ASHA National Office

Rockville, MD

Technical Report II

Photo Courtesy of Boggs & Partners Architects

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Structures Option

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Executive Summary

The ASHA National Office is a five story office building with two floors of subgrade parking. The parking structure is composed of a flat slab system with drop panels and the superstructure is composite steel. The gross area of the building is 133,870 square feet. In this technical report, the existing structural system of the ASHA National Office building is discussed and analyzed. The report includes a detailed description of the building's structural system. Images are used to allow for a better understanding of the system and its components. A list of building codes and standards used to design the building is also included in this report. The properties and strengths of the materials used for the structure of the building are also provided.

This report includes a study of alternative floor systems for the ASHA National Office Building. Four different floor systems were analyzed including the existing floor system. The four systems that were analyzed included composite steel, one-way pan joist and beams, one-way slab and beams, and a precast hollow core plank system supported by steel beams. A three-bay strip of the floor plan was designed for gravity loads for all four systems. These systems were then compared to each other in a number of ways. The factors that were considered for each floor system include architecture, lateral system impacts, cost per square foot, fire protection, weight, vibration, and total depth of system. After the calculations were done for each floor system, a table was made in order to compare all of the floor systems.

It was concluded that the best option for the ASHA National Office Building is the current composite steel floor system. This is due to the lost cost per square foot, the light weight, and the constructability of the composite steel system. With the large 40 foot exterior spans, it seems that the efficiency of the composite steel beams is unmatched. The most viable alternative floor system is the one-way pan joists with beams. This is due to the fact that this system has a system depth of merely 18.5 inches. This would decrease the height of each floor by 7.5 inches. This will decrease the total height of the building, thus helping to decrease the cost of the building. Another viable alternative floor system is the one-way flat slab with beams. Advantages of this system include the ability to span the long 40' bays and the fact that the system allows for a flat ceiling between beams. This allows for adequate space for the terminal mechanical units that are located above the ceiling throughout the building.

Introduction

The ASHA National Office building is a five story office building in Rockville, MD. The American Speech-Language-Hearing Association owns and operates the building. The building was designed with the employees in mind. There is a generous amount of workspace for the employees and the conference rooms are very flexible. A café and kitchen are provided for the employees on the first floor of the office building. There are two levels of subgrade parking beneath the building in addition to surface parking. There are 201 parking spaces in the subgrade parking structure and 224 spaces above grade.

One of the main architectural themes that Boggs & Partners incorporated throughout the building is curves. This was done to mimic the sound waves in the ASHA logo which is shown below. The pre-function space has the curve incorporated into it, and there is a curved piece of art on the landing of the stairway that leads from the lobby to the second floor. The exterior façade has a large three story curved glass curtain wall above the main entrance, and the sidewalks on the exterior of the building are curved as well to further emphasize the main theme of the building.

The five story office building has a total floor area of 133,870 square feet and the roof the building is 69 feet above grade. The top of the penthouse roof is 85 feet above grade. The building façade of the office tower consists of a window wall system and precast concrete spandrels.

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Structural System

Substructure

The substructure of the ASHA National Office building is comprised of two floors of subgrade parking. There is parking underneath the office tower along with a section of the parking structure that is adjacent to the office tower. See Figure 1: Overall Parking Floor Plan. The parking below the office tower is shown in blue and the parking adjacent to the office tower is shown in yellow.

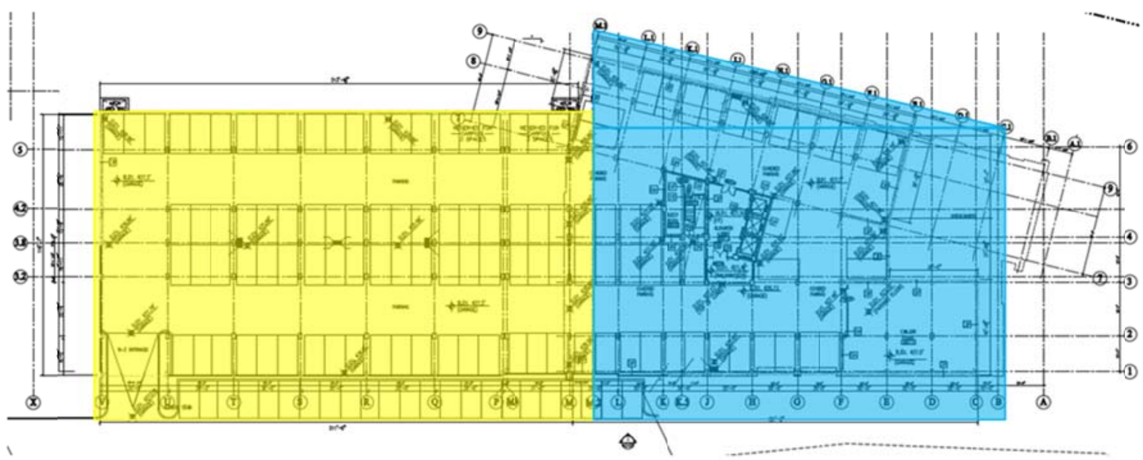


Figure 1: Overall Parking Floor Plan

Foundation

The foundation of the ASHA National Office building consists of a 5" thick reinforced concrete slab with strip footings around the perimeter of the building. There are also footings at the base of all concrete columns. The foundations for the building were designed in accordance with the recommendations included in the geotechnical report prepared by ESC Mid-Atlantic, LLC. See Figure 2: Partial Foundation Plan. The interior column footings are generally 6'x6' and range from 12" to 18" thick. See Figure 3: Column Footing Schedule.

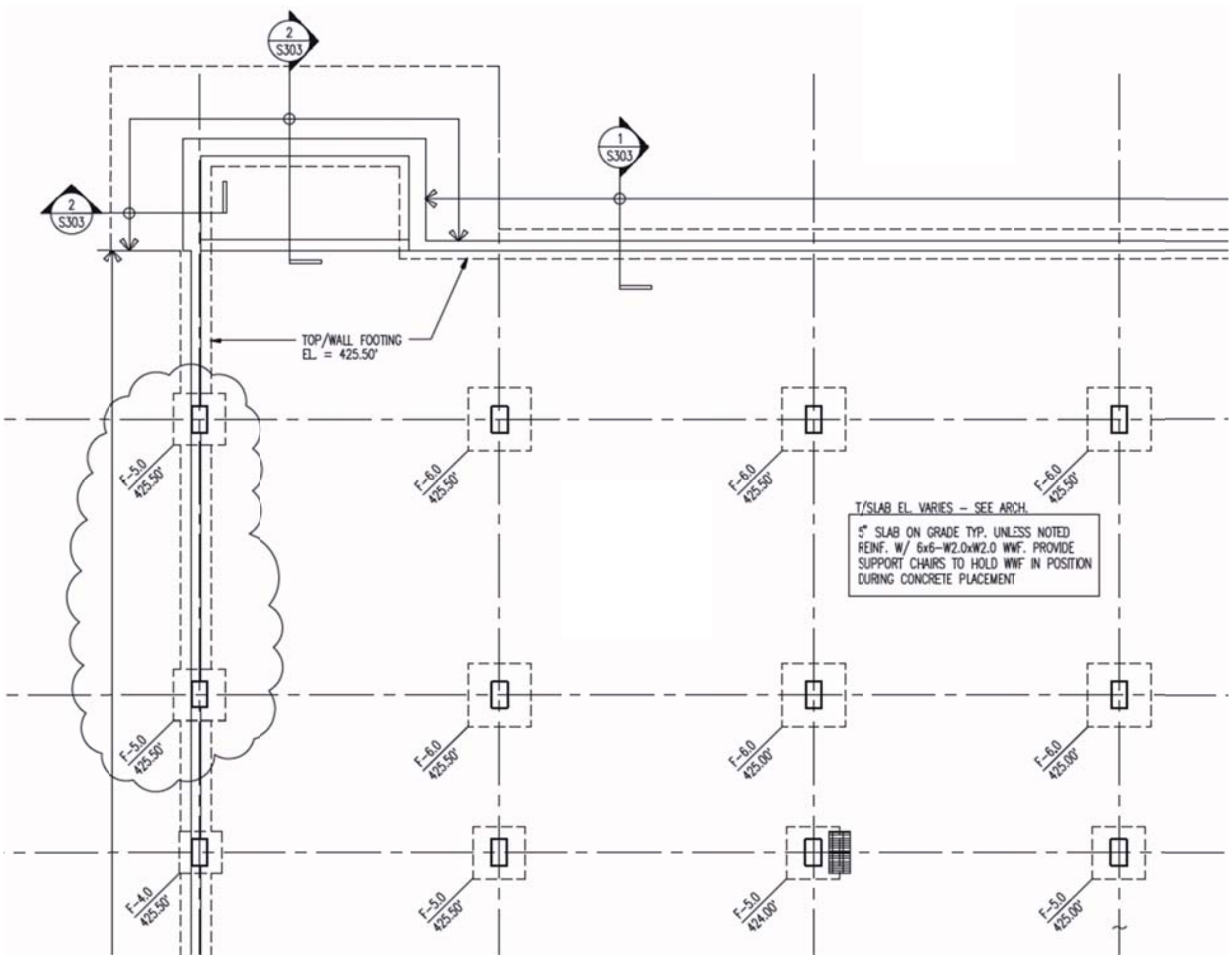
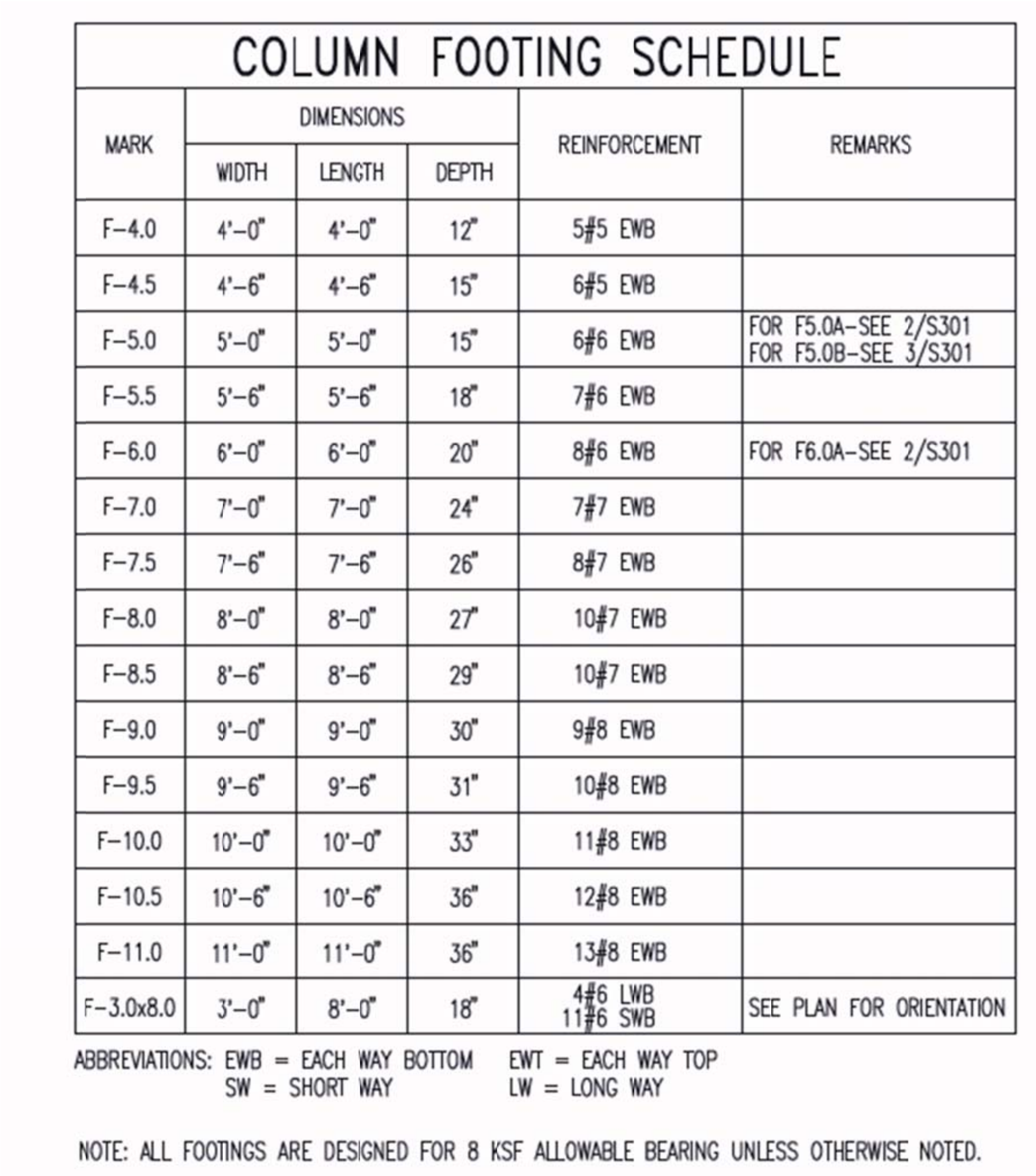


Figure 2: Partial Foundation Plan



COLUMN FOOTING SCHEDULE

MARK	DIMENSIONS			REINFORCEMENT	REMARKS
	WIDTH	LENGTH	DEPTH		
F-4.0	4'-0"	4'-0"	12"	5#5 EWB	
F-4.5	4'-6"	4'-6"	15"	6#5 EWB	
F-5.0	5'-0"	5'-0"	15"	6#6 EWB	FOR F5.0A-SEE 2/S301 FOR F5.0B-SEE 3/S301
F-5.5	5'-6"	5'-6"	18"	7#6 EWB	
F-6.0	6'-0"	6'-0"	20"	8#6 EWB	FOR F6.0A-SEE 2/S301
F-7.0	7'-0"	7'-0"	24"	7#7 EWB	
F-7.5	7'-6"	7'-6"	26"	8#7 EWB	
F-8.0	8'-0"	8'-0"	27"	10#7 EWB	
F-8.5	8'-6"	8'-6"	29"	10#7 EWB	
F-9.0	9'-0"	9'-0"	30"	9#8 EWB	
F-9.5	9'-6"	9'-6"	31"	10#8 EWB	
F-10.0	10'-0"	10'-0"	33"	11#8 EWB	
F-10.5	10'-6"	10'-6"	36"	12#8 EWB	
F-11.0	11'-0"	11'-0"	36"	13#8 EWB	
F-3.0x8.0	3'-0"	8'-0"	18"	4#6 LWB 11#6 SWB	SEE PLAN FOR ORIENTATION

ABBREVIATIONS: EWB = EACH WAY BOTTOM EWT = EACH WAY TOP
SW = SHORT WAY LW = LONG WAY

NOTE: ALL FOOTINGS ARE DESIGNED FOR 8 KSF ALLOWABLE BEARING UNLESS OTHERWISE NOTED.

