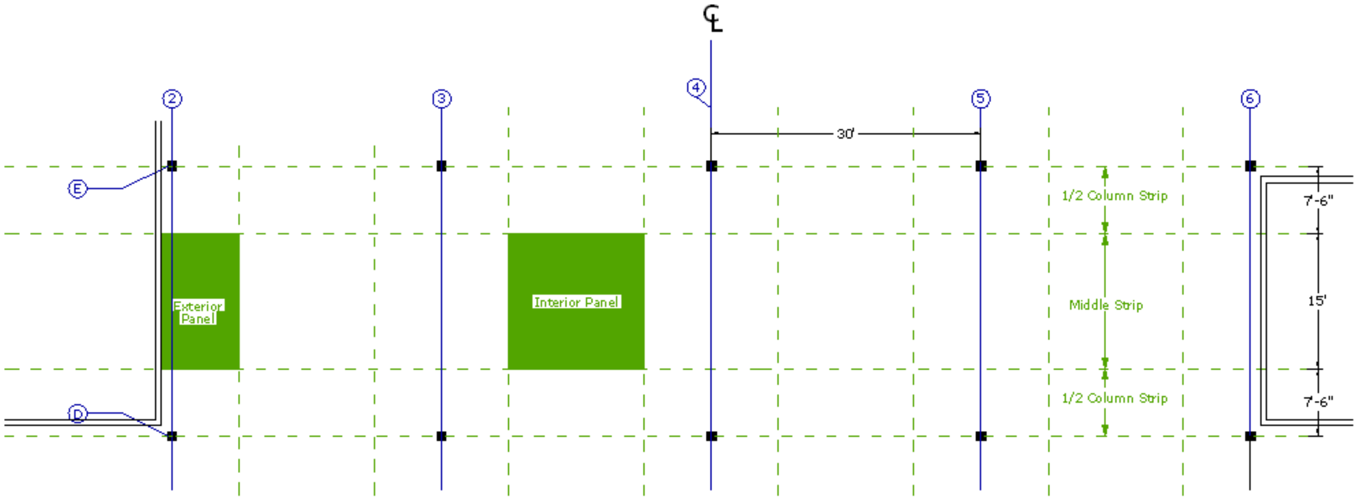


Figure 7 – Flat Plate Slab Plan

The concrete flat plate slab allows the open floor plan to remain intact. No columns must be relocated, and the typical frame, with column and middle strip partitioning, is shown above. Double black lines indicate exterior wall locations. Exterior and interior panels are shown in Figure 7 as well. No corner panels were considered for the typical frame.

12" Concrete Slab
f'_c = 4000 psi
f_y = 60 ksi
Proposed Fire Rating: 2 hrs
Columns are assumed to be 12”x12”

Flat Plate Reinforcing

Bay Number			2-3					3-4					
Side of Bay			Left	Continuous	Middle	Right - Short	Right	Left	Left - Short	Continuous	Middle	Right - Short	Right
pcaSlab Design	Middle Strip	Top	18-#6 83.7				18-#6 118.9	18-#6 146.5					18-#6 118.9
		Bottom		18-#6						18-#6			
	Column Strip	Top	18-#6 121.5			9-#8 76.8	10-#8 132.1	10-#8 158.3	9-#8 76.8			4-#7 76.8	13-#7 124.8
		Bottom		20-#6						18-#6			
Equivalent Area of Steel (in^2)	Middle Strip	Top	7.92				7.92	7.92					7.92
		Bottom		7.92						7.92			
	Column Strip	Top	7.92			7.11	7.9	7.9	7.11			2.4	7.8
		Bottom		8.8						7.92			

Bay Number			4-5						5-6				
Side of Bay			Left	Left - Short	Middle	Continuous	Right - Short	Right	Left	Left - Short	Middle	Continuous	Right
pcaSlab Design	Middle Strip	Top	18-#6 118.9					18-#6 119	18-#6 118.9				18-#6 83.7
		Bottom				18-#6						18-#6	
	Column Strip	Top	13-#7 124.8	4-#7 76.8			9-#8 76.8	10-#8 158	10-#8 132	9-#8 76.8			18-#6 121.5
		Bottom				18-#6						20-#6	
Equivalent Area of Steel (in^2)	Middle Strip	Top	7.92					7.92	7.92				7.92
		Bottom				7.92						7.92	
	Column Strip	Top	7.8	2.4			7.11	7.9	7.9	7.11			7.92
		Bottom				7.92						8.8	

CL

Figure 8 – Flat Plate Reinforcing

All reinforcing for the flat plate slab is described in Figure 8 above. For each value in the "pcaSlab design" row, the top value is the required reinforcing. The bottom value is the required cutoff points from the nearest support in inches.

System Effectiveness

Structural

This system would require drastic changes throughout the structure of Quantum III. No beams are required. Columns would be concrete. Drop panels may be added to increase stiffness around columns. Shear walls could be used for lateral load resistance. In and of itself, flat plate slab is an effective gravity system. The total system depth is the slab depth at 12", limiting the floor to floor height to 12'-8". The poor grade soils and the close proximity of the Monongahela River make foundations a pressing issue. The entire structural system would have increased mass, requiring increased foundation sizes. The fire rating would be 2 hours.

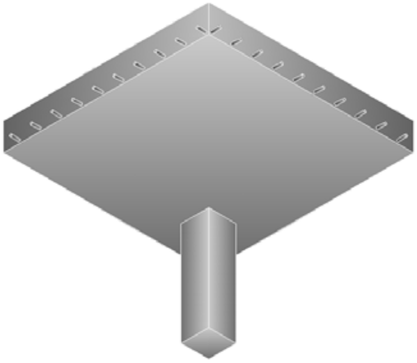


Figure 9 –Flat Plate Slab Nea Column

Construction and Cost

Concrete structural systems require more time to construct and the low cost of materials is contrasted by the increased labor costs. Since the flat plate was assumed to be 12" thick, a generous supply of reinforcing is required. This drastically increased system cost. Other trades, such as mechanical and electrical, must wait until the concrete cures 28 days before beginning work, greatly increasing construction time. Shoring and forms are needed. Structural engineers must be wary when specifying reinforcing, as it can get congested around columns and lateral systems. Aggregates must be vibrated, especially around these congested areas. This insures the effectiveness of the flat plate system.

Architectural and Mechanical Issues

Flat plate allows more than enough room for mechanical and electrical systems while maintaining a comfortable ceiling height. The open plan is kept intact since the bay sizes are equal. Vibrations are all but eliminated considering the increased system mass and stiffness. The flat plate acts as an acoustic barrier as well, limiting transfer of mechanical equipment sound between floors.

System Advantages

- Thin total system that provides 12’-8” floor to floor height
- System maintains large bay spacing
- Acoustic barrier
- Low cost of materials
- Bottom of flat plate slab can be used as ceiling finish
- No beams to interfere with mechanical system

System Disadvantages

- Longer construction time
- Heavy concrete system increases foundation size
- Forms and shoring required
- Higher cost of labor
- Large amount of reinforcing for thin slab increases cost significantly

VIII. System II: Waffle Slab

Framing Plan and General Parameters

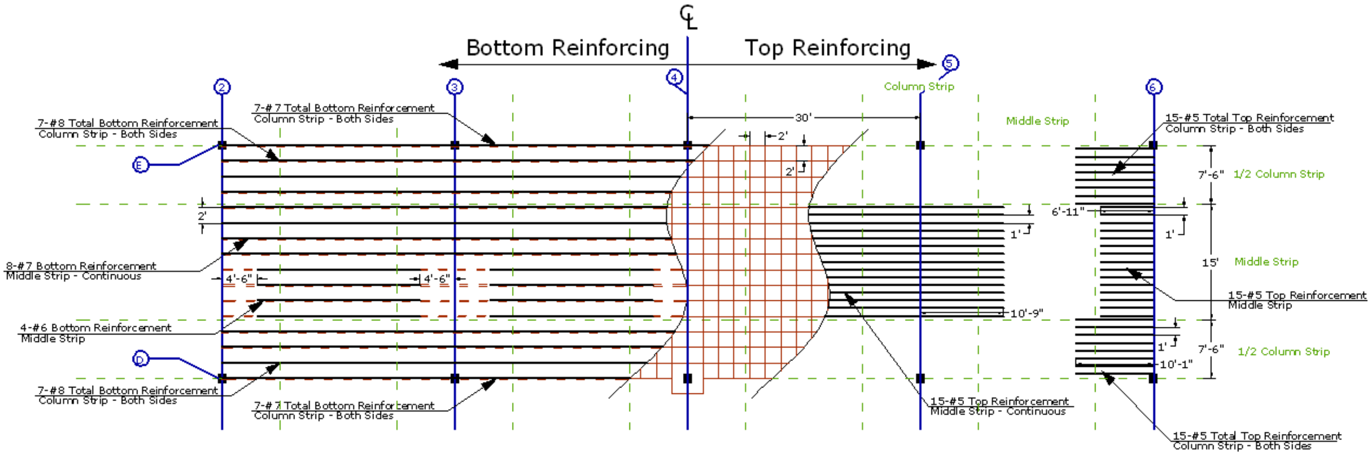


Figure 10 – Waffle Slab Reinforcing Plan

The above figure shows the layout for the reinforcing required in one direction of the waffle slab. The left side shows all bottom reinforcing, and the right side displays the top reinforcing required. Fifteen #5’s are required over the <u>entire</u> column strip. The middle orange section displays the waffle slab joist layout relative to the columns. Figure 27 on page 33 shows required reinforcing based on the diagram above.

Material Properties

4” NW Top Slab
12” Deep Ribs Spaced at 24” On Center
2.5” Bottom Rib Width
16” Total Waffle Slab Depth
$f'_c = 4000$ psi
$f_y = 60$ ksi
Proposed Fire Rating: 2 hrs
4’x4’ Drop Panels at All Columns
Columns are Assumed to be 12” x 12”

Design Parameters and Results

The focus of this design was to achieve the most economical waffle slab (joist slab) alternative to the existing composite steel design using pcaSlab. A preliminary joist depth of 8” was selected to achieve an incredibly thin system depth without the concrete mass introduced by the flat plate system. Through analysis, more than a single #6 would have been required in each joist to achieve the tension reinforcement requirement. This would raise the bottom joist width over 3.25”, so the current system was developed as an alternative. The 16” total depth system was the best available waffle slab design because the 4” of extra depth significantly lowered the tension reinforcement requirement, keeping the bottom joist width to just 2.5”. A close-up of Figure 10, Waffle Slab Reinforcing Plan, is shown in Figures 11 and 12 for the Bottom and Top Reinforcing.