Figure 3: Column Footing Schedule

<u>Floor Structure</u>

The parking structure is a two way reinforced concrete flat slab system that is comprised of a 9" thick slab and 5 ½" thick drop panels. Unless otherwise noted on the plans, the drop panels are 7'-0"x9'-0" and 10'-0"x10'-0". The bay sizes vary depending on the part of the building, but the typical span ranges from 20' to 40'. The bottom reinforcing mat consists of #5 bars at 12" or 14" each way. The top reinforcing bars vary depending on the location, but are typically #5, #6 or #7 bars. See Figure 4: Parking Level Framing Plan.

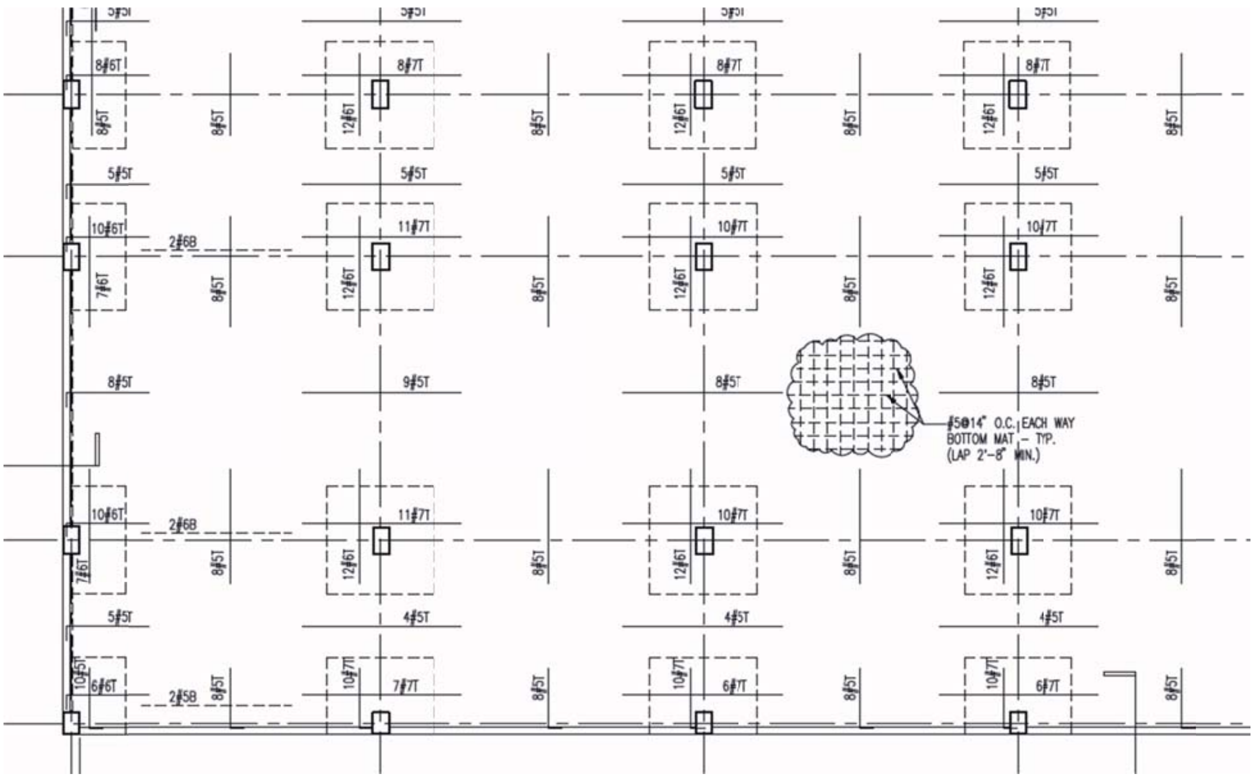
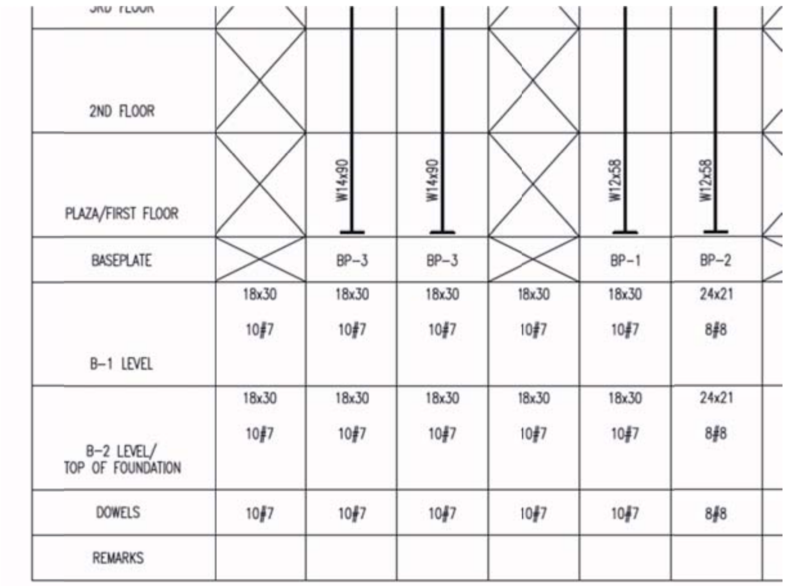


Figure 4: Parking Level Framing Plan

<u>Columns</u>

The concrete columns in the parking structure are generally 18”x30” with 10 #7 bars, and 24”x21” with 8 #8 bars. The columns have a minimum 28 day compressive strength of 4000 psi. See Figure 5: Partial Column Schedule. The concrete columns of the parking structure are connected to the steel columns in the office tower above with column base plates. See Figure 6: Baseplate Pocket Detail.



2ND FLOOR						
PLAZA/FIRST FLOOR		W14x90	W14x90		W12x58	W12x58
BASEPLATE		BP-3	BP-3		BP-1	BP-2
B-1 LEVEL	18x30 10#7	18x30 10#7	18x30 10#7	18x30 10#7	18x30 10#7	24x21 8#8
B-2 LEVEL/ TOP OF FOUNDATION	18x30 10#7	18x30 10#7	18x30 10#7	18x30 10#7	18x30 10#7	24x21 8#8
DOWELS	10#7	10#7	10#7	10#7	10#7	8#8
REMARKS						

Figure 5: Partial Column Schedule

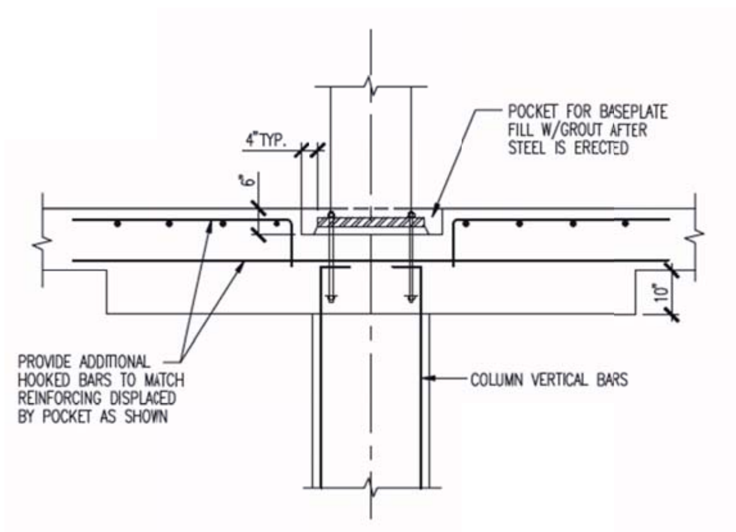


Figure 6: Baseplate Pocket Detail

Superstructure

A five story office tower is the superstructure of the ASHA National Office building. The first level has a large conference room that can be subdivided into five smaller conference rooms. The upper four floors are composed of offices in the central core of the building, and open office space with cubicles on the exterior of the building. There is a penthouse on top of the office tower that houses mechanical and elevator equipment.

Floor Structure

The floor structure for the tower consists of cambered steel beams with a composite concrete floor slab on metal deck. The composite slab consists of 3 ½” normal weight concrete on top of 2” deep 18 gauge galvanized composite steel deck. The composite beams are generally W21x44 and W14x22 members with ¾” diameter shear studs. The girders running along the exterior of the building vary in size, but are mostly W18x35’s. See Figure 7: Partial Framing Plan.

Figure 7: Partial Framing Plan

Columns

The columns for the office tower are steel wide flange shapes. The columns are all W12 and W14 members. The columns are spliced above level 3. The columns that extend to the penthouse roof are spliced again above level 5. See figure 8: Partial Column Schedule.

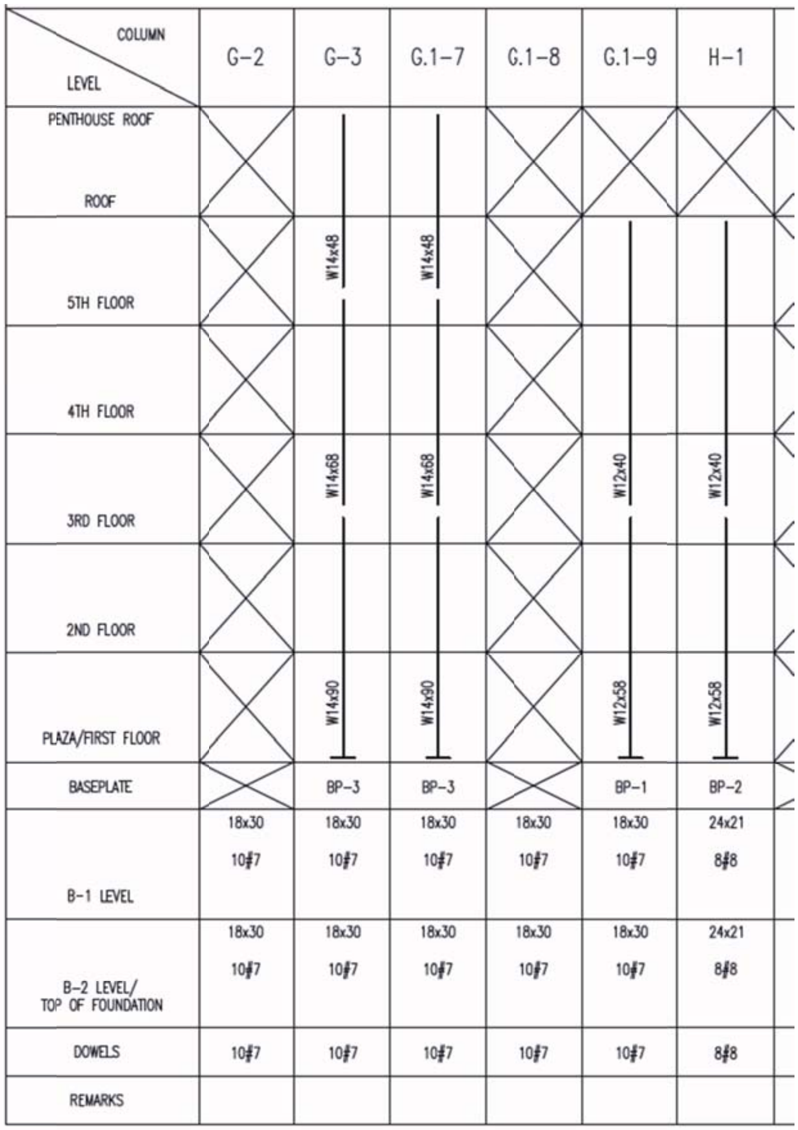


Figure 8: Partial Column Schedule

Roof System

The roof structure consists of K series open web joists and wide flange shapes. The structural roof slab consists of 3 ½” normal weight concrete on top of 2” deep 18 gauge composite steel deck. See Figure 9: Partial roof framing plan.