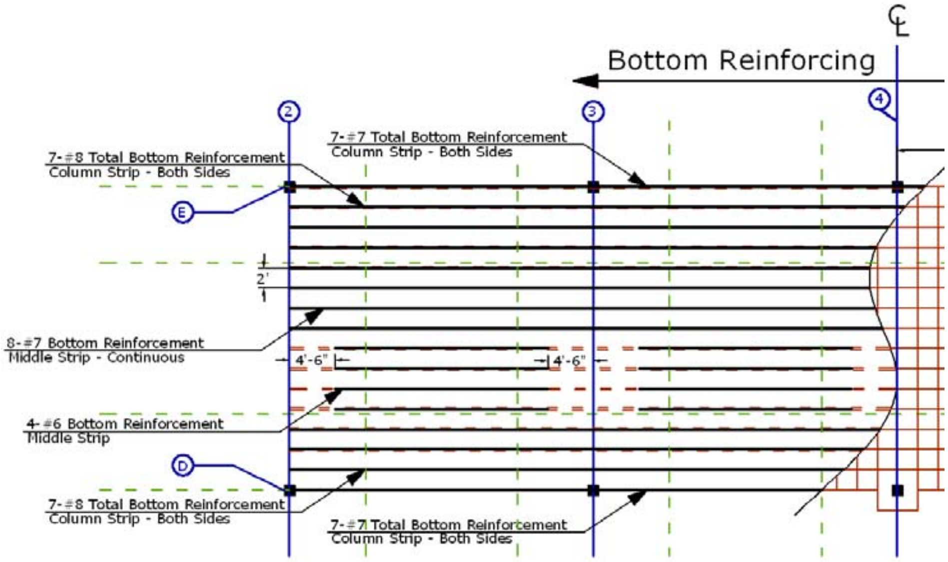


Figure 11 – Waffle Slab Bottom Reinforcing

The dashed green lines separate the column and middle strips, and the left-most column strip is exterior. Rebar cutoffs from the center of the column are dimensioned, and the orange dashed lines represent the bottom concrete joist width (2.5”). The middle strip is divided into two different rebar layouts to exercise the need for two layers; the uppermost rebar in the joist has the cutoffs shown above. In other words, two bars are required in a vertical alignment for each middle strip joist.

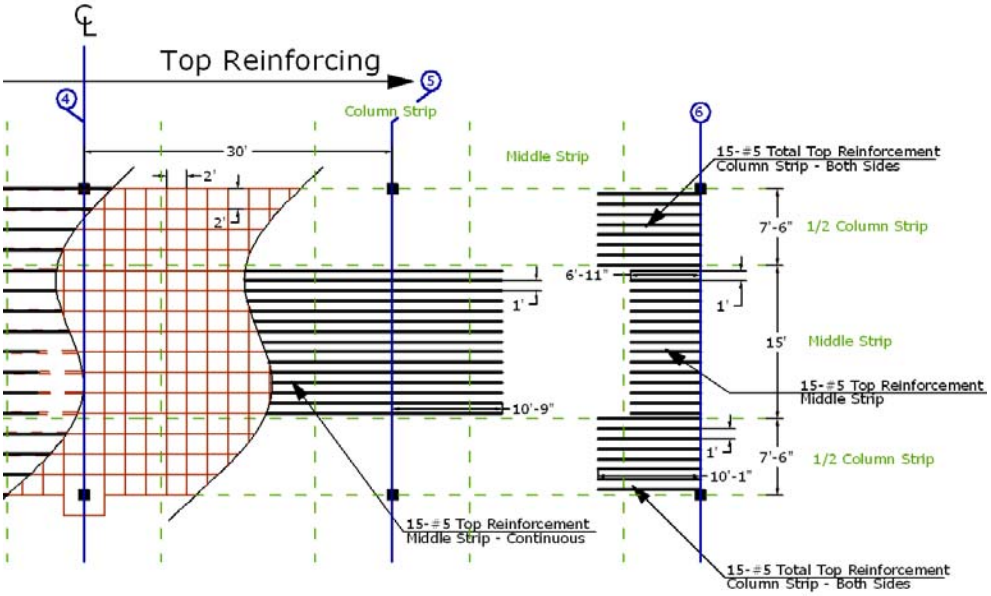


Figure 12 – Waffle Slab Top Reinforcing

The orange square layout illustrates the joists present in the system and their location. Once again, the column strip is split into two sections, and the rebar amounts shown are for the entire column strip. Fifteen #5's are distributed across 100 percent of the column strip. The middle strip continuous reinforcing is only continuous in the middle two bays, and is cutoff 10'-9" into the exterior bay. Total reinforcing is outlined in Figure 27 on page 33.

System Effectiveness

Structural

Joist slabs, also known as waffle slabs, are lighter than flat plate slabs but still supply a thin system depth. Columns must be concrete and no beams are required. Drop panels are added to avoid conflicts between the column and waffle forms. Shear walls or concrete frames can be used for lateral load resistance. The total system depth is only 16", with 4" slab and 12" deep ribs. This limits the floor to floor height to 12'-4". The poor grade soils and the close proximity of the Monongahela River make foundations a pressing issue. The entire structural system would have increased mass, requiring increased foundation sizes. Deflection is minimized with joists present every 24". The fire rating would be 2 hours.

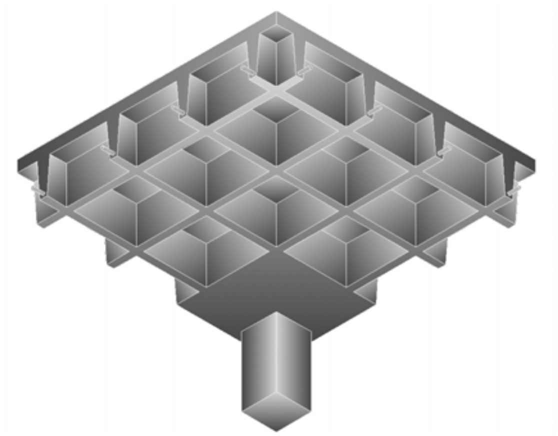


Figure 13 – Waffle Slab Near Column

Construction and Cost

Concrete structural systems require more time to construct and the low cost of materials is contrasted by the increased labor costs. Concrete needs 28 days to cure before other trades can install mechanical or electrical equipment, greatly increasing construction time. Significant time is invested in the forms of a waffle slab system. Aggregates must be vibrated, especially at the bottom of the ribs. This insures there is no spalling, and allows the system to handle the flexural loads as specified by the engineer.

Architectural and Mechanical Issues

Waffle slabs allow more than enough room for mechanical and electrical systems while maintaining a comfortable ceiling height. The open plan is kept intact since the bay sizes are equal. Vibrations are all but eliminated considering the increased system mass and stiffness. The waffle slab acts as an acoustic barrier as well, limiting transmission of mechanical equipment sound between floors. Unlike the clean concrete ceiling of the flat plate slab, the waffle slab is not a desirable architectural feature, and a drop ceiling or similar system will have to be installed for this to be eliminated.

System Advantages

- Thin total system that provides 12’-4” floor to floor height
- System maintains large bay spacing
- Acoustic barrier
- Low cost of materials
- Minimal deflection

System Disadvantages

- Longer construction time
- Forms and shoring required
- More time required for formwork
- Higher cost of labor and forms
- Heavy concrete system increases foundation size
- Ribs protrude into clear height and interfere with mechanical ductwork

IX. System III: Slab and Noncomposite Metal Deck on Steel Joists

Framing Plans and General Parameters

The framing plan for the slab on joist system is shown at right. All joists are spaced at 6’ on center; placed to avoid conflict with column and girder connections. Existing columns are intact, and the girder sizes are changed to W24x62 from a W24x55. The noncomposite deck and beams account for this change in girder size. Bay sizes remain the same. Material and system properties are outlined below.

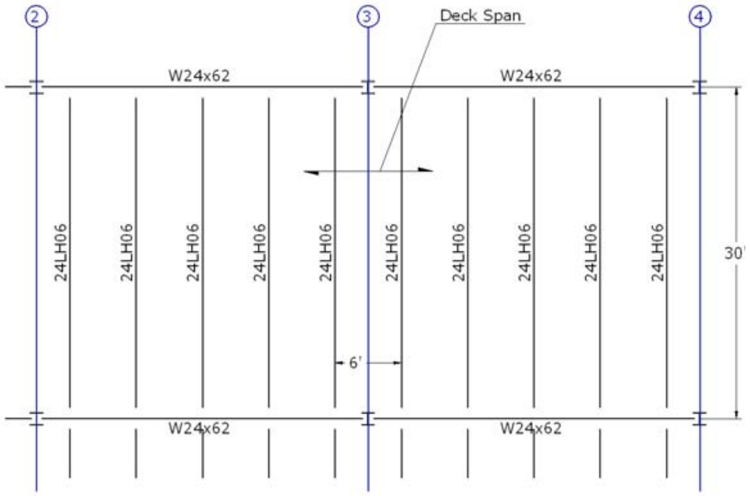


Figure ?!?!?12l – Slab on Joist Plan

2.5” LW Top Slab
1½” 22-Gage Steel Deck
4” Total Deck and Slab Thickness
Non-Composite
WWF Present
$f'_c = 3000$ psi
$f_y = 33$ ksi
Proposed Fire Rating: 0 hrs

System Effectiveness

Structural
The joist and slab combination is the lightest of all systems studied. The thick structural sandwich is acceptable since mechanical ductwork and electrical cables can pass through the web of the joist members. The overall depth of the system is 28” making the floor to floor height 11’-4”. Fire protection would be an issue for joists. Each joist must be surrounded by fireproofing, or chicken wire to receive spray on fire proofing. Not only is this a labor intensive task, but it isn’t effective structurally or economically. The proposed fire rating is 0 hrs because no fireproofing was specified for the open plan areas of Quantum III. Finally, existing foundations or smaller ones would be adequate for the slab on joist system.

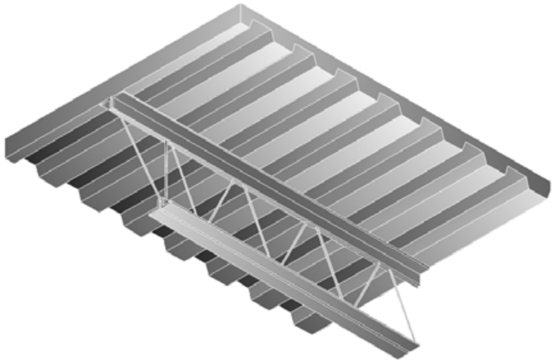


Figure ???? – Joist and Slab System

Construction and Cost
As stated in the structural section, application of fire proofing is not cost effective. More problems arise where the fireproofing meets mechanical ductwork and electrical components. These systems would puncture the fire proofing and provide an indirect path for fire to the structure. In essence, the fireproofing would be useless unless significant precautions were taken. All other construction would go fast, even relative to the composite system because of the lack of field welding required. Multiple disciplines can work on the structure simultaneously, and the installation of connections and details is simple and fast as well. No forms or shoring are needed. Excluding fireproofing, construction would be economically feasible.

Architectural and Mechanical Issues

A light system such as joists and slab would allow for mechanical vibrations to be noticeable. Such a flexible and light system could allow for resonance or amplification of vibrations. Bay sizes are kept intact. If mechanical ductwork is not placed through the joist web, the already deep structural sandwich would reduce clear height even further. This could cause an uncomfortable environment for offices. Slab and steel deck on joists is not an effective acoustic barrier.

System Advantages

- System maintains large bay spacing
- Light system could lower foundation size
- Low cost
- Fast construction
- Simple steel constructability
- No forms or shoring

System Disadvantages

- Thick structural sandwich
- Difficult to achieve fire rating
- High cost of fire proofing
- Labor intensive fire proofing
- Not an effective vibration dampener
- Poor acoustic barrier

X. System IV: Concrete One Way Slab and Beams

Framing Plans and General Parameters

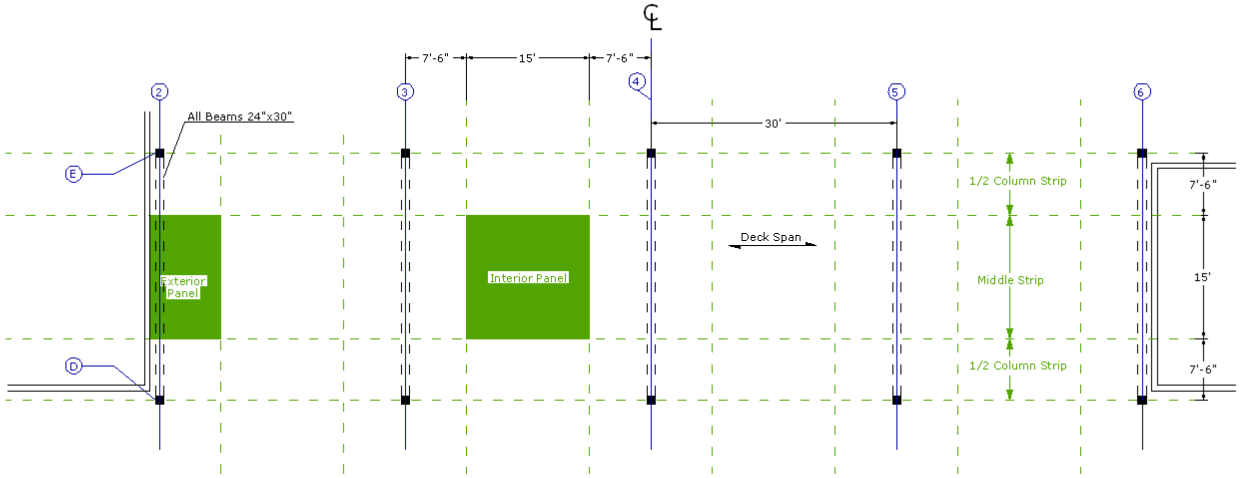


Figure 16 – One Way Slab Plan

No changes to the existing bay size were required to design a one way slab. Beams are outlined with dashed black lines and the deck spans left and right. Figure 16 also depicts the column and middle strips used in calculating reinforcing. The green rectangles show the location of interior and exterior panels used by pcaSlab to design the rebar that is placed in the longitudinal beams and deck. Material and system properties are shown to the right.

4" NW Slab
24"x30" NW Beams
30" Maximum System Depth
f'_c = 5000 psi
f_y = 60 ksi
Proposed Fire Rating: 2 hrs
12"x12" Columns were Assumed

Reinforcing Diagrams

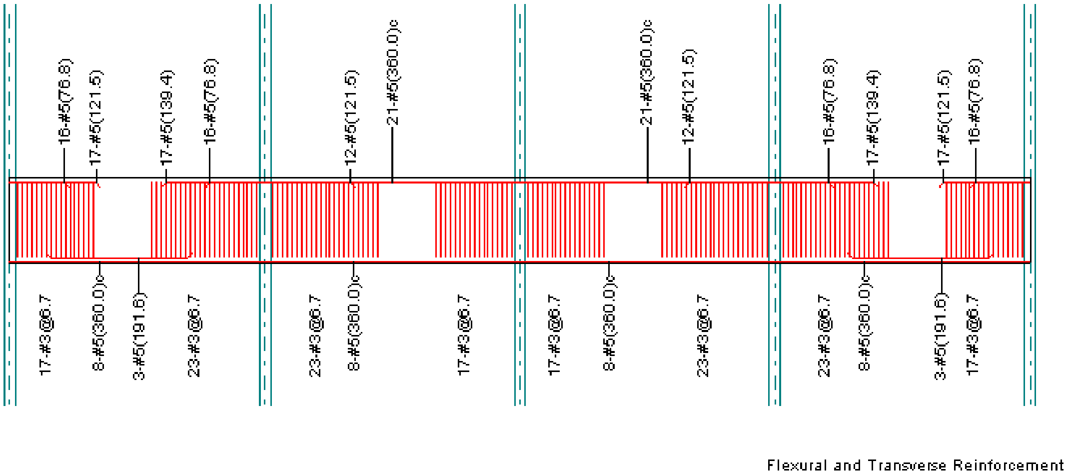


Figure 17 – One Way Slab and Beam Reinforcing

System Effectiveness

Structural

Concrete one way slab on beams provides the thickest structural sandwich. The entire system is a maximum 30" deep, making the clear height of each floor 11'-2". Columns are assumed to be 12"x12" and beams are 24"x30". Shear walls or concrete frames can be used for lateral load resistance as with the flat plate and waffle slab systems. Again, heavy systems drive foundation sizes up due to the poor grade soils deposited by the Monongahela River. Fire rating is 2 hours.

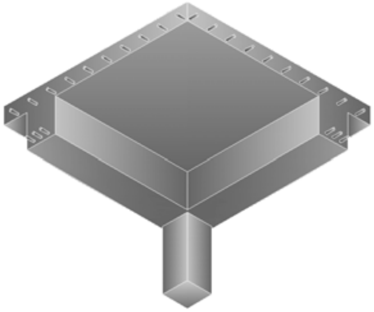


Figure 18 - Concrete Slab and Beam

Construction and Cost

The low cost of materials is contrasted with increased labor costs and a concrete system requires more time to construct. Forms are required that add to the labor costs. Construction time increases since the concrete needs 28 days to construct. The system must be vibrated, especially near columns, to insure proper aggregate distribution. This is essential to prevent spalling and insuring the structural integrity of the system.

Architectural and Mechanical Issues

The heavy system dampens mechanical vibrations and acts as an acoustic barrier. Bay sizes are kept intact so the open floor plan is not affected. There is ample space for mechanical ductwork and electrical conduit to allow for a comfortable ceiling height throughout American Eagle Outfitters: Quantum III.

System Advantages

- System maintains large bay spacing
- Acoustic barrier
- Low cost of materials
- Lightest concrete floor framing system available

System Disadvantages

- Longer construction time
- Forms and shoring required
- Higher cost of labor
- More difficult to sequence construction
- Beams protrude into clear height and can interfere with mechanical ductwork
- Thick structural sandwich

XI. System Comparison and Conclusion

The preliminary designs presented in this report are intended to provide a basis from which to expand understanding of American Eagle Outfitters: Quantum III. Four alternate systems were analyzed. A schematic design was presented for each and was studied for feasibility for use in this building. The four systems were: two way concrete flat plate, waffle or joist slab, non-composite slab and metal deck on steel joists, and concrete one way slab and beams. The comparison for these systems can be found on the following page in Figure 19.

Steel joists can be eliminated from consideration. They are a light and economic solution but require labor intensive installation of fire proofing and mechanical ductwork. Vibrations are not dampened by this system either. Concrete flat plate slab can also be eliminated. This is an expensive and heavy system. Foundations would have to be significantly enlarged. Construction time would also lengthen. The symmetrical 30’x30’ bays mean columns will not be relocated for any system.

Although concrete one way slab and beam is a slightly more expensive and heavy solution, its vibration damping, aesthetic qualities, and minimal deflection make it a viable solution. The waffle slab, though unattractive, allows ample space for mechanical ductwork. The large clear height it allows means it can be hid from sight by a drop ceiling. A waffle slab system would provide minimal deflection, a 2 hour fire rating, and intermediate system weight requiring minimal foundation redesign. The complex formwork, contrasted with the system’s minimal cost makes it an effective solution to the structural needs of Quantum III.

	System Comparison				
	Existing System	System 1	System 2	System 3	System 4
	Composite Steel	Flat Plate	Waffle Slab	Steel Joists	Concrete One Way Slab and Beams
Depth of Structure	29.1"	12"	16"	28"	30"
Slab Depth	5.5"	12"	4"	4"	4"
Structure Weight	43.3 PSF	163.2 PSF	93.6 PSF	34.6 PSF	74.1 PSF
Cost (per SF)	$13.73	$21.20	$14.45	$10.55	$14.15
Deflection: Total Load	L/398	L/755	L/625	< L/360	Negligible
Deflection: Live Load	-	L/1418	L/1101	-	Negligible
Fireproofing	Requires SOFP	2 Hour	2 Hour	Requires FP, significant interference with mechanical system	2 Hour
Vibration Resistance	Average	Excellent	Average	Minimal	Excellent
Construct-ability	Easy	Intermediate	Complex formwork detailing increases construction time significantly	Easy	Formwork detailing increases construction time
Foundation Changes Required	No	Required foundation bearing increases significantly	Required foundation sizes slightly increase	No	Required foundation sizes slightly increase
Aesthetics	Deep system can interfere with mechanical system	Thin system that can be used as ceiling	Unattractive	Deep system interferes with fire proofing and mechanical system	Deep system can interfere with mechanical system
Feasible Option	**Yes**	**No**	**Yes**	**No**	**Yes**

Figure 19 – System Comparison

Appendix A: Loads

Dead Loads

5½“ Composite Steel

2½“ LW Concrete Topping Slab = $\frac{115 \text{ lb}}{\text{ft}^3} \times \frac{2.5 \text{ in}}{12 \text{ inches/ft}} =$ 24 psf + 2.5 psf deck

3” LW Composite Slab = 75% $\times \frac{115 \text{ lb}}{\text{ft}^3} \times \frac{3 \text{ in}}{12 \text{ inches/ft}} =$ 21.6 psf

5” Composite Steel

3" LW Concrete Composite Slab = $\frac{115 \text{ lb}}{\text{ft}^3} \times \frac{3 \text{ in}}{12 \text{ inches/ft}} =$ 28.8 psf + 1.5 psf deck

2” LW Composite Slab = 75% $\times \frac{115 \text{ lb}}{\text{ft}^3} \times \frac{2 \text{ in}}{12 \text{ inches/ft}} =$ 14.4 psf

4” Noncomposite Steel

From United Steel Deck, Inc. Design Manual:

1½” 22-Gage Non-Composite Deck with 2.5” Topping = 29 psf
Reference available upon request

Roof System

6" Rigid Insulation = $\frac{1.5 \text{ lb}}{\text{in-ft}^2} \times$ 6 in = 9 psf

Roof Deck and Insulation = 2 psf + 9 psf = 11 psf + 2 psf misc

Wall Systems

Curtain Walls = 20 psf x 13.67 ft = 275 plf
Partitions = 20 psf x 13.67 ft = 275 plf
8" Concrete Masonry Wall = 51 psf : based on 125 pcf unit with grout at 24” on center