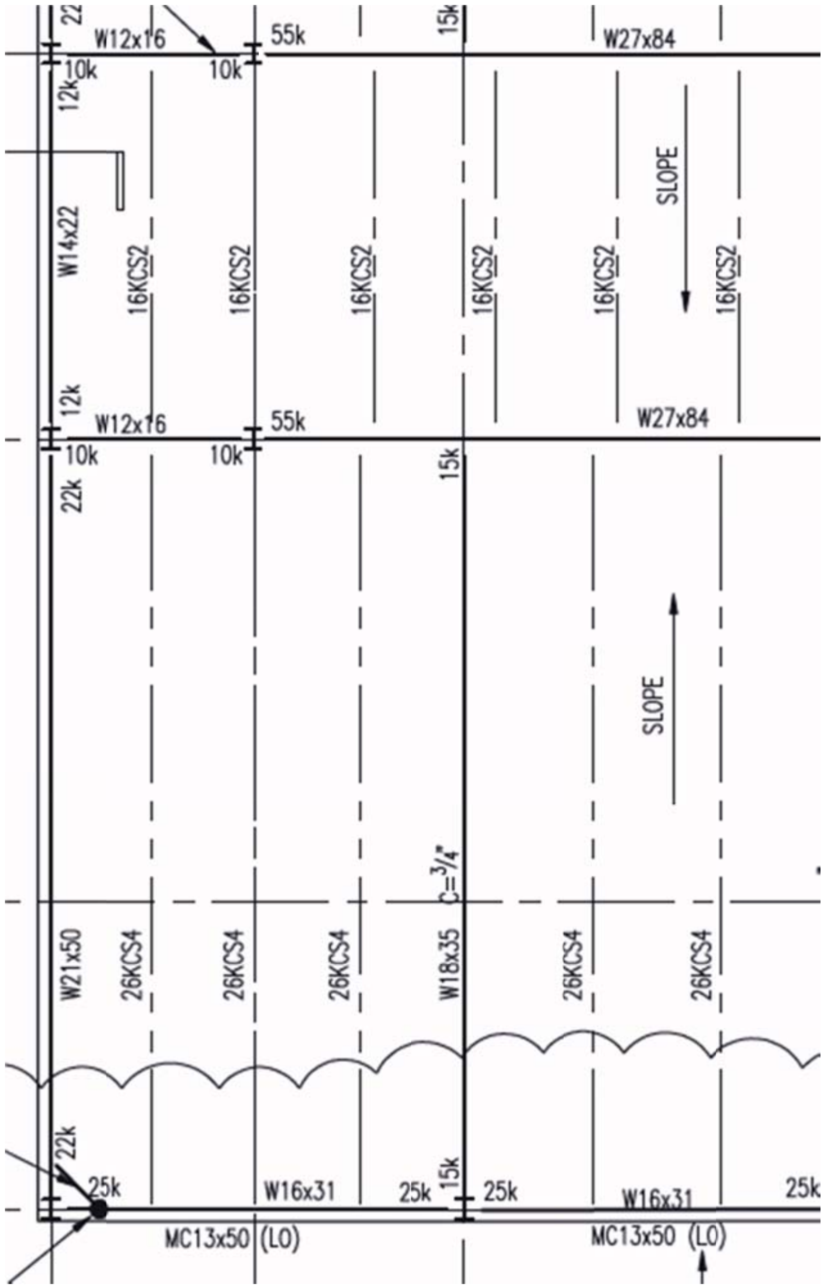


Figure 9: Partial Roof Framing Plan

Lateral System

The lateral force resisting elements in the ASHA National Office building consist of shear walls in the subgrade parking structure of the building and braced frames in the office tower. The shear walls below work in combination with the braced frames above to resist the lateral loads on the building. The wind loads are collected by the precast concrete spandrels that make up the façade of the building. These loads are then distributed to the composite floor slabs and beams which then are transmitted to the braced frames in the core of the building. These loads are then transfered to the shear walls below and to the footings at the base of the shear walls. See figure 10: Braced Frame and Shear Wall Elevation.

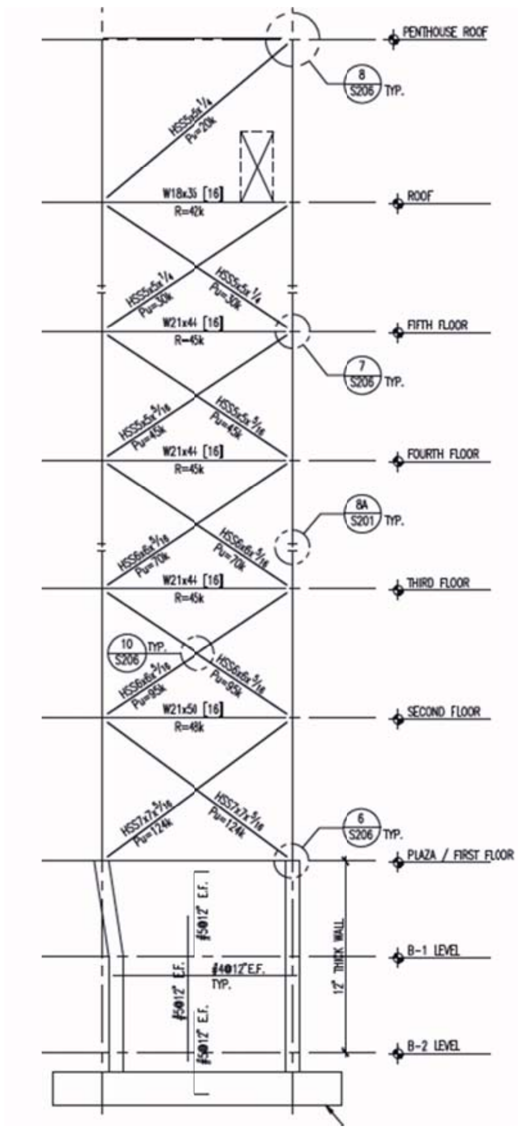


Figure 10: Braced Frame and Shear Wall Elevation

Codes and References

Design Codes and References

"The International Building Code – 2003", International Code Council.

"Minimum Design Loads for Buildings and Other Structures" (ASCE 7), American Society of Civil Engineers.

"Building Code Requirements for Structural Concrete, ACI 318-02", American Concrete Institute.

"ACI Manual of Concrete Practice – Parts 1 through 5", American Concrete Institute.

"Manual of Standard Practice", Concrete Reinforcing Steel Institute.

"Building Code Requirements for Masonry Structures (ACI 530, ASCE 5/ TMS 402)", American Concrete Institute, American Society of Civil Engineers, and The Masonry Society.

"Specifications for Masonry Structures (ACI 530.1/ASCE 6/TMS 602)", American Concrete Institute, American Society of Civil Engineers, and The Masonry Society.

"Manual of Steel Construction – Load and Resistance Factor Design", Third Edition, 2001, American Institute of Steel Construction (Including Specifications for Structural Steel Buildings, Specification for Structural Joints using ASTM A325 or A490 bolts, and AISC Code of Standard Practice.

"Detailing for Steel Construction", American Institute of Steel Construction.

"Structural Welding Code ANSI/AWS D1.1" American Welding Society.

"Design Manual for Floor Decks and Roof Decks", Steel Deck Institute.

"Standard Specifications for Open Web Steel Joists, K-Series", Steel Joist Institute.

"Standard Specifications for Longspan Steel Joists, LH-Series and Deep Longspan Steel Joists, DLH-Series", Steel Joist Institute.

Thesis Codes and References

Steel Construction Manual 13th edition, American Institute of Steel Construction (AISC).

Building Code Requirements for Structural Concrete, American Concrete Institute (ACI 318-08).

Minimum Design Loads for Buildings and Other Structures, American Society of Civil Engineers (ASCE 7-10).

PCI Design Handbook, Precast and Prestressed Concrete, 6th Edition.

RSMeans CostWorks. <www.meanscostworks.com>.

Material Properties

Minimum Concrete Compressive Strength (f'c)	
Member Type	28 Day Strength
Footings	3000 psi
Grade Beams	3000 psi
Foundation Walls	4000 psi
Shear Walls	4000 psi
Columns	4000 psi
Slabs-on-grade	3500 psi
Reinforced Slabs	5000 psi
Reinforced Beams	5000 psi
Parking Structure	5000 psi
Normal Weight on Steel Deck	3000 psi
Elevator Machine Room	4000 psi
Lightweight Topping	3000 psi

Reinforcement:

Deformed Reinforcing Bars	ASTM A615, Grade 60
Weldable Deformed Reinforcing Bars	ASTM A706
Welded Wire Reinforcement (WWF)	ASTM A185
Full Mechanical Connection Splices (Threadbar and Coupler)	Dywidag, Lenton or equal meeting ACI 318 Section 12.14.3
Adhesive Reinforcing Bar Dowels	Hilti HIT HY-150 System or equal
Slab Shear Reinforcement	Decon Studrails or equal

Steel:

Wide Flange Shapes and Tees	ASTM A992
Round Hollow Structural Shapes	ASTM A53, Grade B, Fy=35 ksi or ASTM A501, Fy=36 ksi
Square or Rectangular Hollow Structural Shapes	ASTM A500, Grade B, Fy=46 ksi
Base Plates and Rigid Frame Continuity Plates	ASTM A572, Grade 50
Other Structural Shapes and Plates	ASTM A36
High Strength Bolts	ASTM A325-N or ASTM F1852
Anchor Bolts	ASTM F1554, Grade 36
Galvanized Steel Floor Deck	ASTM A653 SS, Grade 33, G-60
Galvanized Steel Roof Deck	ASTM A653 SS, Grade 33, G-90
Grout	ASTM C1107, Non-Shrink, Non-Metallic f'c = 5000 psi

Gravity Loads

Live Loads		
Area	**Design Load**	**ASCE 7-10 Load**
Assembly Areas	100 psf	100 psf
Corridors	100 psf	100 psf
Corridors Above the First Floor	80 psf	80 psf
Mechanical Rooms	150 psf	-
Offices	80 + 20 psf	50 + 15 psf
Parking Garages	50 psf	40 psf
Stairs & Exitways	100 psf	100 psf
Storage (Light)	125 psf	125 psf
Roof (Minimum)	30 psf	20 psf

Snow Loads		
Load Type	**Design Load**	**ASCE 7-10 Load**
Flat Roof Snow Load p_f	21.0 psf	21.0 psf
Drift Surcharge Load p_d	-	55.5 psf

Superimposed Dead Loads	
Area	**Design Load**
Floors	10 psf
Roof	15 psf
Mech/Elec	15 psf

Composite Slab and Deck Weight			
Floor	**Area (sq. ft.)**	**Load (psf)**	**Weight**
2nd	24116	54	1302.3 k
3rd	24116	44	1061.1 k
4th	24116	44	1061.1 k
5th	23615	44	1039.1 k
Roof	23615	44	1039.1 k

Column Self Weight					
Floor	Height Below (ft)	Height Above (ft)	Weight Below (plf)	Weight Above (plf)	Total Weight
2nd	15	6.75	3097	3097	67.4 k
3rd	10.75	2.75	3097	2167	39.3 k
4th	6.75	6.75	2167	2167	29.3 k
5th	6.75	6.75	2167	2167	29.3 k
Roof	6.75	0	2167	0	14.6 k

Alternative Floor Systems

Four different floor systems were analyzed for this report. See Figure 11: Partial Typical Floor Plan. The strip highlighted in yellow between gridline H and G is the part of the floor plan that was analyzed for the floor systems. The interior bay was analyzed as a rectangular bay in order to simplify the calculations and computer modeling done in this report.

The following four systems were considered:

1. Composite Steel
2. One-Way Pan Joists and Beams
3. One-Way Slab and Beams
4. Precast Hollow Core Plank

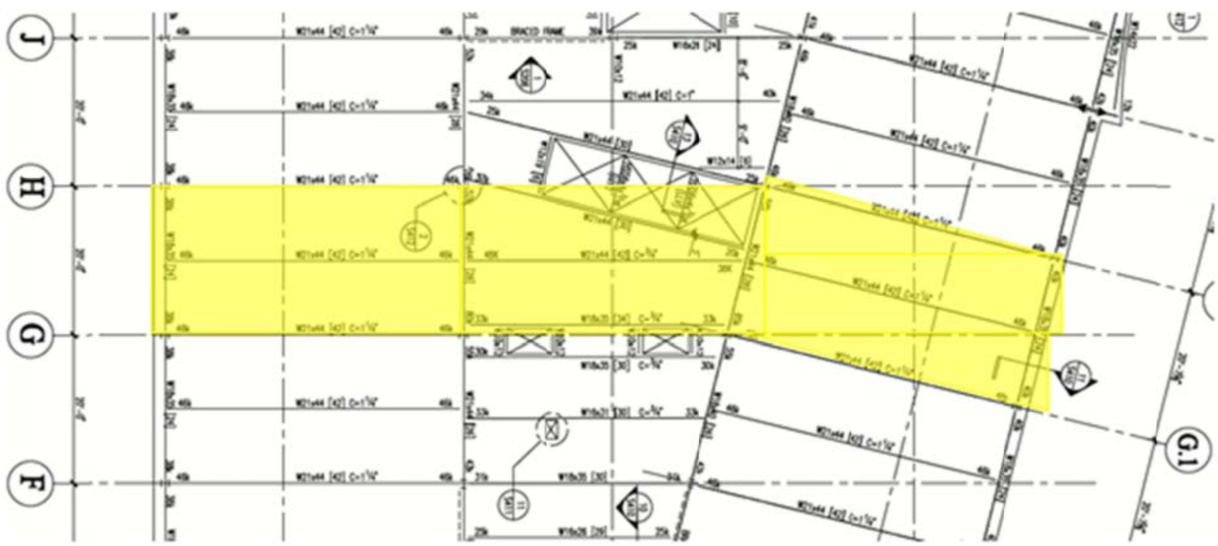


Figure 11: Partial Typical Floor Plan

Composite Steel

The current composite steel floor system was analyzed in order to compare it to the three alternative floor systems. The beams and girders were designed for the gravity loads using RAM Structural System. The member sizes determined are slightly smaller than the actual design. This is partially due to the fact that the live loads used for this report are less than that of the actual design. See Figure 12: RAM Structural System Composite Steel Design.

There are many advantages to a composite steel floor system, which is why it was chosen for the actual design of the building. One of those advantages is that constructing a composite steel floor system is efficient and very fast. Also, the floor structure is relatively light compared to the other alternative systems that are compared in this report. A composite steel floor system can span long distances due to the strength of the composite action of the steel beams. This is important for the ASHA National Office Building because the exterior spans are 40' long.

There are also disadvantages of a composite steel system. One of those disadvantages is that the system depth is larger than some of the other system options. The total depth of the actual design is over 26" deep, and the thesis design is over 23" deep. This depth reduces the floor to ceiling height of the stories. Also, fireproofing is required on the bottom of the floor deck and on the steel members. This requires extra labor and materials to achieve. The shear studs also have to be put welded onto the steel beams, which also requires more labor and materials.

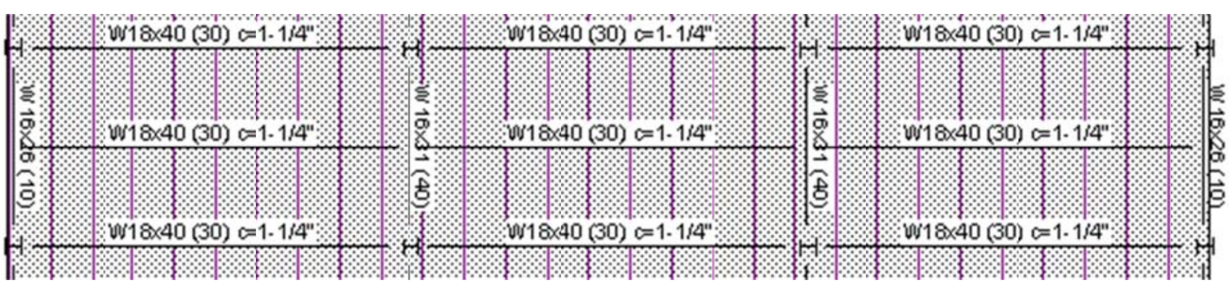


Figure 12: RAM Structural System Composite Steel Design

One-Way Pan Joists and Beams

The first alternative floor system considered is a one-way pan joist and beam system. Two variations of this system were analyzed. The first system analyzed is a one-way skip joist system in which the joists span the 20 foot direction. The other system analyzed is one that the joists span the 40 foot direction. Both of these were done in order to determine which direction the joists should span to be more efficient. Figure 13 shows the skip joists that span the 20 foot direction and Figure 14 shows the skip joists that span the 40 foot direction. Hand calculations were done to design the skip joists for both systems and the beams were designed using SP beam, and the top reinforcing at the interior support was checked by hand. Detailed calculations are shown in Appendix A for the one-way joist systems in both directions. Both systems have a 4 ½" slab to achieve a two hour fire rating. The skip joists that span 20 feet are 14" deep, which makes the beams 18.5" deep. The skip joists that span 40 feet are 20" deep with 24.5" deep beams. It was found that the system with the joists that span the 40' direction has a lower cost per square foot.

There are multiple advantages to a one-way pan joist and beam floor system. One is that the systems are relatively shallow compared to most of the other systems analyzed. The system with the joists that span the 20' direction has a total depth of 18.5". This is a reduction of 7.5" per floor compared to the actual design of the building. This can reduce the total height of the building, which will decrease the costs of the façade. Skip joists can span large spans efficiently. As seen in the cost analysis in Appendix B. The joist system in which the joists span the 40' direction costs less per square foot than the joist system in which the joists span the 20' direction.

The disadvantages of the one-way joist and beam system are also apparent. One of those disadvantages is the fact that the foundations will have to be redesigned for the higher dead loads due to the heavier concrete floor system. In addition, the 6' pan joists will not fit equally in the 20'x40' bays. This will require an adjustment of the size of the bays. Also, the interior core bays of the building vary greatly depending on the location in the floor plan. The pan forms will most likely have to be custom made for these bays, which drive the cost of the system up.

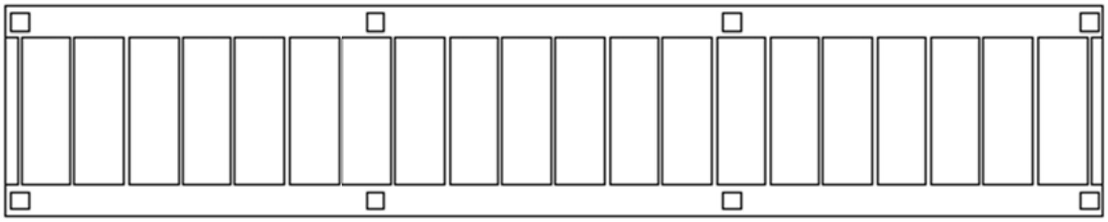


Figure 13: One-Way Pan Joist and Beam System (Joists Over 20' Span)

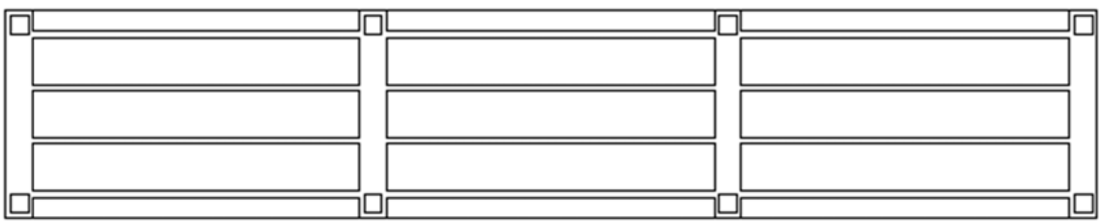


Figure 14: One-Way Pan Joist and Beam System (Joists Over 40' Span)

One-Way Slab and Beams

The second alternative system considered is a one-way slab and beam system shown in Figure 15. This system was considered because it is efficient for the large 40' spans of the building and allows for flat ceilings between beams. The slab spans the 20 foot direction and was designed to be 9" deep. The beam is 20" wide and 30" deep and the reinforcing was designed in SP Beam and spot checked by hand. The hand calculations and SP Beam output is shown in Appendix A. A post-tensioned one-way slab and beam system was also going to be analyzed, but time constraints and the lack of knowledge about this type of system prevented this. This type of system will be explored further in the future.

An advantage of a one-way slab and beam system is that it spans the 40' span with relative ease. Another advantage is that the system provides flat ceilings between the beams. This provides a lot of space in the ceiling for the mechanical equipment.

There are also disadvantages to this type of system. One is that complicated formwork is required. This requires a lot of materials and labor, and makes the system expensive and time consuming to construct. Another disadvantage is that the system is deep. The total floor system depth is 30 inches. This is 4" deeper per floor than the actual composite steel design. This system also requires the highest volume of concrete and the most steel reinforcement out of all of the systems investigated in this report. The one-way slab and beam system is the heaviest floor system, which means that the foundation sizes will have to be increased drastically to account for the higher dead loads.

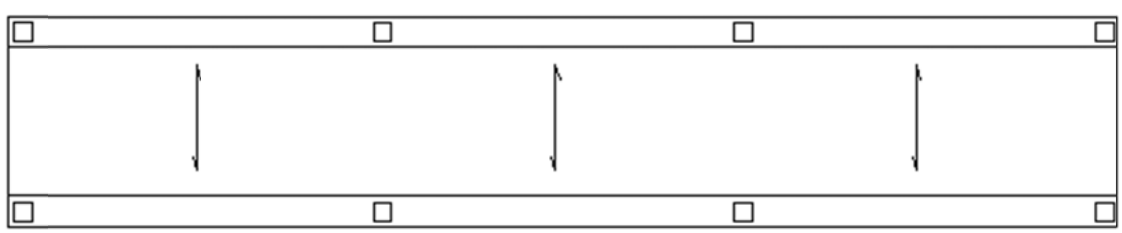


Figure 15: One-Way Slab and Beam System

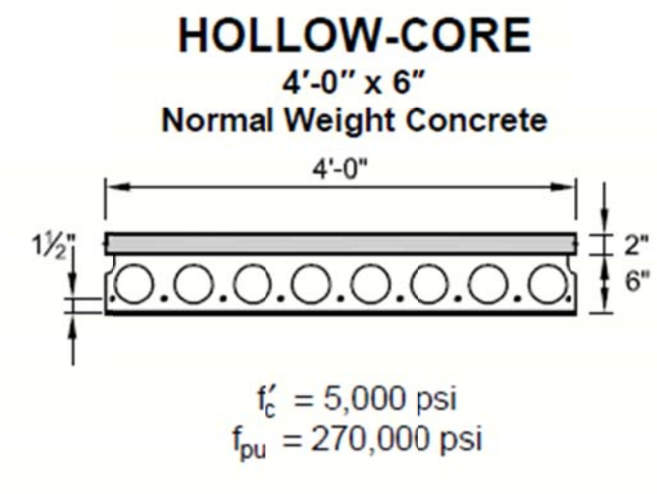
Precast Hollow Core Plank on Steel Beams

The final alternative considered for this report is a precast hollow core plank system supported by steel beams. This provides an alternative steel system that can be explored. As shown in Figure 16, the precast planks have to span the 20’ direction because the planks cannot support the large superimposed loads of the office floors for a 40’ span. The precast planks were designed using the design tables in the PCI Design Handbook, 6th Edition. It was determined that a 4HC6 plank shown in Figure 17 will be used with a 2” normal weight topping slab. The topping slab is incorporated to decrease the effect of the differential camber of the precast planks. The steel beams that support the precast plank were designed using RAM Structural system shown in Figure 16 below.

An advantage of a precast hollow core plank system is that it is a relatively light floor system compared to the concrete systems that were analyzed. In addition, the construction of the hollow core planks is very fast and efficient.

A disadvantage of this system is that it has the highest cost per square foot. This is due to the fact that the steel beams that support the precast planks must be very large to support the loads and meet the deflection requirements. In addition, the precast planks are expensive compared to the price of a composite deck. This system also has the largest total depth out of the systems that were compared with a total depth of 33 inches.

Figure 16: Ram Structural System Precast Plank Steel Beam Design



Section Properties

	Untopped		Topped	
A =	187	in.^{2}	283	in.^{2}
I =	763	in.^{4}	1,640	in.^{4}
y_b =	3.00	in.	4.14	in.
y_t =	3.00	in.	3.86	in.
S_b =	254	in.^{3}	396	in.^{3}
S_t =	254	in.^{3}	425	in.^{3}
wt =	195	plf	295	plf
DL =	49	psf	74	psf
V/S =	1.73	in.		