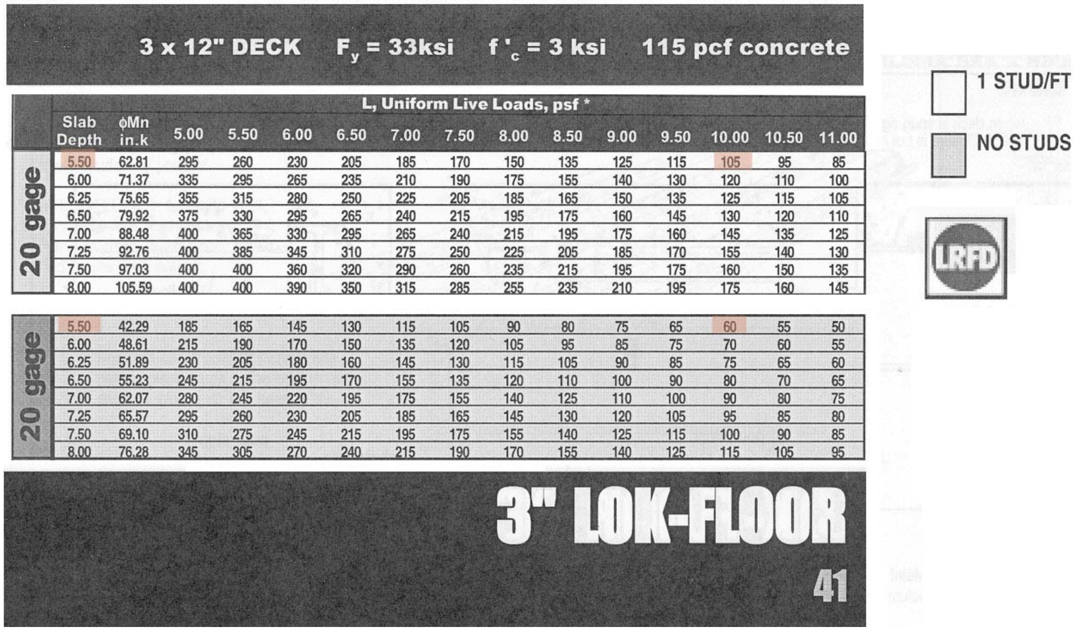
Appendix B: Existing Frame

Decking Check

From United Steel Deck, Inc. Design Manual:

3" 20-Gage Composite Deck with 2.5" Topping:
With Studs: 105 lbs/ft^2 uniform live load at 10' spacing
Without Studs: 60 lbs/ft^2 uniform live load at 10' spacing

Since the existing system is composite, the deck is adequate for the 80 psf live load applied over the structure.



3 x 12" DECK F_y = 33ksi f'_c = 3 ksi 115 pcf concrete

☐ 1 STUD/FT
▨ NO STUDS

LRFD

			L, Uniform Live Loads, psf *												
	Slab Depth	φMn in.k	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00
20 gage	5.50	62.81	295	260	230	205	185	170	150	135	125	115	105	95	85
	6.00	71.37	335	295	265	235	210	190	175	155	140	130	120	110	100
	6.25	75.65	355	315	280	250	225	205	185	165	150	135	125	115	105
	6.50	79.92	375	330	295	265	240	215	195	175	160	145	130	120	110
	7.00	88.48	400	365	330	295	265	240	215	195	175	160	145	135	125
	7.25	92.76	400	385	345	310	275	250	225	205	185	170	155	140	130
	7.50	97.03	400	400	360	320	290	260	235	215	195	175	160	150	135
	8.00	105.59	400	400	390	350	315	285	255	235	210	195	175	160	145
20 gage	5.50	42.29	185	165	145	130	115	105	90	80	75	65	60	55	50
	6.00	48.61	215	190	170	150	135	120	105	95	85	75	70	60	55
	6.25	51.89	230	205	180	160	145	130	115	105	90	85	75	65	60
	6.50	55.23	245	215	195	170	155	135	120	110	100	90	80	70	65
	7.00	62.07	280	245	220	195	175	155	140	125	110	100	90	80	75
	7.25	65.57	295	260	230	205	185	165	145	130	120	105	95	85	80
	7.50	69.10	310	275	245	215	195	175	155	140	125	115	100	90	85
	8.00	76.28	345	305	270	240	215	190	170	155	140	125	115	105	95

3" LOK-FLOOR

41

Figure 20 – 3" Deck Strength

Typical Composite Beam Check

Determine Beam Forces:

$$w_u = \frac{10 \text{ ft x } (1.2 \text{ x } 65 \text{ psf} + 1.6 \text{ x } 80 \text{ psf})}{1000 \text{ lbs}} = 2.06 \text{ k/ft}$$

$$M_u = \frac{wl^2}{8} = \frac{2.06 \text{ k/ft x } 30^2}{8} = 232 \text{ k-ft}$$

$$V_u = \frac{wl}{2} = \frac{2.06 \text{ k/ft x } 30}{2} = 30.9 \text{ k}$$

Find Plastic Neutral Axis Location:

b_{eff} = spacing = 10 ft

b_{eff} = 0.25 x span = 0.25 x 30 ft = 7.5 ft **minimum controls**

P_c = b_{eff} x d_{slab} x f'_c * 0.85 = 7.5 ft x 12 in/ft x 5.5 in x 4 ksi x 0.85 = 1683 k

P_t = A_s x F_y = 10.3 in^2 x 50 ksi = 515 k

∴ Plastic Neutral Axis is in concrete. Since concrete cannot act in tension, assume full composite action, or the axis to be at the top of the flange

Calculate Nominal Moment Capacity:

$\sum Q_n$ = 515 k : for full composite action

$$a = \frac{P_t}{0.85 \times f'_c \times b} = \frac{515\ k}{0.85 \times 4\ ksi \times 7.5\ ft \times 12\ in/ft} = 1.683\ in$$

Y2 = d_{slab} - a/2 = 5.5 in - (1.683 in)/2 = 4.66 in

$\varnothing M_n$ = 535 k-ft > $\varnothing M_n$ > 515 k-ft >> 232 k-ft OK ☑

Check Deflection:

I_{LB} = 1430 in^4 (conservative)

$$\Delta_{max} = \frac{5wl^4}{384EI} = \frac{5 \times 2.06\ k/ft \times (30\ ft)^4 \times 1728}{384 \times 29{,}000\ ksi \times 1430\ in^4} = 0.905\ in = \frac{L}{398}$$ OK ☑

Typical Composite Girder Check

Determine Girder Forces:

$$P = \frac{wl}{2} = \frac{1.654\ k/ft \times 30}{2} = 24.81\ k$$

Point loads from beams are at 1/3 points along girder

M_u = P x a = 24.81 k x 10 ft = 248.1 k-ft

V_u = P = 24.81 k

Find Plastic Neutral Axis Location:

b_{eff} = spacing = 30 ft

b_{eff} = 0.5 x span = 0.25 x 30 ft = 7.5 ft **minimum controls**

P_c = b_{eff} x d_{slab} x f'_c x 0.85 = 7.5 ft x 12 in/ft x 5.5 in x 4 ksi x 0.85 = 1683 k

$P_t = A_s \times F_y = 50\ \text{ksi} \times 16.2\ \text{in}^2 = 810\ \text{k}$

∴ Plastic Neutral Axis is in concrete. Since concrete cannot act in tension, assume full composite action, or the axis to be at the top of the flange

Calculate Nominal Moment Capacity:

$\sum Q_n = 810\ \text{k}$: for full composite action

$$a = \frac{P_t}{0.85 \times f'_c \times b} = \frac{810\ \text{k}}{0.85 \times 4\ \text{ksi} \times 7.5\ \text{ft} \times 12\ \text{in/ft}} = 2.65\ \text{in}$$

$$Y2 = d_{slab} - a/2 = 5.5\ \text{in} - (2.65\ \text{in})/2 = 4.175\ \text{in}$$

$\varnothing M_n = 989\ \text{k-ft} > \varnothing M_n > 959\ \text{k-ft} >> 248\ \text{k-ft}$ OK ☑

Check Deflection:

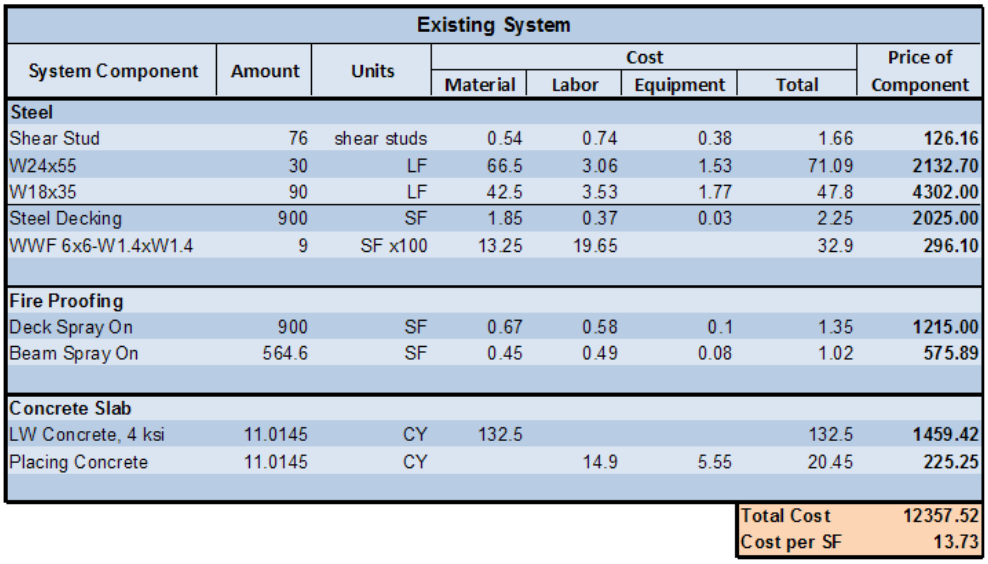
$I_{LB} = 3370\ \text{in}^4$ (conservative)

$$\Delta_{max} = \frac{0.036Pl^3}{EI} = \frac{0.036 \times 24.81\ \text{k} \times (30\ \text{ft})^3 \times 1728}{29{,}000\ \text{ksi} \times 3370\ \text{in}^4} = 0.426\ \text{in} = \frac{L}{845}$$ OK ☑

The beam design was controlled by deflection. Girder design seems to be controlled by neither strength nor deflection. An obvious answer is the engineer had a number of bays that had greater loading. This can be from a simple drafting mistake of specifying the incorrect concrete weight. The drawings specified lightweight concrete, or a deck and slab weight of 38 psf. With the superimposed MEP and miscellaneous loads, the total load would be 48 psf. Analysis in RAMSTEEL found the existing system can handle a maximum 58.1 psf. This is ideal for a normal weight system. The United Steel Deck Design Manual puts the normal weight deck and slab at 48 psf—exactly the MEP load below the max distributed load the existing system can withstand. In other words, 48 psf + 10 psf MEP is the maximum load carrying capacity of the existing system as calculated in RAMSTEEL. Supplementary calculations are available upon request.

System Cost

The figure below outlines the cost estimate for the existing system. Hand calculations of concrete volumes and fire proofing square footages are available on request.