Figure 17: PCI Design Handbook: Hollow Core Plank

Floor System Comparison Chart					
Item	**Composite Beam (Existing)**	**One-Way Joist and Beams (Joists Span 20')**	**One-Way Joist and Beams (Joists Span 40')**	**One-Way Slab and Beams**	**Precast Hollow Core Plank**
Weight	65 psf	101 psf	105 psf	134 psf	82 psf
Slab Depth	5.5 in.	4.5 in.	4.5 in.	9 in.	6 in.
Depth of System	23.5 in.	18.5 in.	24.5 in.	30 in.	33 in.
Fire Rating	1 hr. with spray fireproofing	2 hr.	2 hr.	2 hr.	1 hr. with spray fireproofing
Impact on Foundations	No Change	Increase Necessary	Increase Necessary	Increase Necessary	Increase Necessary
Deflection Criteria	Okay	Okay	Okay	Okay	Okay
Vibration Criteria	Further Investigate	Further Investigate	Further Investigate	Further Investigate	Further Investigate
Architectural Criteria (Bay Sizes Unchanged?)	Yes	Yes	Yes	Yes	Yes
Lateral System	No Change	Shear Walls	Shear Walls	Shear Walls	No Change
Construction Process	Efficient Construction	Longer Construction Process	Longer Construction Process	Longer Construction Process	Long Lead Time, Efficient Construction
Cost Per Square Foot	$18.71/sq. ft.	$22.36/sq. ft.	$21.23/sq. ft.	$22.98/sq. ft.	$24.28/sq. ft.
Viable System?	Yes	Yes	Yes	Yes	No

Conclusions

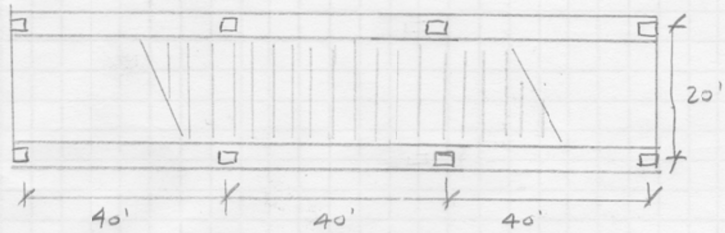
This report explores alternative floor systems for the ASHA National Office building. The four systems that were analyzed include composite steel, one-way pan joist and beams, one-way flat slab and beams, and a hollow precast plank system supported by steel beams. It was determined that the current composite steel floor system is the best option for the building. This is due to the low cost, light weight and constructability of the system. Other viable alternative systems were found to be the one-way pan joist and beam system and the one-way slab and beam system. A reason why both of these systems would be feasible is that the subgrade parking structure has a two-way flat slab floor system with drop panels. It is not practical to continue this system into the office tower due to the 40' spans, so using a one-way slab and beam system or a pan-joist system would be a good way to use reinforced concrete for the entire building. These two systems cost more per square foot than the current system, but minimizing the number of trades on the project by using concrete for the office tower would save money and time. The pan joist system would be a good alternative because it has a total floor system depth of 18.5 inches. The one-way slab and beam system allows for flat ceilings between beams, which provide space for the terminal mechanical units above the ceiling. A post-tensioned flat slab and beam system will also be in future reports.

The systems that will be investigated further include the composite beam system, the one-way pan joist system, and the one-way slab and beam system. The only system that will not be considered further is the precast hollow core plank system. This is due to the high cost and the large total depth of the floor system. In addition, the precast planks would not be practical due to the irregular bays in the interior core of the building. The remaining systems will be examined for vibration criteria, impact on the foundations, and the impact on the lateral system.

Appendix A: Floor System Calculations

Tech Report II | One way pan joists and beams | 10/20/10

Joists over 20' span



SDL = 25 psf

LL = 80 psf

$f'_c = 4$ ksi

$f_y = 60$ ksi

Assume $4\frac{1}{2}$" slab

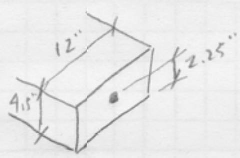
2-hr fire rating

min slab reinf / ft = $0.0018 A_g = 0.0018 \cdot 4.5 \cdot 12 = 0.097 \text{ in}^2$
Shrinkage & temp

#3 $A_s = 0.11 \text{ in}^2$

max spacing = $3t = 3 \cdot 4.5 = 13.5$ in

Try #3 bars @ 12" $A_s = 0.11 \text{ in}^2$



$$a = \frac{A_s f_y}{0.85 f'_c b} = \frac{0.11 \cdot 60}{0.85 \cdot 4 \cdot 12} = 0.16 \text{ in}$$

$$c = \frac{0.16}{0.85} = 0.19 \text{ in} < 0.375d = 0.375 \cdot 2.25 = 0.84 \text{ in}$$

$\therefore \varepsilon_t > 0.005 \quad \phi = 0.9$

$$\phi M_n = 0.9 \cdot 0.11 \cdot 60 \left(2.25 - \frac{0.16}{2}\right) = 12.9^{\text{"k}} = 1.07^{\text{'k}}$$

$$w_u = 1.2\left(25 \cdot 1 + 150 \cdot \frac{4.5}{12} \cdot 1\right) + 1.6 \cdot 80 = 226 \ \frac{\text{lb}}{\text{ft}} = 0.226 \ \frac{\text{k}}{\text{ft}}$$

$$M_u = \frac{0.226 \cdot 6^2}{8} = 1.02^{\text{'k}} < \phi M_n = 1.07^{\text{'k}} \quad \therefore \text{okay}$$

Pan Joist loading

Slab = $150 \cdot \frac{4.5}{12} = 56$ psf $\quad (56+25)\frac{\text{lb}}{\text{ft}^2} \cdot 6 \text{ ft} = 486 \ \frac{\text{lb}}{\text{ft}}$

SDL = 25 psf

PJ self wt = $150 \cdot \frac{6}{12} \cdot \frac{14}{12} = 87.5$ lb/ft

LL = 80 psf

$l_n/21 = 20/21 = 0.95'$

Try 14" pans

Try 66/6 skip joists

$$w_u = 1.2(486 + 87.5) + 1.6(80 \cdot 6) = 1456 \ \frac{\text{lb}}{\text{ft}} = 1.456 \ \frac{\text{k}}{\text{ft}}$$

Tech Report II | One way Pan Joists and beams | 10/20/10

max neg. moment $= w_u l_n^2/10 = 1.456 \cdot 17^2/10 = 42.1^{\text{'k}}$

max pos moment $= w_u l_n^2/14 = 1.456 \cdot 17^2/14 = 30.1^{\text{'k}}$

TOP REINF

$\dfrac{42.1}{4 \cdot 16} = 0.66 \text{ in}^2$ Try 3 #5 $A_s = 3 \cdot 0.31 = 0.93 \text{ in}^2$

$a = \dfrac{A_s f_y}{0.85 f'_c b} = \dfrac{0.93 \cdot 60}{0.85 \cdot 4 \cdot 6} = 2.74 \text{ in}$

$c = \dfrac{2.74}{0.85} = 3.22 \text{ in} < 0.375\, d = 0.375 \cdot 16.25 = 6.09 \text{ in}$

$\therefore \varepsilon_t > 0.005$ $d = 18.5 - 2.25 = 16.25 \text{ in}$

$\phi = 0.9$

$\phi M_n = 0.9 \cdot 0.93 \cdot 60 \left(16.25 - \dfrac{2.74}{2}\right) = 830.3^{\text{''k}} = 69.2^{\text{'k}} > M_u = 42.1^{\text{'k}}$

$\therefore$ OKAY

BOTTOM REINF

Try 1 #7 $A_s = 0.60 \text{ in}^2$

$\dfrac{30.1}{4 \cdot 16} = 0.470$

$b = \begin{cases} 0.25 \cdot 20 \cdot 12 = \underline{60 \text{ in}} \\ \min \begin{cases} 8 \cdot 4.5 = 36 \text{ in} \\ \tfrac{1}{2} \cdot 5.5 \cdot 12 = 33 \text{ in} \end{cases} + \min \begin{cases} 36 \text{ in} \\ 33 \text{ in} \end{cases} + 6 = 66'' \end{cases}$

$a = \dfrac{0.60 \cdot 60}{0.85 \cdot 4 \cdot 66} = 0.16 \text{ in}$ $\phi M_n = 0.9 \cdot 0.6 \cdot 60 \left(16 - \dfrac{0.16}{2}\right)/12$

$\phi M_n = 43.0^{\text{'k}} > M_u = 30.1^{\text{'k}}$ $\therefore$ OKAY

Shear Reinf

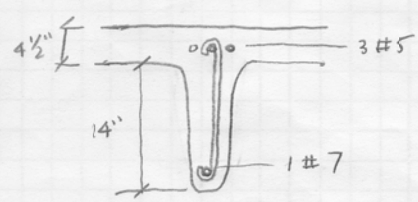
$V_u = \dfrac{w_u l_n}{2} = \dfrac{1.456 \cdot 17}{2} = 12.4 \text{ k}$

$V_c = 2\sqrt{4000} \cdot 6 \cdot 16/1000 = 12.1 \text{ k}$

$\phi V_n = \tfrac{1}{2} \phi V_c = \tfrac{1}{2} \cdot 0.75 \cdot 12.1 = 4.54 \text{ k}$

Try #3 bars $A_v = 0.11 \text{ in}^2$

min spacing $= d/2 = 16/2 = 8''$

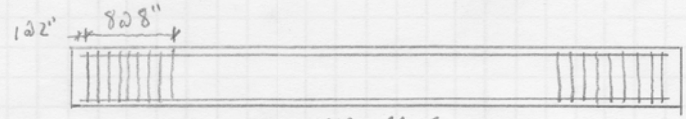


$V_s = \dfrac{0.11 \cdot 60 \cdot 16}{8} = 13.2 < 4\sqrt{4000} \cdot 6 \cdot 16/1000 = 24.3 \text{ k}$ $\therefore$ OKAY for $d/2$ spacing

$\phi V_{n\,min} = 0.75\,(12.1 + 13.2) = 19.0 \text{ k} > V_u = 12.4 \text{ k}$ $\therefore$ MIN REINF IS SUFFICIENT

$4.54 = 12.4 - 1.456\, x$ $x = 5.4' = 65''$

Tech Report II | One Way Pan Joists + Beams | 10/21/10



JOIST SHEAR REINF
#3 BARS

Girder Design

Try 18.5" x 40" girder

SDL = 25 psf

LL = 80 psf

Slab = $150 \cdot \frac{4.5}{12} = 56$ psf

joists = $150 \cdot 6/12 \cdot 14/12 \div 6 = 14.6$ psf

girder = $150 \cdot 40/12 \cdot 14/12 = 583.3$ lb/ft

$w_u = [1.2(25 \cdot 20 + 56 \cdot 20 + 14.6 \cdot 16.67 + 583.3) + 1.6(80 \cdot 20)]/1000$

$w_u = 5.49$ k/ft

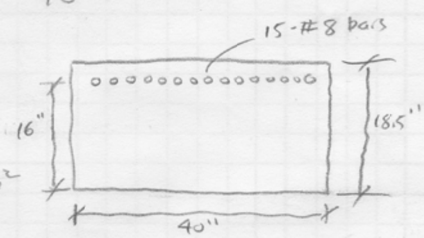
USED SP BEAM to design reinforcement

verify top reinf at first interior support by hand

$M_u = -797.6^{\prime k}$ (FROM SP BEAM)

M_u at face $= \frac{5.49 \cdot 1}{2}(40 - 1) + \frac{644 - 797.6}{40} \cdot 1 - 797.6^{\prime k}$

M_u at face $= -694^{\prime k}$



$\frac{694}{4 \cdot 16} = 10.84$ in^2

Try 15-#8 $A_s = 15 \cdot 0.79 = 11.85$ in^2

$a = \frac{11.85 \cdot 60}{0.85 \cdot 4 \cdot 40} = 5.22$ in $\quad c = \frac{5.22}{0.85} = 6.14"$ $\quad \varepsilon_t = \frac{0.003}{6.14}(16 - 6.14) = 0.0048$

$\phi = 0.48 + 83 \cdot 0.0048 = 0.88$

$\phi M_n = 0.88 \cdot 11.85 \cdot 60(16 - 5.22/2)/12 = 698.2^{\prime k} > M_u = 694^{\prime k}$

$\therefore$ OKAY

SP BEAM DESIGN OKAY

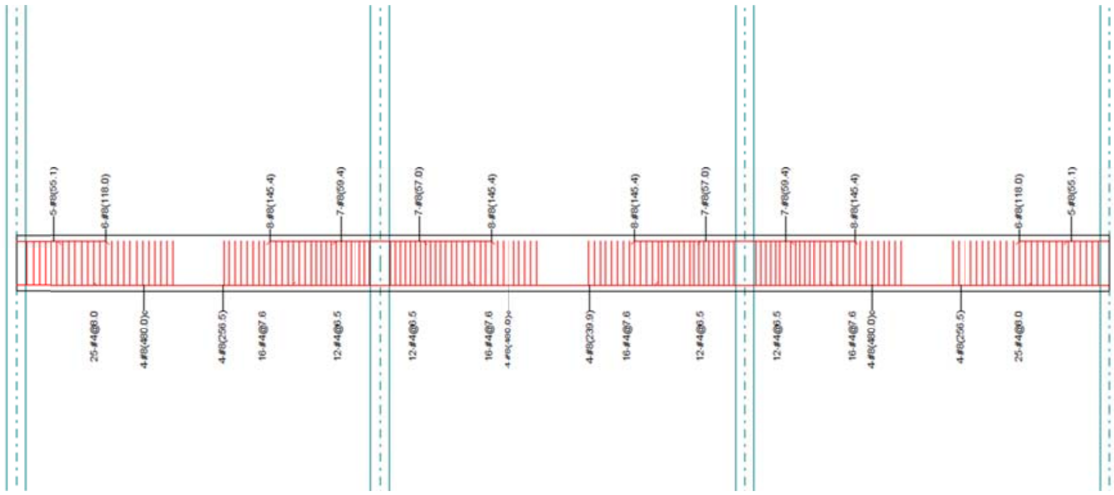


Figure 18: SP Beam Reinforcement Output (40' Beam Spans)