Existing System							
System Component	Amount	Units	Cost				Price of Component
			Material	Labor	Equipment	Total	
Steel							
Shear Stud	76	shear studs	0.54	0.74	0.38	1.66	**126.16**
W24x55	30	LF	66.5	3.06	1.53	71.09	**2132.70**
W18x35	90	LF	42.5	3.53	1.77	47.8	**4302.00**
Steel Decking	900	SF	1.85	0.37	0.03	2.25	**2025.00**
WWF 6x6-W1.4xW1.4	9	SF x100	13.25	19.65		32.9	**296.10**
Fire Proofing							
Deck Spray On	900	SF	0.67	0.58	0.1	1.35	**1215.00**
Beam Spray On	564.6	SF	0.45	0.49	0.08	1.02	**575.89**
Concrete Slab							
LW Concrete, 4 ksi	11.0145	CY	132.5			132.5	**1459.42**
Placing Concrete	11.0145	CY		14.9	5.55	20.45	**225.25**
						Total Cost	12357.52
						Cost per SF	13.73

Figure 21 – Existing System Costs

Appendix C: System I: Flat Plate Slab

Loads

Dead ....10 psf superimposed
Live ....80 psf including partition loads

Material Properties

f'_c ....4 ksi
f'_y ....60 ksi
Young’s Modulus (E) ....29,000 ksi
Normal Weight Concrete

System Properties

Flat Plate Depth...12” > $l_n/30 = 29'*12/30 = 11.6$” OK ☑
Columns ....12”x12”

Results

Flat Plate Reinforcing																								
Bay Number			2-3					3-4						4-5						5-6				
Side of Bay			Left	Continuous	Middle	Right - Short	Right	Left	Left - Short	Continuous	Middle	Right - Short	Right	Left	Left - Short	Middle	Continuous	Right - Short	Right	Left	Left - Short	Middle	Continuous	Right
pcaSlab Design	Middle Strip	Top	18-#6 83.7				18-#6 118.9	18-#6 146.5					18-#6 118.9	18-#6 118.9					18-#6 119	18-#6 118.9				18-#6 83.7
		Bottom		18-#6						18-#6							18-#6						18-#6	
	Column Strip	Top	18-#6 121.5			9-#8 76.8	10-#8 132.1	10-#8 158.3	9-#8 76.8			4-#7 76.8	13-#7 124.8	13-#7 124.8	4-#7 76.8			9-#8 76.8	10-#8 158	10-#8 132	9-#8 76.8			18-#6 121.5
		Bottom		20-#6						18-#6							18-#6						20-#6	
Equivalent Area of Steel (in^2)	Middle Strip	Top	7.92				7.92	7.92					7.92	7.92					7.92	7.92				7.92
		Bottom		7.92						7.92							7.92						7.92	
	Column Strip	Top	7.92			7.11	7.9	7.9	7.11			2.4	7.8	7.8	2.4			7.11	7.9	7.9	7.11			7.92
		Bottom		8.8						7.92							7.92						8.8	

CL

Table 22 – Flat Plate Reinforcing

Deflection Criteria

LL + DL deflection = 0.477” = L/754.7 << L/240 OK ☑

LL deflection = 0.254” = L/1417.3 << L/360 OK ☑

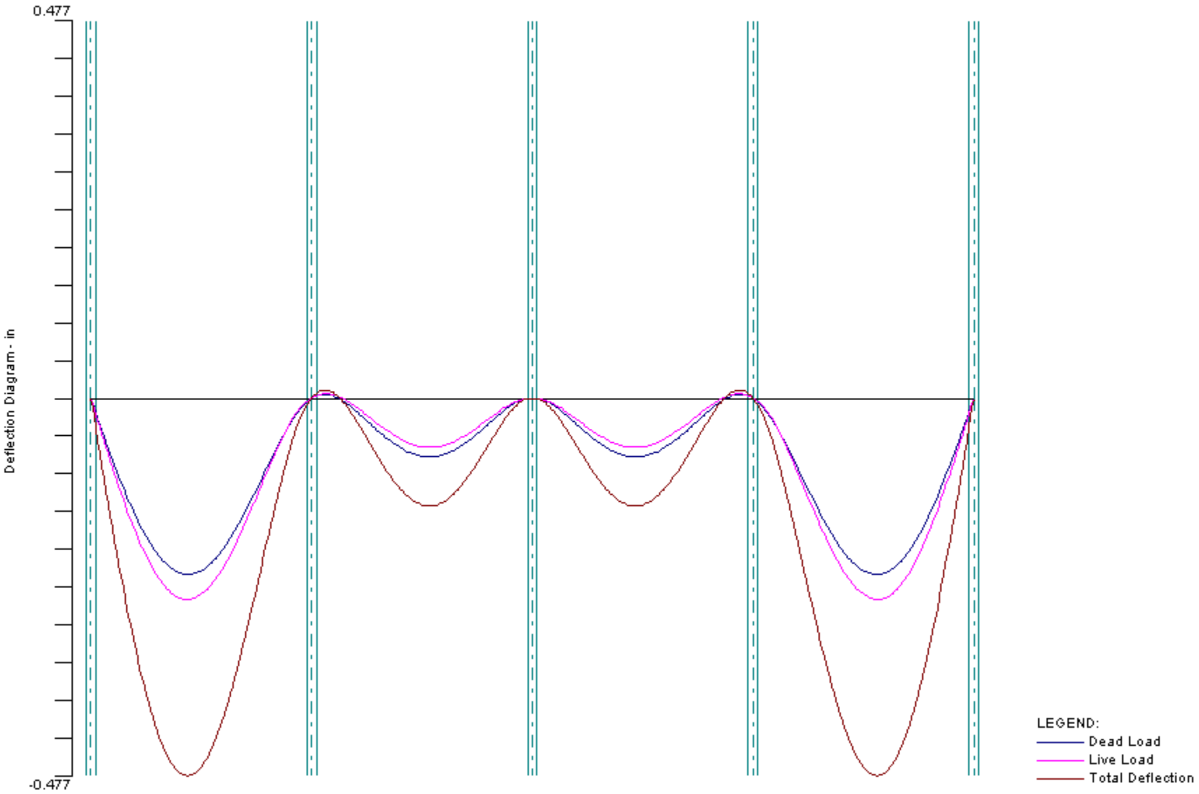
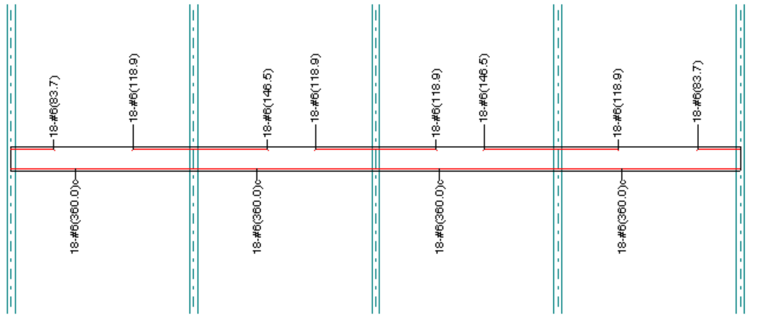
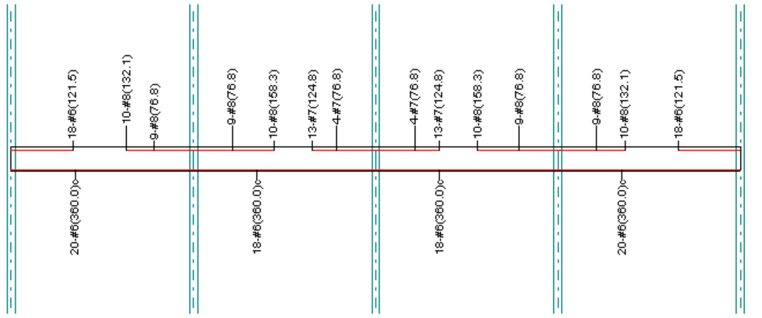


Figure 23 – Flat Plate Deflection

pcaSlab Reinforcing Diagram



Middle Strip Flexural Reinforcement

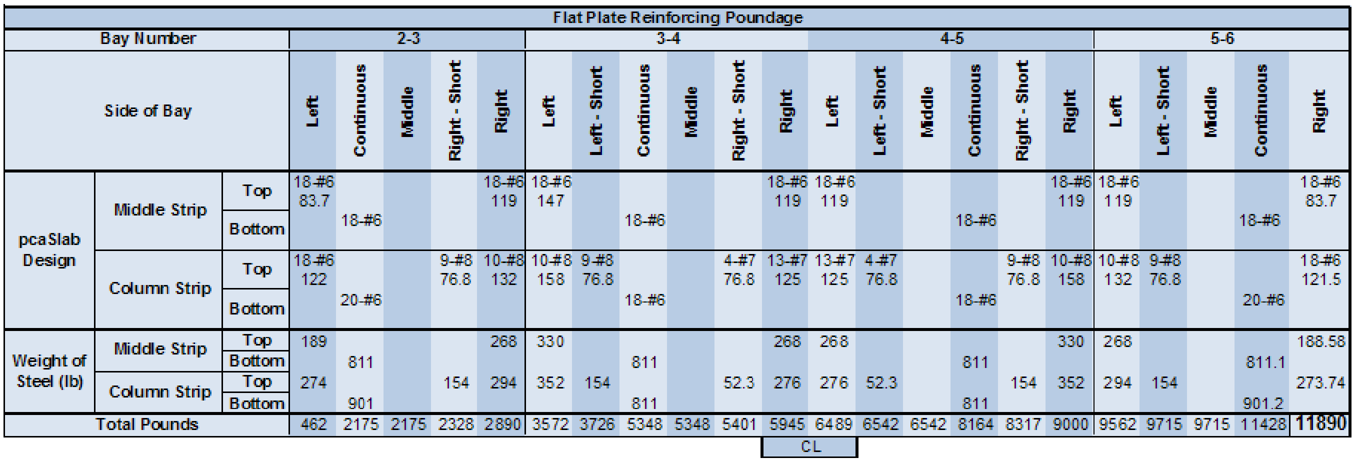


Column Strip Flexural Reinforcement

Figure 24 – pcaSlab Reinforcing Design

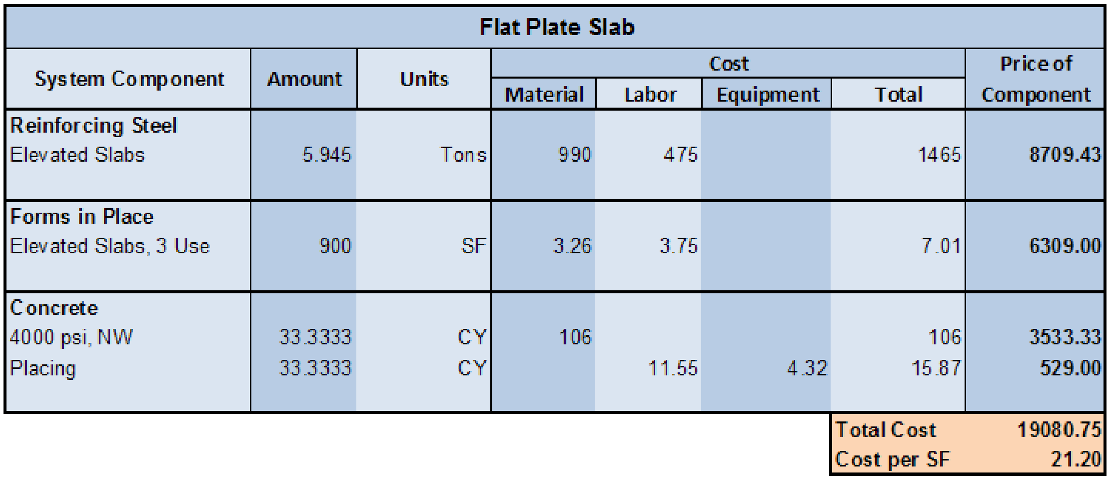
System Cost

The figures below outline the reinforcing poundage calculation and the cost estimate for the flat plate slab system. Hand calculations of concrete volumes and fire proofing square footages are available on request.