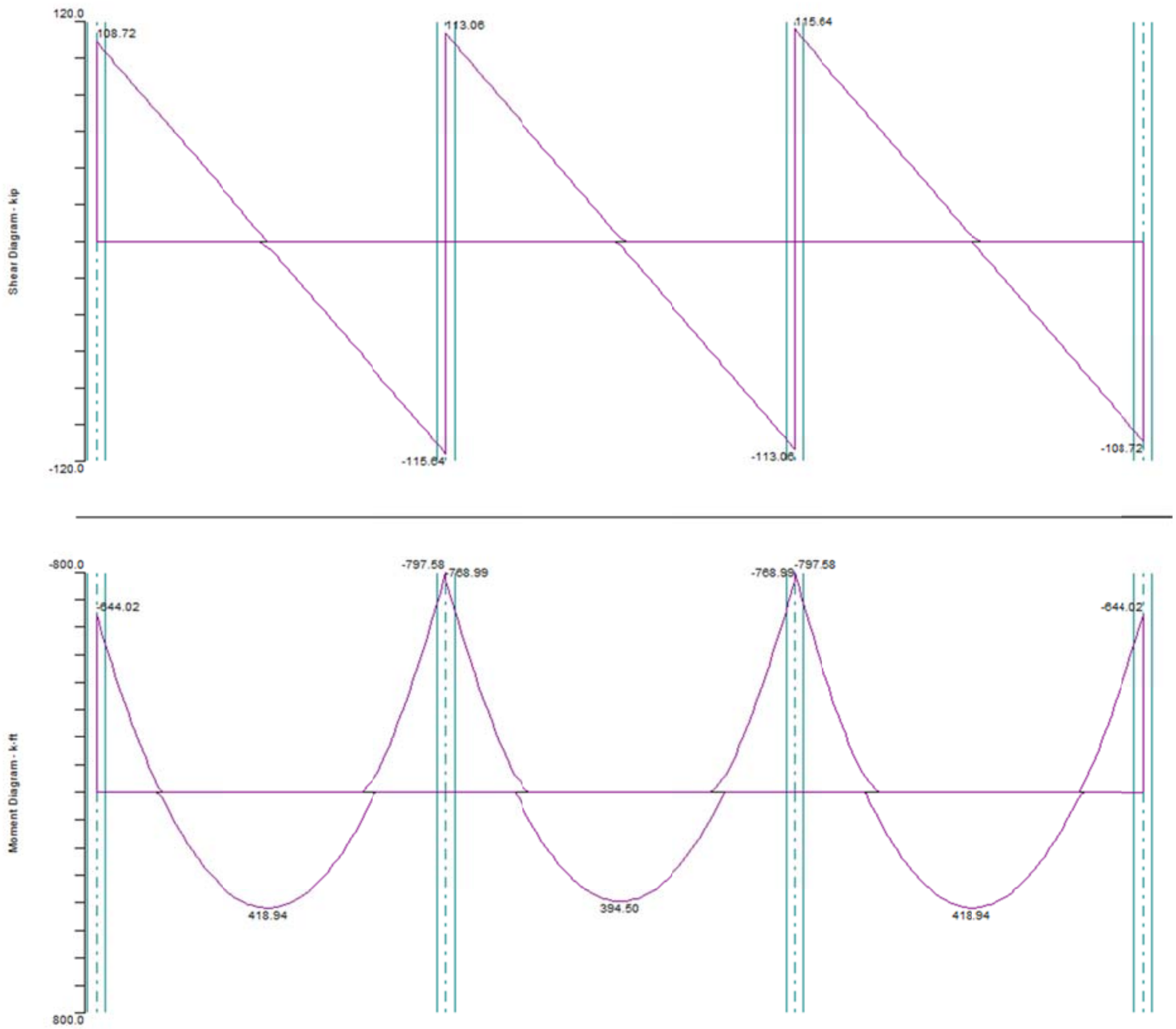
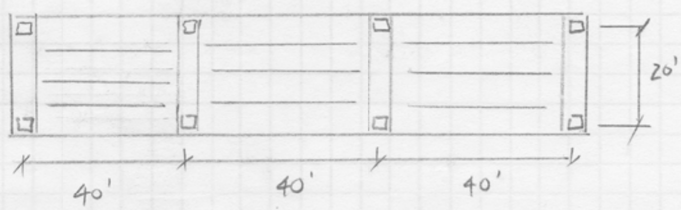


Figure 19: SP Beam Shear and Moment Diagrams (40' Beam Spans)

Tech Report II | One Way Pan Joists and Beams | 10/21/10

JOISTS OVER 40' SPAN



SDL = 25 psf

LL = 80 psf

$f'_c = 4$ ksi

$f_y = 60$ ksi

SLAB CALCULATIONS PREVIOUSLY DONE

USE 4½" SLAB WITH # 3 BARS @ 12" O.C.

Pan Joist Loading

Slab = 56 psf
SDL = 25 psf

$(56+25)\cdot 6 = 486 \frac{lb}{ft}$

$l_n/21 = 1.9'$

Try 20" pans

Try 66/8 skip joists

$w_u = 1.2\left(486 + 150\cdot\frac{6}{12}\cdot\frac{20}{12}\right) + 1.6\cdot 80\cdot 6 = 1.50\ k/ft$

Max neg moment = 200 ᴵᵏ
Max pos moment = 102 ᴵᵏ

(RESULTS FROM SPBEAM ATTACHED)

TOP REINF

$\frac{200}{4\cdot 22} = 2.28\ in^2$

Try 3 # 7

$A_s = 3\cdot 0.79 = 2.37\ in^2$

$a = \frac{2.37\cdot 60}{0.85\cdot 4\cdot 6} = 6.97\ in$

$c = \frac{6.97}{0.85} = 8.2\ in < 0.375d = 0.375\cdot 22 = 8.25\ in$

$\therefore \varepsilon_t > 0.005 \quad \phi = 0.9$

$\phi M_n = 0.9\cdot 2.37\cdot 60\left(22.25 - \frac{6.97}{2}\right)/12 = 200.2^{1k} > 200^{1k}$

$\therefore$ OKAY

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Advisor: Dr. Thomas Boothby

Tech Report II | One way pan joists + beams | 10/21/10

Bottom Reinf

$\frac{102}{4 \cdot 22} = 1.16 \text{ in}^2$

Try 1 #10
$A_s = 1.27 \text{ in}^2$

$b_{min} = \begin{cases} 0.25 \cdot 40 \cdot 12 = 120 \text{ in} \\ \min \begin{cases} 8 \cdot 4.5 = 36 \text{ in} \\ \frac{1}{2} \cdot 5.5 \cdot 12 = 33 \text{ in} \end{cases} + \min \begin{cases} 36 \\ 33 \end{cases} + 6 = 72'' \end{cases}$

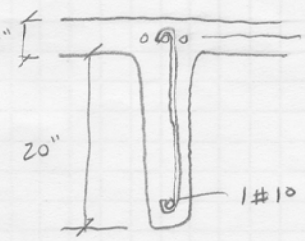
$a = \frac{1.27 \cdot 60}{0.85 \cdot 4 \cdot 72} = 0.31 \text{ in}$

$\phi M_n = 0.9 \cdot 1.27 \cdot 60 \left(22 - \frac{0.31}{2}\right)/12 = 125^{'k} > M_u = 102^{'k}$
$\therefore$ OKAY

SHEAR REINF

$V_u = \frac{w_u l_n}{2} = \frac{1.50 \cdot 38}{2} = 28.5 \text{ k}$

$V_c = 2\sqrt{4000} \cdot 6 \cdot 22/1000 = 16.7 \text{ k}$



$\phi V_n = \frac{1}{2} \phi V_c = \frac{1}{2} \cdot 0.75 \cdot 16.7 = 6.26 \text{ k}$

Try #3 bars $A_v = 0.11 \text{ in}^2$

min spacing $= d/2 = \frac{22}{2} = 11$ in

Try 6" spacing

$V_s = \frac{0.11 \cdot 60 \cdot 22}{6} = 24.2 \text{ k} < 4\sqrt{4000} \cdot 6 \cdot 22/1000 = 33.4 \quad \therefore$ OKAY

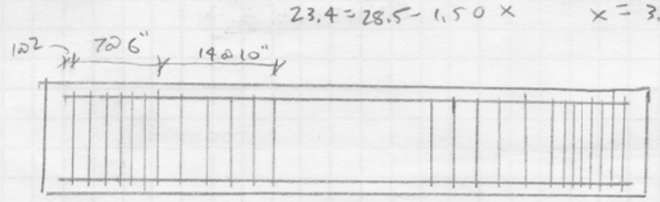
$\phi V_n = 0.75\,(24.2 + 16.7) = 30.7 \text{ k} > V_u = 28.5 \text{ k}$

$6.26 = 28.5 - 1.50x \qquad x = 14.82' = 178''$

Reduce to 10" spacing

$V_s = \frac{0.11 \cdot 60 \cdot 22}{10} = 14.5 \text{ k} \qquad \phi V_n = 0.75\,(14.5 + 16.7) = 23.4 \text{ k}$

$23.4 = 28.5 - 1.50x \qquad x = 3.4' = 40.8''$



JOIST SHEAR REINF
#3 BARS

Tech Report II | One way pan joists and Beams | 10/21/10

Girder Design

Try 24.5" × 24" girder

SDL = 25 psf

LL = 80 psf

slab = 56 psf

joists = $150 \cdot 6/12 \cdot 20/12 \div 6 = 20.83$ psf

girder = $150 \cdot \frac{24.5 \cdot 24}{12 \cdot 12} = 612.5$ lb/ft

$w_u = \left[1.2\left(25 \cdot 40 + 56 \cdot 40 + 20.83 \cdot 38 + 612.5\right) + 1.6 \cdot 80 \cdot 40\right]/1000$

$w_u = 10.7$ k/ft

USED SPBEAM TO DESIGN REINFORCEMENT

$M_u = 281^{1k}$ at exterior support

M_u at face $= \frac{10.7 \cdot 1}{2}(20 - 1) - 281$

M_u at face $= 174^{1k}$

$\frac{174}{4 \cdot 22} = 1.98$ in^2

Try 7 # 5 $A_s = 5 \cdot 0.31 = 2.17$ in^2

$a = \frac{2.17 \cdot 60}{0.85 \cdot 4 \cdot 24} = 1.60$ in $c = \frac{1.60}{0.85} = 1.88$ in^2 $< 0.375d$
$= 0.375 \cdot 22$
$= 8.25"$
$\therefore \varepsilon_t > 0.005$ $\phi = 0.9$

$\phi M_n = 0.9 \cdot 2.17 \cdot 60 \left(22 - \frac{1.60}{2}\right)/12$

$\phi M_n = 207^{1k} > M_u = 174^{1k}$ ∴ SP BEAM DESIGN OKAY

Ryan Dalrymple – Structures Option
Advisor: Dr. Thomas Boothby

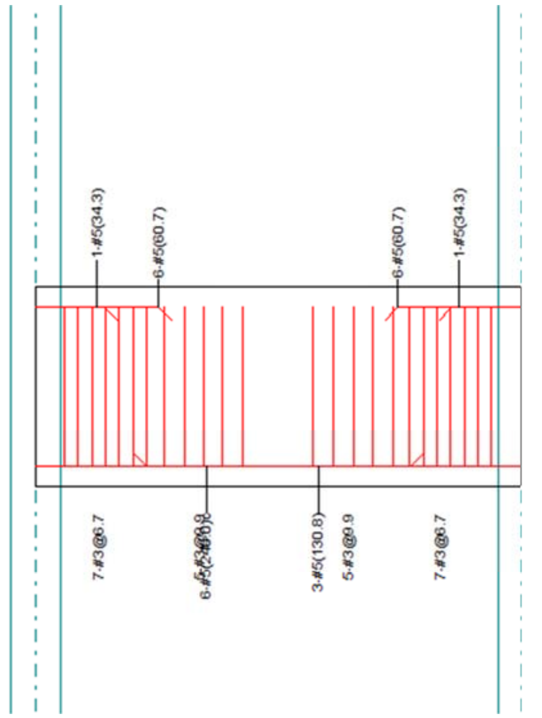


Figure 19: SP Beam Reinforcement Output (20’ Beam Span)