Flat Plate Reinforcing Poundage																								
Bay Number			2-3					3-4						4-5						5-6				
Side of Bay			Left	Continuous	Middle	Right - Short	Right	Left	Left - Short	Continuous	Middle	Right - Short	Right	Left	Left - Short	Middle	Continuous	Right - Short	Right	Left	Left - Short	Middle	Continuous	Right
pcaSlab Design	Middle Strip	Top	18#6 83.7				18-#6 119	18#6 147					18-#6 119	18#6 119					18-#6 119	18#6 119				18#6 83.7
		Bottom		18-#6						18-#6							18-#6						18-#6	
	Column Strip	Top	18#6 122			9-#8 76.8	10-#8 132	10-#8 158	9-#8 76.8			4-#7 76.8	13-#7 125	13-#7 125	4-#7 76.8			9-#8 76.8	10-#8 158	10-#8 132	9-#8 76.8			18#6 121.5
		Bottom		20-#6						18-#6							18-#6						20-#6	
Weight of Steel (lb)	Middle Strip	Top	189				268	330					268	268					330	268				188.58
		Bottom		811						811							811						811.1	
	Column Strip	Top	274			154	294	352	154			52.3	276	276	52.3			154	352	294	154			273.74
		Bottom		901						811							811						901.2	
Total Pounds			462	2175	2175	2328	2890	3572	3726	5348	5348	5401	5945	6489	6542	6542	8164	8317	9000	9562	9715	9715	11428	11890
													CL											

Figure 25 – Flat Plate Reinforcing Poundage



Flat Plate Slab

System Component	Amount	Units	Cost				Price of Component
			Material	Labor	Equipment	Total	
Reinforcing Steel							
Elevated Slabs	5.945	Tons	990	475		1465	**8709.43**
Forms in Place							
Elevated Slabs, 3 Use	900	SF	3.26	3.75		7.01	**6309.00**
Concrete							
4000 psi, NW	33.3333	CY	106			106	**3533.33**
Placing	33.3333	CY		11.55	4.32	15.87	**529.00**
						Total Cost	**19080.75**
						Cost per SF	**21.20**

Figure 26 – Flat Plate Slab Cost

Appendix D: System II: Waffle Slab

Loads

Dead ....10 psf superimposed
Live ....80 psf including partition loads

Material Properties

f'$_c$ ....4 ksi
f'$_y$ ....60 ksi
Young's Modulus (E) ....29,000 ksi
Normal Weight Concrete

System Properties

Topping Slab..4"
Concrete Joist Depth.....................................12"
Joist Spacing ....24" center to center
Bottom Rib Depth..2.5"
Columns ....12"x12"
Drop Panels..4'x4' at each column

Waffle Slab Reinforcing																
Bay Number			**2-3**				**3-4**		**4-5**		**5-6**			
Side of Bay			**Left**	**Continuous**	**Middle**	**Right**	**Continuous**	**Middle**	**Middle**	**Continuous**	**Left**	**Middle**	**Continuous**	**Right**
pcaSlab Design	**Middle Strip**	**Top**	15-#5 82.6			15-#5 128.7	15-#5			15-#5	15-#5 128.7			15-#5 82.6
		Bottom		**10-#6**	**4-#6** 252		**10-#6**	**4-#6** 252	**4-#6** 252	**10-#6**		**4-#6** 252	**10-#6**	
	Column Strip	**Top**	15-#5 120.8											15-#5 120.8
		Bottom		**12-#6**			**12-#6**			**12-#6**			**12-#6**	
Equivalent Area of Steel (in^2)	**Middle Strip**	**Top**	4.65			4.65	4.65			4.65	4.65			
		Bottom		4.4	1.76		4.4	1.76	1.76	4.4		1.76	4.4	
	Column Strip	**Top**	4.65											4.65
		Bottom		5.28			5.28			5.28			5.28	

CL

Table 27 – Waffle Slab Reinforcing

The numbers above represent the reinforcing required for the waffle slab. There is a reason for the discrepancy between the above numbers and Figures 10 through 12, pages 15-17. The waffle slab joists are spaced at 24" on center, so no more than 8 joists can be in either the column or middle strip. Having 10 or 12 bars across this plane would require a thicker bottom depth of ribs or fewer bars. From the equivalent area of steel of all **bold** values above, a fewer number of heavier bars was calculated. These new values are in the diagrams listed above. The numbers below the number and type of bars represents the cutoff point of the bars from the nearest support center.

Deflection Criteria

LL + DL deflection = 0.576”
= L/625
OK ☑

LL deflection = 0.327”
= L/1101
OK ☑

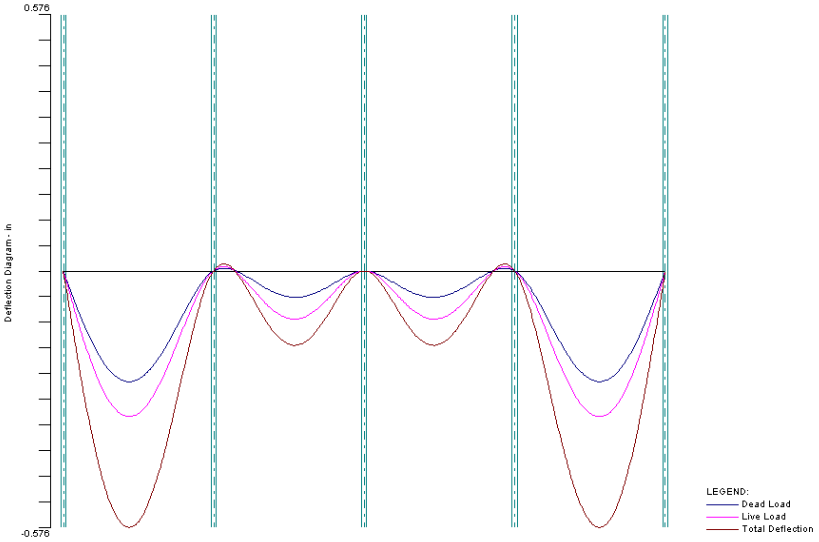
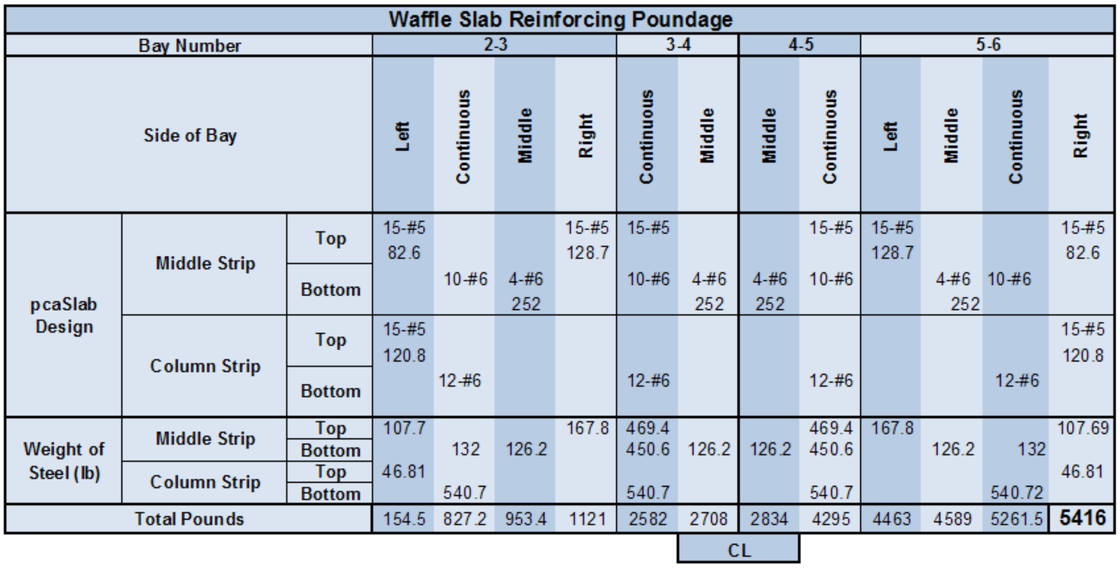


Figure 28 – pcaSlab Deflection Results

System Cost

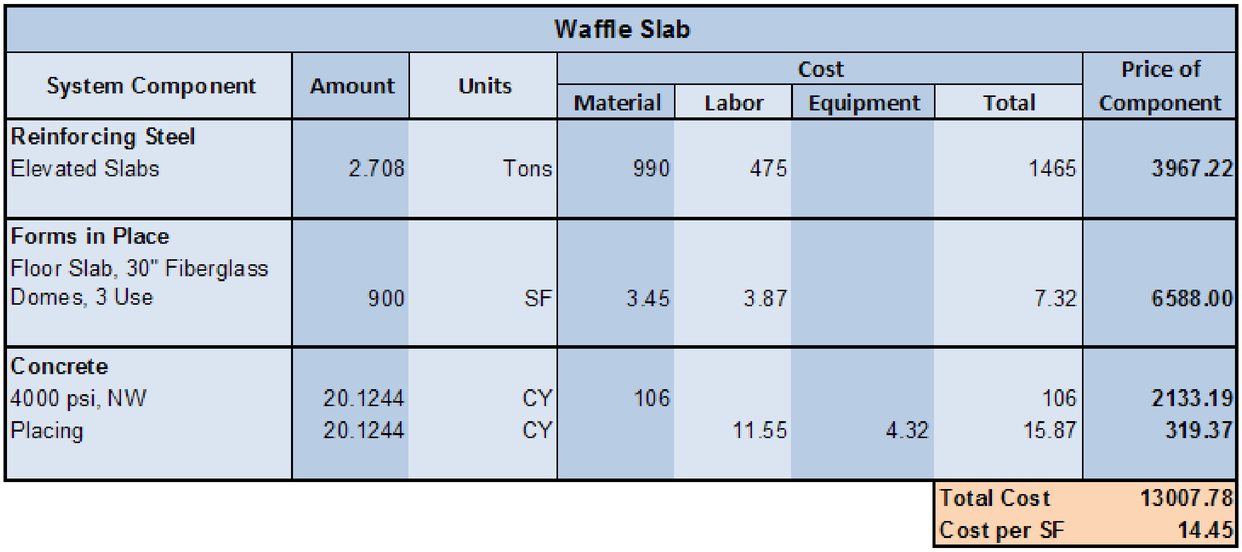
The figures below outline the reinforcing poundage calculation and the cost estimate for the waffle slab system. Hand calculations of concrete volumes and fire proofing square footages are available on request.



Waffle Slab Reinforcing Poundage														
Bay Number			2-3				3-4		4-5		5-6			
Side of Bay			Left	Continuous	Middle	Right	Continuous	Middle	Middle	Continuous	Left	Middle	Continuous	Right
pcaSlab Design	Middle Strip	Top	15-#5 82.6			15-#5 128.7	15-#5			15-#5	15-#5 128.7			15-#5 82.6
		Bottom		10-#6	4-#6 252		10-#6	4-#6 252	4-#6 252	10-#6		4-#6 252	10-#6	
	Column Strip	Top	15-#5 120.8											15-#5 120.8
		Bottom		12-#6			12-#6			12-#6			12-#6	
Weight of Steel (lb)	Middle Strip	Top	107.7			167.8	469.4			469.4	167.8			107.69
		Bottom		132	126.2		450.6	126.2	126.2	450.6		126.2	132	
	Column Strip	Top	46.81											46.81
		Bottom		540.7			540.7			540.7			540.72	
Total Pounds			154.5	827.2	953.4	1121	2582	2708	2834	4295	4463	4589	5261.5	**5416**

CL

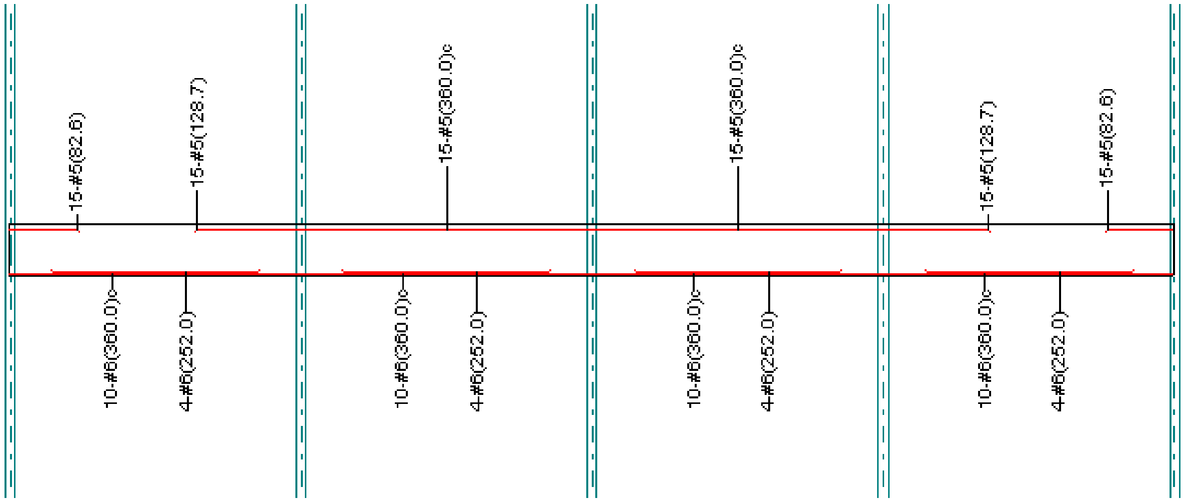
Figure 29 – Waffle Slab Reinforcing Poundage



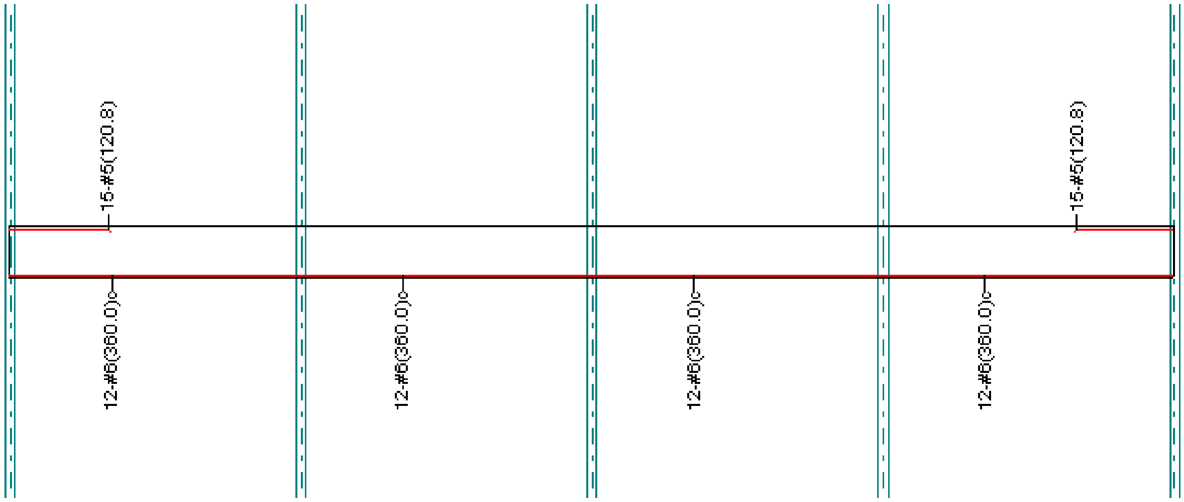
Waffle Slab

System Component	Amount	Units	Cost				Price of Component
			Material	Labor	Equipment	Total	
Reinforcing Steel Elevated Slabs	2.708	Tons	990	475		1465	**3967.22**
Forms in Place Floor Slab, 30" Fiberglass Domes, 3 Use	900	SF	3.45	3.87		7.32	**6588.00**
Concrete							
4000 psi, NW	20.1244	CY	106			106	**2133.19**
Placing	20.1244	CY		11.55	4.32	15.87	**319.37**
						Total Cost	13007.78
						Cost per SF	14.45

Figure 30 - Waffle Slab Cost



Middle Strip Flexural Reinforcement



Column Strip Flexural Reinforcement

Figure 31 – Waffle Slab Reinforcing Design

Appendix E: System III: Steel Joists and One Way Slab

Loads

Dead ....10 psf superimposed
Live ....80 psf including partition loads
Decking ....29 psf

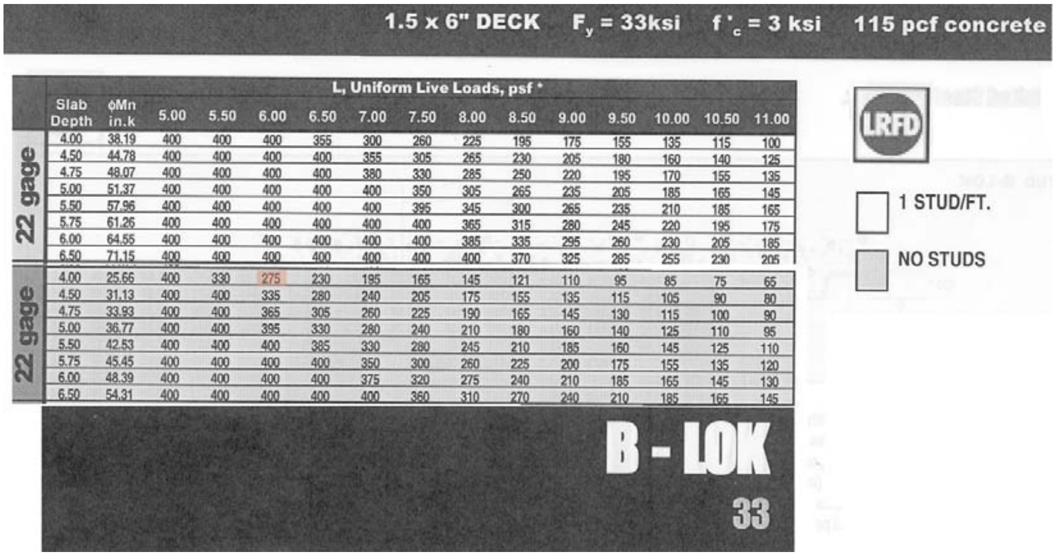
Material Properties

f'$_c$ ....3 ksi
f'$_y$ ....33 ksi
Young's Modulus (E) ....29,000 ksi
Light Weight Concrete

Decking Check

From United Steel Deck, Inc. Design Manual:

1½" 22-Gage Non-Composite Deck with 2.5" Topping:
Without Studs: 275 lbs/ft^2 uniform live load at 6' spacing



1.5 x 6" DECK F_y = 33ksi f '$_c$ = 3 ksi 115 pcf concrete

	Slab Depth	ϕMn in.k	L, Uniform Live Loads, psf *												
			5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00
22 gage	4.00	38.19	400	400	400	355	300	260	225	195	175	155	135	115	100
	4.50	44.78	400	400	400	400	355	305	265	230	205	180	160	140	125
	4.75	48.07	400	400	400	400	380	330	285	250	220	195	170	155	135
	5.00	51.37	400	400	400	400	400	350	305	265	235	205	185	165	145
	5.50	57.96	400	400	400	400	400	395	345	300	265	235	210	185	165
	5.75	61.26	400	400	400	400	400	400	365	315	280	245	220	195	175
	6.00	64.55	400	400	400	400	400	400	385	335	295	260	230	205	185
	6.50	71.15	400	400	400	400	400	400	400	370	325	285	255	230	205
22 gage	4.00	25.66	400	330	275	230	195	165	145	121	110	95	85	75	65
	4.50	31.13	400	400	335	280	240	205	175	155	135	115	105	90	80
	4.75	33.93	400	400	365	305	260	225	190	165	145	130	115	100	90
	5.00	36.77	400	400	395	330	280	240	210	180	160	140	125	110	95
	5.50	42.53	400	400	400	385	330	280	245	210	185	160	145	125	110
	5.75	45.45	400	400	400	400	350	300	260	225	200	175	155	135	120
	6.00	48.39	400	400	400	400	375	320	275	240	210	185	165	145	130
	6.50	54.31	400	400	400	400	400	360	310	270	240	210	185	165	145

LRFD

☐ 1 STUD/FT.

▨ NO STUDS

B - LOK
33

Figure 32 – 1½" Noncomposite Deck Strength

System Properties

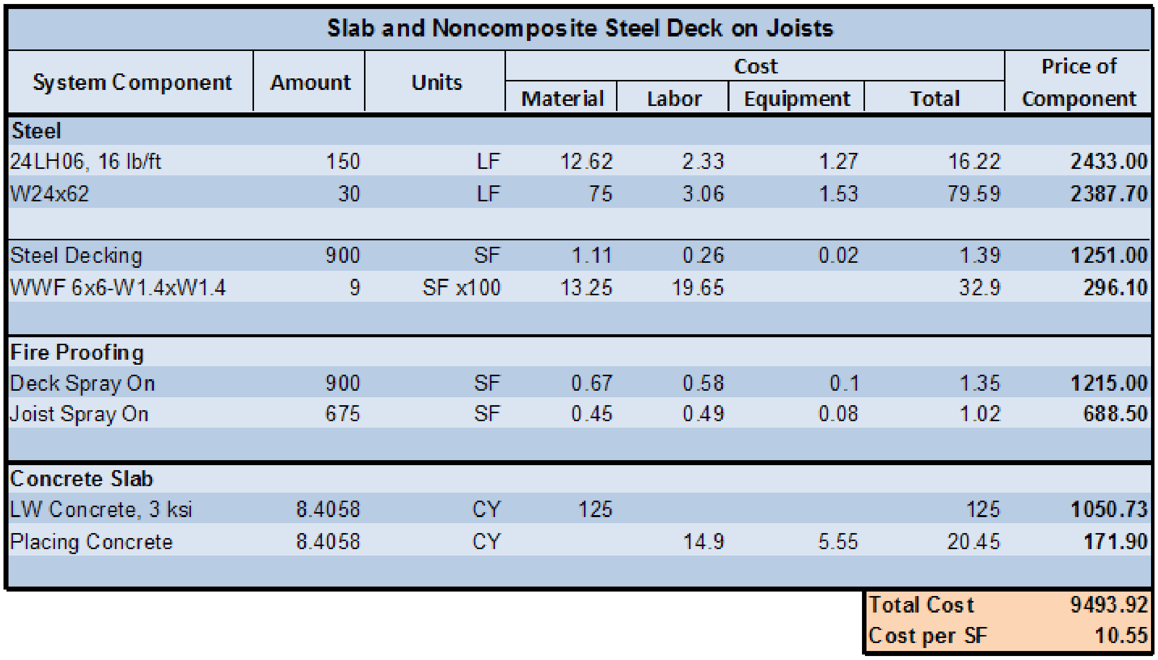
Topping Slab ....2.5"
22-Gage Steel Deck Depth.............................1.5"
Joist Spacing ....6' center to center
Columns ....Existing Steel Columns

Deflection Criteria

Steel Joist Institute 42nd Edition Catalog specifies all deflections < L/360

System Cost

The figure below outlines the cost estimate for the slab and noncomposite metal deck on steel joists system. Hand calculations of concrete volumes and fire proofing square footages are available on request.