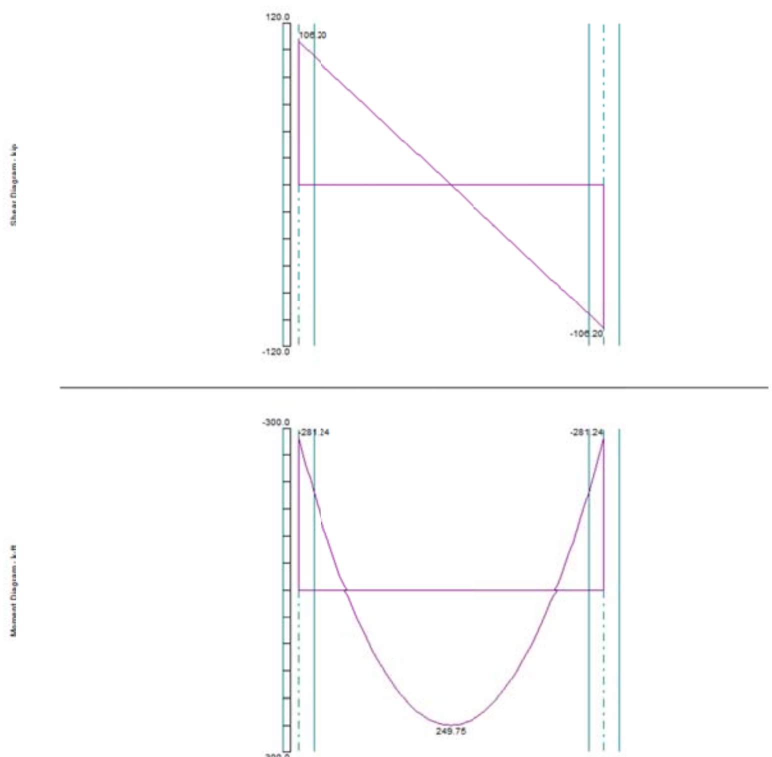
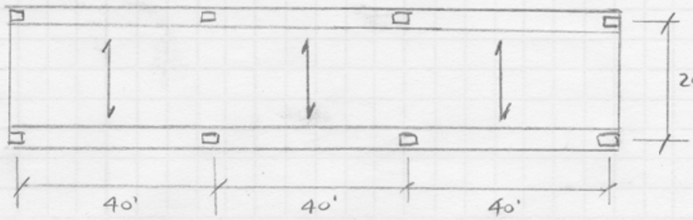


Figure 20: SP Beam Shear and Moment Diagrams (20’ Beam Span)

Tech Report II | One-Way Slab and Beams | 10/21/10



SDL = 25 psf

LL = 80 psf

$f'_c = 4$ ksi

$f_y = 60$ ksi

$l/28 = 0.714' = 8.57" \approx 9"$

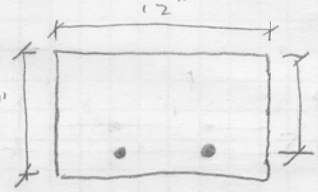
$A_{s\,min} = 0.0018 \cdot 12 \cdot 6 = 0.13\ in^2$

Try 9" Slab

$w_u = [1.2(25 \cdot 1 + 150 \cdot 9/12 \cdot 1) + 1.6 \cdot 80]/1000 = 0.339\ ^{k}/_{ft}$

$M_u = \dfrac{0.339 \cdot 20^2}{8} = 16.95^{1k}$

$\dfrac{16.95}{4 \cdot 7.94} = 0.53\ in^2$



$d = 9 - 3/4 - 1/2 \cdot 5/8 = 7.94$

Try #5 bars @ 6"

$A_s = 2 \cdot 0.31 = 0.62\ in^2$

$a = \dfrac{0.62 \cdot 60}{0.85 \cdot 4 \cdot 12} = 0.912$ in

$c = \dfrac{0.912}{0.85} = 1.07_{in} < 0.375d = 0.375 \cdot 7.94 = 2.98$

$\therefore \varepsilon_t > 0.005$

$\phi = 0.9$

$\phi M_n = 0.9 \cdot 0.62 \cdot 60 \left(7.94 - \dfrac{0.91}{2}\right)/12$

$\phi M_n = 20.9^{1k} > M_u = 16.95^{1k}$ $\therefore$ OKAY

Girder Design

SDL = 25 psf

LL = 80 psf

Slab = $150 \cdot 9/12 = 112.5$ psf

Try 24 x 36 girder

girder = $150 \cdot 20/12 \cdot 30/12 = 625\ ^{lb}/_{ft}$

$w_u = [1.2(25 \cdot 20 + 112.5 \cdot 20 + 625) + 1.6(80 \cdot 20)]/1000 = 6.61\ ^{k}/_{ft}$

Tech Report II | One Way Slab and Beams | 10/21/10

USED SPBEAM TO DESIGN REINFORCEMENT

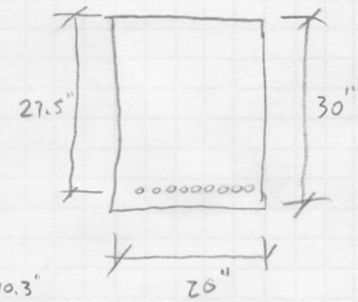
VERIFY TOP REINF AT INTERIOR SUPPORT BY HAND

$M_u = -973.6^{\,\prime k}$

$M_u \text{ at face} = \frac{6.61 \cdot 1}{2}(40 - 1) + \frac{597.2 - 973.6}{40} \cdot 1 - 973.6$

$M_u \text{ at face} = -854^{\,\prime k}$

$\frac{854}{4 \cdot 27.5} = 7.76 \text{ in}^2$



Try 10-#8 $A_s = 10 \cdot 0.79 = 7.90 \text{ in}^2$

$a = \frac{7.90 \cdot 60}{0.85 \cdot 4 \cdot 20} = 6.97 \text{ in}$

$c = \frac{6.97}{0.85} = 8.2 \text{ in} < 0.375d = 0.375 \cdot 27.5 = 10.3"$

$\therefore \varepsilon_t > 0.005 \quad \phi = 0.9$

$\phi M_n = 0.9 \cdot 7.90 \cdot 60\left(27.5 - \frac{6.97}{2}\right)/12 = 854^{\,\prime k} = M_u = 854^{\,\prime k}$

$\therefore$ OKAY

SPBEAM DESIGN OKAY

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Advisor: Dr. Thomas Boothby

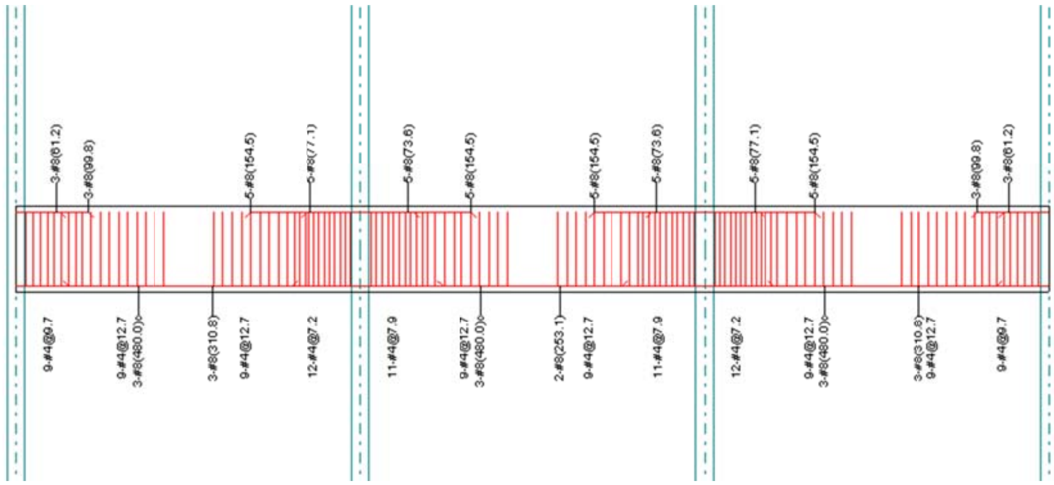


Figure 21: SP Beam Reinforcement Output (40’ Beam Spans)

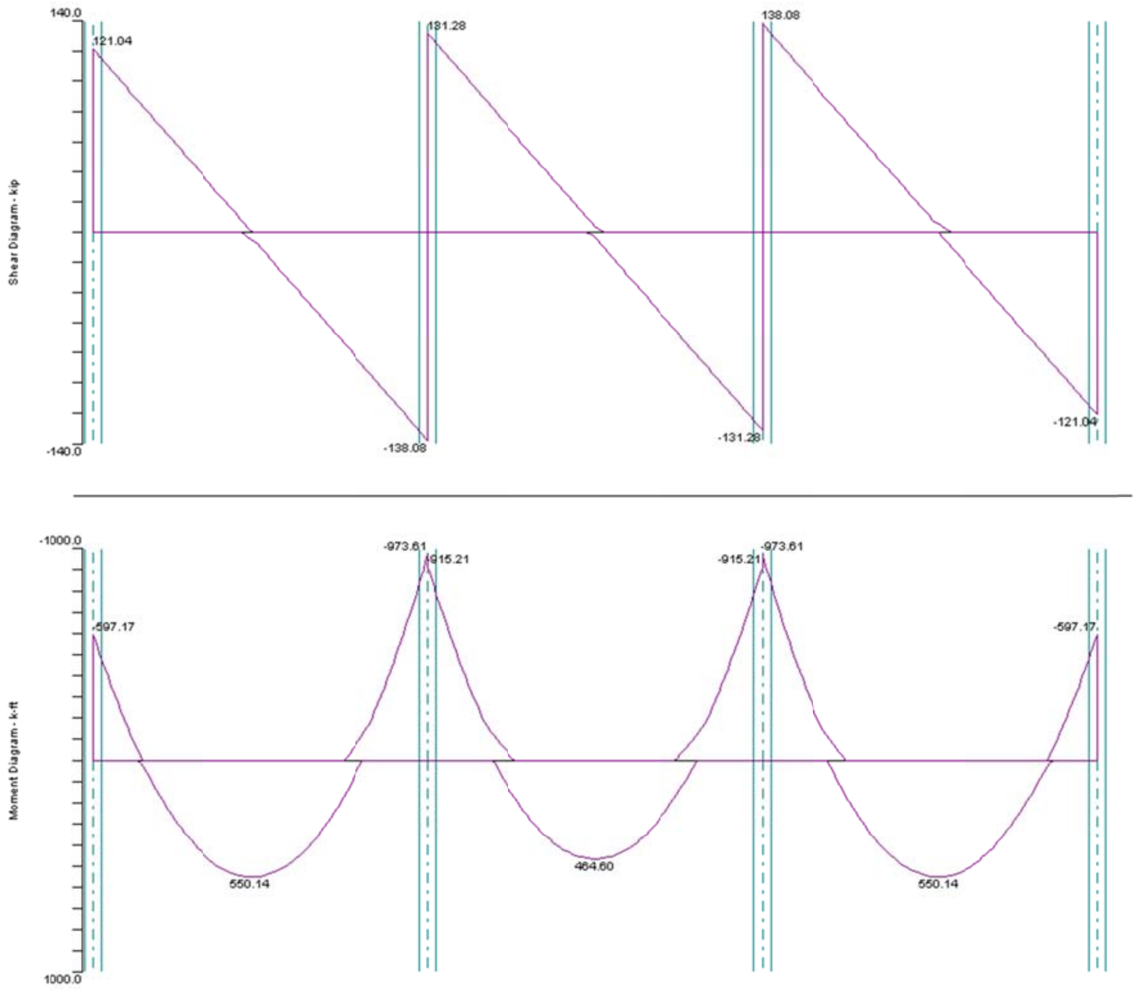
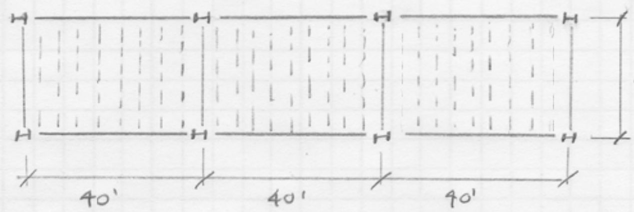


Figure 22: SP Beam Shear and Moment Diagrams (40’ Beam Spans)

Tech Report II | Precast Plank on Steel Beams | 10/24/10



LL = 80 psf
SDL = 25 psf

HOLLOW CORE PRECAST PLANK → PCI INDUSTRY HANDBOOK

SIL = 80 + 25 = 105 psf

USE 4'-0" x 6" plank + 2" topping

66-S SPAN = 20 ft => ALLOWABLE SIL = 136 psf > 105 psf
∴ OKAY

$\boxed{\text{USE 4HC6+2 with 66-S}}$

SLAB WT = 74 psf

DESIGNED STEEL BEAMS USING RAM STEEL

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Advisor: Dr. Thomas Boothby

Appendix B: Takeoff Calculations

Tech Report II | Cost Estimating | 10/24/10

PAN JOISTS AND BEAM System (JOISTS OVER 20' SPAN)

- Volume of concrete

SLAB

$$\frac{4.5}{12} \cdot \frac{(20 \cdot 12 - 40)}{12} \cdot 120 = 750 \text{ ft}^3$$