Slab and Noncomposite Steel Deck on Joists							
System Component	Amount	Units	Cost				Price of Component
			Material	Labor	Equipment	Total	
Steel							
24LH06, 16 lb/ft	150	LF	12.62	2.33	1.27	16.22	**2433.00**
W24x62	30	LF	75	3.06	1.53	79.59	**2387.70**
Steel Decking	900	SF	1.11	0.26	0.02	1.39	**1251.00**
WWF 6x6-W1.4xW1.4	9	SF x100	13.25	19.65		32.9	**296.10**
Fire Proofing							
Deck Spray On	900	SF	0.67	0.58	0.1	1.35	**1215.00**
Joist Spray On	675	SF	0.45	0.49	0.08	1.02	**688.50**
Concrete Slab							
LW Concrete, 3 ksi	8.4058	CY	125			125	**1050.73**
Placing Concrete	8.4058	CY		14.9	5.55	20.45	**171.90**
						Total Cost	**9493.92**
						Cost per SF	**10.55**

Figure 33 – Joist System Cost

Appendix F: System IV: Concrete One Way Slab and Beams

Loads

Dead ....10 psf superimposed
Live ....80 psf including partition loads

Material Properties

f'_c ....4 ksi
f'_y ....60 ksi
Young's Modulus (E) ....29,000 ksi
Normal Weight Concrete

System Properties

Slab ....12"
Beam Dimensions ....14"x16" (depth from top of slab)
Columns ....12"x12"

Deflection Criteria:

LL + DL deflection ~= 0.152" = 0 << L/240 OK ☑
LL deflection = 0.101" ~= 0 << L/360 OK ☑

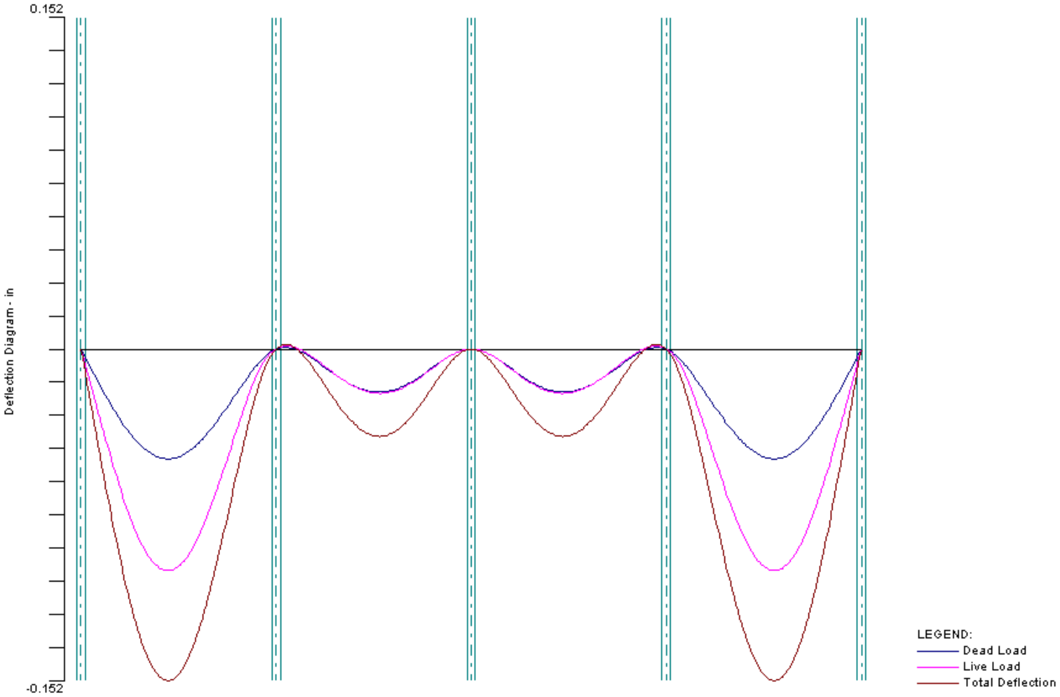
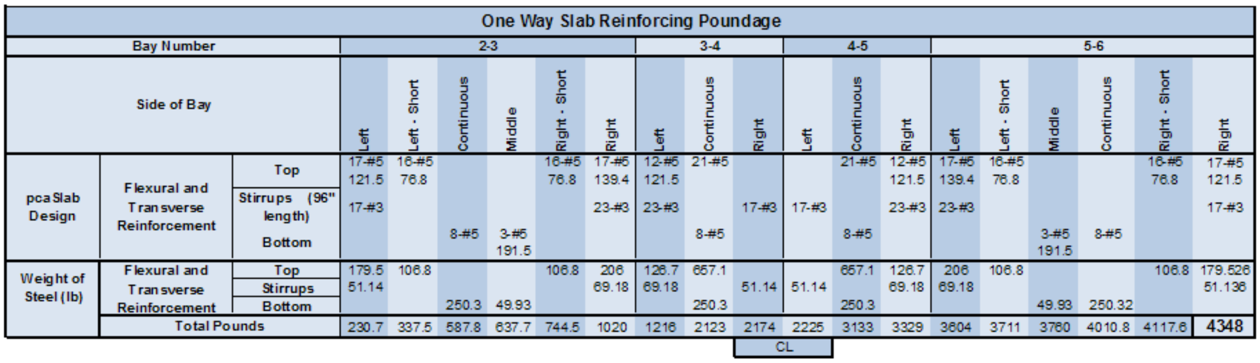


Figure 34 – One Way Slab Deflection

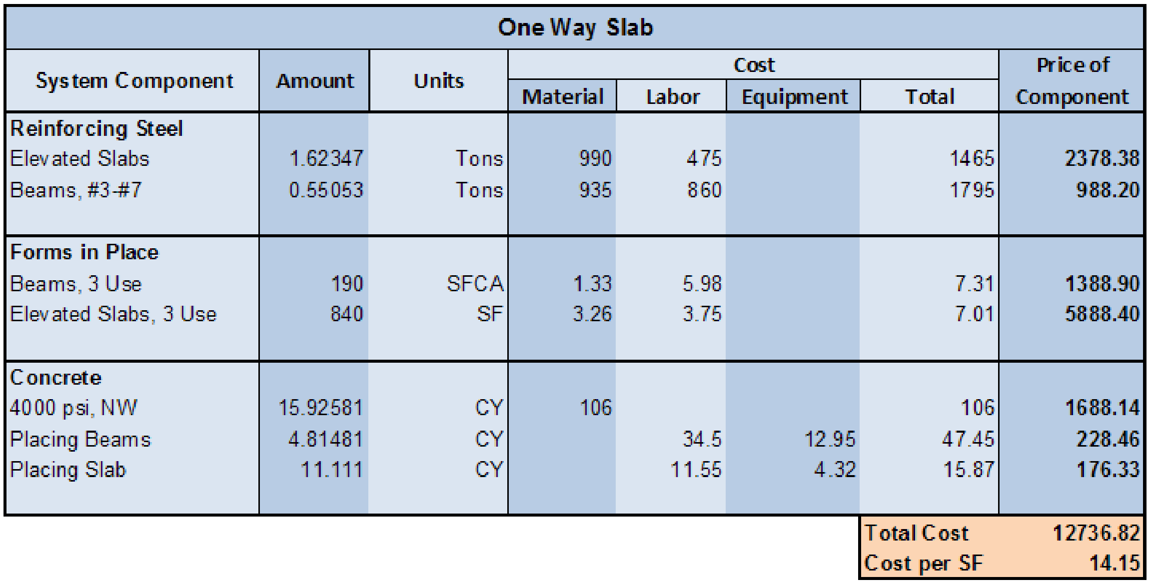
System Cost

The figures below outline the reinforcing poundage calculation and the cost estimate for the one way slab and beams system. Hand calculations of concrete volumes and fire proofing square footages are available on request.



One Way Slab Reinforcing Poundage																				
Bay Number			2-3						3-4			4-5			5-6					
Side of Bay			Left	Left - Short	Continuous	Middle	Right - Short	Right	Left	Continuous	Right	Left	Continuous	Right	Left	Left - Short	Middle	Continuous	Right - Short	Right
pca Slab Design	Flexural and Transverse Reinforcement	Top	17-#5 121.5	16-#5 76.8			16-#5 76.8	17-#5 139.4	12-#5 121.5	21-#5			21-#5	12-#5 121.5	17-#5 139.4	16-#5 76.8			16-#5 76.8	17-#5 121.5
		Stirrups (96" length)	17-#3					23-#3	23-#3		17-#3	17-#3		23-#3	23-#3					17-#3
		Bottom			8-#5	3-#5 191.5				8-#5			8-#5				3-#5 191.5	8-#5		
Weight of Steel (lb)	Flexural and Transverse Reinforcement	Top	179.5	106.8			106.8	206	126.7	657.1			657.1	126.7	206	106.8			106.8	179.526
		Stirrups	51.14					69.18	69.18		51.14	51.14		69.18	69.18					51.136
		Bottom			250.3	49.93				250.3			250.3				49.93	250.32		
	Total Pounds		230.7	337.5	587.8	637.7	744.5	1020	1216	2123	2174	2225	3133	3329	3604	3711	3760	4010.8	4117.6	4348
											CL									

Figure 35 - One Way Slab Reinforcing Poundage



One Way Slab							
System Component	Amount	Units	Cost				Price of Component
			Material	Labor	Equipment	Total	
Reinforcing Steel							
Elevated Slabs	1.62347	Tons	990	475		1465	**2378.38**
Beams, #3-#7	0.55053	Tons	935	860		1795	**988.20**
Forms in Place							
Beams, 3 Use	190	SFCA	1.33	5.98		7.31	**1388.90**
Elevated Slabs, 3 Use	840	SF	3.26	3.75		7.01	**5888.40**
Concrete							
4000 psi, NW	15.92581	CY	106			106	**1688.14**
Placing Beams	4.81481	CY		34.5	12.95	47.45	**228.46**
Placing Slab	11.111	CY		11.55	4.32	15.87	**176.33**
						Total Cost	**12736.82**
						Cost per SF	**14.15**

Figure 36 – One Way Slab Cost