Pan joists

$$21 \cdot \frac{14}{12} \cdot \frac{6}{12} \cdot 20 = 245 \text{ ft}^3$$

Beams

$$\frac{40 \cdot 18.5}{12 \cdot 12} \cdot 120 = 616.67 \text{ ft}^3$$

$$\text{Total volume} = \frac{750 + 245 + 616.67}{27} = \underline{59.7 \text{ cy}}$$

- Reinforcing steel weight

Slab Reinf.

$$120 \cdot 20 \cdot 0.376 = 902.4 \text{ lb} \quad (\#3\text{-}\#7)$$

Joist Reinf

$$\left.\begin{array}{l} 21 \cdot 20 \cdot 3 \cdot 1.043 = 1314.2 \text{ lb} \\ 21 \cdot 20 \cdot 2.044 = 858.5 \text{ lb} \\ \frac{16}{12} \cdot 18 \cdot 21 \cdot 0.376 = 189.5 \text{ lb} \end{array}\right\} (\#3\text{-}\#7)$$

Beam Reinf

$$2 \cdot \left[2 \cdot \frac{5508.5}{12} + \frac{6004}{12}\right] \cdot 2.67 = 3787.2 \text{ lb} \quad (\#8\text{-}\#18)$$

$$\frac{16 \cdot 2 + 38}{12} \cdot 162 \cdot 0.376 = 355.3 \text{ lb} \quad (\#3\text{-}\#7)$$

$$\text{Total weight}_{(\#3-7)} = \frac{902.4 + 1314.2 + 858.5 + 189.5 + 355.3}{2000} = \underline{1.81 \text{ tons}}$$

$$\text{Total weight } (\#8\text{-}18) = \frac{3787.2}{2000} = \underline{1.89 \text{ tons}}$$

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Advisor: Dr. Thomas Boothby

Tech Report II | Cost Estimating | 10/24/10

- Formwork SFCA

Slab = $\left(20 - \frac{40}{12}\right)\left(120 - \frac{1}{2} \cdot 21\right) = 1825$ SFCA

joists = $21 \cdot \left(\frac{6}{12} + \frac{14}{12} \cdot 2\right) 16.67 = 991.9$ SFCA

girder = $\frac{40}{12}\left(120 - 0.5 \cdot 42\right) = 330$ SFCA

Total$_{(\text{slab + joists})}$ = 1825 + 583.4 = 2816.9 SFCA

Total$_{(\text{girder})}$ = 330 SFCA

Pan Joists and Beam System (Joists over 40' span)

- Volume of concrete

Slab

$\frac{4.5}{12} \cdot (120 - 2 \cdot 4) \cdot 20 = 840 \text{ ft}^3$

Pan joists

$4 \cdot \frac{20}{12} \cdot \frac{8}{12} \cdot (120 - 4) = 515 \text{ ft}^3$

Beams

$4 \cdot \frac{24.5}{12} \cdot 2 \cdot 20 = 326.67 \text{ ft}^3$

Total volume = $\frac{840 + 515 + 326.67}{27} = 62.3$ CY

- Reinf. Steel wt

Slab Reinf

$20 \cdot 120 \cdot 0.376 = 902.4$ lb (#3-7)

Joist Reinf

$4 \cdot 120 \cdot 3 \cdot 2.044 = 2943.4$ lb (#3-7)

$4 \cdot 120 \cdot 4.303 = 2065.4$ lb (#8-18)

$\frac{22}{12} \cdot 22 \cdot 2 \cdot 4 \cdot 0.376 = 322.7$ lb (#3-7)

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Beam Reinf

$4 \cdot \frac{2689.4}{12} \cdot 1.043 = 467.5$ lb (# 3-7)

$\frac{22 \cdot 2 + 22}{12} \cdot 24 \cdot 4 \cdot 0.376 = 198.5$ lb (#3-7)

Total weight (# 3-7) $= \frac{902.4 + 2943.4 + 322.7 + 467.5 + 148.5}{2000} = 2.42$ tons

Total Weight (# 8-18) $= \frac{2065.4}{2000} = 1.03$ tons

• Formwork SFCA

Slab $= (120 - 4 \cdot 2)\left(20 - 4 \cdot \frac{8}{12}\right) = 1941.33$ SFCA

joists $= 4\left(\frac{8}{12} + \frac{20}{12} \cdot 2\right) \cdot (120 - 8) = 1792$ SFCA

girders $= 4 \cdot 2 \cdot 20 = 160$ SFCA

Total (slab + joists) $= 1941.33 + 1792 = \underline{3733.3}$ SFCA

Total (girders) $= \underline{160 \text{ SFCA}}$

One-Way Slab + Beams

• Volume of concrete

Slab $= \frac{9}{12} \cdot \left(20 - \frac{20}{12}\right) \cdot 120 = 1650$ ft^3

Beams $= \frac{30}{12} \cdot \frac{20}{12} \cdot 120 = 500$ ft^3

Total volume $= \frac{1650 + 500}{27} = \underline{79.6 \text{ cy}}$

• Reinforcing Steel wt.

Slab Reinf. wt.

$120 \cdot 2 \cdot 20 \cdot 1.043 = 5006.4$ lb (# 3-7)

Beam Reinf. wt.

$\frac{12000.9}{12} \cdot 2.67 = 2670.2$ lb (# 8-18)

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$$\left(\frac{18}{12} + \frac{27}{12} \cdot 2\right) \cdot 118 \cdot 0.668 = 472.9 \text{ lb} \quad (\#3\text{-}7)$$

$$\text{Total weight } (\#3\text{-}7) = \frac{5006.4 + 472.9}{2000} = \underline{2.74 \text{ tons}}$$

$$\text{Total weight } (\#8\text{-}18) = \frac{2670.2}{2000} = \underline{1.34 \text{ tons}}$$

- Formwork SFCA

$$\text{Slab} = \left(20 - \frac{20}{12}\right) \cdot 120 = \underline{2200 \text{ SFCA}}$$

$$\text{Beam} = \left[\frac{20}{12} + 2 \cdot \frac{(30-9)}{12}\right] \cdot 120 \cdot 2 = \underline{1240 \text{ SFCA}}$$

Appendix C: Floor System Cost Analysis

Composite Steel Beam System (Original System)

Line Number			Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl. O&P
Division 03 Concrete							
033105350150			Structural concrete, ready mix, normal weight, 3000 psi, includes local aggregate, sand, Portland cement and water, delivered, excludes all additives and treatments	40.7	C.Y.	$107.00	$4,354.90
033529300150			Concrete finishing, floors, basic finishing for unspecified flatwork, bull float, manual float & broom finish, includes edging and joints, excludes placing, striking off & consolidating	2400	S.F.	$0.72	$1,728.00
Division 03 Concrete Subtotal							**$6,082.90**
Division 05 Metals							
051223752700			Structural steel member, 100-ton project, 1 to 2 story building, W16x25, A992 steel, shop fabricated, incl shop primer, bolted connections	40	L.F.	$40.59	$1,623.60
051223752900			Structural steel member, 100-ton project, 1 to 2 story building, W16x31, A992 steel, shop fabricated, incl shop primer, bolted connections	40	L.F.	$48.26	$1,930.40
051223753500			Structural steel member, 100-ton project, 1 to 2 story building, W18x40, A992 steel, shop fabricated, incl shop primer, bolted connections	360	L.F.	$61.61	$22,179.60
053113505400			Metal floor decking, steel, non-cellular, composite, galvanized, 2" D, 18 gauge	2400	S.F.	$2.70	$6,480.00
Division 05 Metals Subtotal							**$32,213.60**
Division 07 Thermal And Moisture Protection							
078116100100			Sprayed cementitious fireproofing, sprayed mineral fiber or cementitious for fireproofing, on flat plate steel, 1" thick, excl. tamping or canvas protection	5417	S.F.	$1.05	$5,687.85
Division 07 Thermal And Moisture Protection Subtotal							**$5,687.85**

This price includes shear studs → Total Cost = $44,901.75

Cost Per Square Foot = $18.71/sq. ft.

One-Way Pan Joist and Girder System (Joists over 20' span)

Line Number			Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl. O&P
Division 03 Concrete							
031113203500			C.I.P. concrete forms, beams, bottom only, plywood, to 30' wide, 1 use, includes shoring, erecting, bracing, stripping and cleaning	330	SFCA	$16.97	$5,600.10
031113353500			C.I.P. concrete forms, elevated slab, floor, with 1-way joist pans, 1 use, includes shoring, erecting, bracing, stripping and cleaning	2400	S.F.	$14.00	$33,600.00
032110600100			Reinforcing Steel, in place, beams and girders, #3 to #7, A615, grade 60, incl labor for accessories, excl material for accessories	1.89	Ton	$2,380.00	$4,498.20
032110600150			Reinforcing Steel, in place, beams and girders, #8 to #18, A615, grade 60, incl labor for accessories, excl material for accessories	1.81	Ton	$1,775.00	$3,212.75
033105350300			Structural concrete, ready mix, normal weight, 4000 PSI, includes local aggregate, sand, Portland cement and water, delivered, excludes all additives and treatments	59.7	C.Y.	$113.00	$6,746.10
Division 03 Concrete Subtotal							**$53,657.15**

Total Cost = $53,657.15

Cost Per Square Foot = $22.36/sq. ft.

One-Way Pan Joist and Girder System (Joists over 40' span)

Line Number			Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl. O&P
Division 03 Concrete							
031113203500			C.I.P. concrete forms, beams, bottom only, plywood, to 30' wide, 1 use, includes shoring, erecting, bracing, stripping and cleaning	160	SFCA	$16.97	$2,715.20
031113353500			C.I.P. concrete forms, elevated slab, floor, with 1-way joist pans, 1 use, includes shoring, erecting, bracing, stripping and cleaning	2400	S.F.	$14.00	$33,600.00
032110600100			Reinforcing Steel, in place, beams and girders, #3 to #7, A615, grade 60, incl labor for accessories, excl material for accessories	2.42	Ton	$2,380.00	$5,759.60
032110600150			Reinforcing Steel, in place, beams and girders, #8 to #18, A615, grade 60, incl labor for accessories, excl material for accessories	1.03	Ton	$1,775.00	$1,828.25
033105350300			Structural concrete, ready mix, normal weight, 4000 PSI, includes local aggregate, sand, Portland cement and water, delivered, excludes all additives and treatments	62.3	C.Y.	$113.00	$7,039.90
Division 03 Concrete Subtotal							**$50,942.95**

Total Cost = $50,942.95

Cost Per Square Foot = $21.23/sq. ft.

One-Way Slab and Beam System

Line Number			Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl. O&P
Division 03 Concrete							
031113202550			C.I.P. concrete forms, beams and girders, interior, plywood, 24" wide, 2 use, includes shoring, erecting, bracing, stripping and cleaning	1240	SFCA	$9.79	$12,139.60
031113351000			C.I.P. concrete forms, elevated slab, flat plate, plywood, to 15' high, 1 use, includes shoring, erecting, bracing, stripping and cleaning	2400	S.F.	$10.82	$25,968.00
032110600100			Reinforcing Steel, in place, beams and girders, #3 to #7, A615, grade 60, incl labor for accessories, excl material for accessories	1.34	Ton	$2,380.00	$3,189.20
032110600150			Reinforcing Steel, in place, beams and girders, #8 to #18, A615, grade 60, incl labor for accessories, excl material for accessories	2.74	Ton	$1,775.00	$4,863.50
033105350300			Structural concrete, ready mix, normal weight, 4000 PSI, includes local aggregate, sand, Portland cement and water, delivered, excludes all additives and treatments	79.6	C.Y.	$113.00	$8,994.80
Division 03 Concrete Subtotal							**$55,155.10**

Total Cost = $51,155.10

Cost Per Square Foot = $22.98/sq. ft.

Hollow Core Plank System

Line Number			Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl. O&P
Division 03 Concrete							
033105350150			Structural concrete, ready mix, normal weight, 3000 psi, includes local aggregate, sand, Portland cement and water, delivered, excludes all additives and treatments	14.8	C.Y.	$107.00	$1,583.60
034113500050			Precast slab, roof/floor members, grouted, solid, 6" thick, prestressed	2400	S.F.	$9.95	$23,880.00
Division 03 Concrete Subtotal							**$25,463.60**
Division 05 Metals							
051223750300			Structural steel member, 100-ton project, 1 to 2 story building, W8x10, A992 steel, shop fabricated, incl shop primer, bolted connections	80	L.F.	$23.45	$1,876.00
051223753960			Structural steel member, 100-ton project, 1 to 2 story building, W18x86, A992 steel, shop fabricated, incl shop primer, bolted connections	234	L.F.	$123.19	$28,826.46
Division 05 Metals Subtotal							**$30,702.46**
Division 07 Thermal And Moisture Protection							
078116100100			Sprayed cementitious fireproofing, sprayed mineral fiber or cementitious for fireproofing, on flat plate steel, 1" thick, excl. tamping or canvas protection	2017	S.F.	$1.05	$2,117.85
Division 07 Thermal And Moisture Protection Subtotal							**$2,117.85**

Total Cost = $58,283.91

Cost Per Square Foot = $24.28/sq. ft.