Washington Park Condominiums

Mt. Lebanon, Pennsylvania

Technical Report #2
Pro-Con Structural Study of Alternative Floor Systems

Architectural Engineering
2008-2009 Senior Thesis

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Executive Summary:

The purpose of Technical Report #2 was to investigate possible alternative floor systems for Washington Park Condominiums through analysis and ultimately schematic design. The designs of the three alternative systems are compared to each other and to the existing system on various different grounds. Some of these factors include: foundation impact, fire protection, square footage cost, constructability, system weight, slab depth and finally integration with other systems. The existing floor system is VESCOM composite steel joists and it is efficient in its ability to carry the necessary gravity loads as well as an architectural element since the ceiling can be installed directly to the joist bottom chord and the mechanical systems (HVAC, plumbing, fire protection, electrical and telecommunications) could be installed within the joist system. The other three systems that are analyzed are as follows:

- Girder-Slab
- Two Way Flat Slab Concrete
- Composite Steel

After researching and analyzing each system, it was determined that the Girder-Slab system was not a viable option because the design required the reduction of the typical interior bay size from 28’-0 x 28’-4 to 14’-0 x 28’-4. This would add more columns and foundations, therefore making the overall structure of the project more expensive. The two way flat slab concrete system and the composite steel system were able to be designed using the pre-existing grid and therefore will require no extra columns or foundations. The two way slab had a slab thickness of 9” and drop panel thickness of 12.5” while the concrete columns were 16” x 16”. The composite steel system has a slab thickness of 2 ½” of normal weight concrete above the 1 ½” Vulcraft 1.5VL decking. This design would have a W12x16 beam with 22 shear studs spaced at 7’-0” on center being supported by a W18x40 girder with 38 shear studs. Both the two way flat slab system and the composite steel system are considered to be viable alternatives for the floor system design. Technical Report #3 will further analyze and discuss the viable alternative options and how they will affect the current design of the main lateral force resisting system. In doing so, Technical Report #3 will either confirm or reject the two systems as possible design substitutes.

Introduction:

Washington Park Condominiums is a multi-use retail and residential building located at the intersection of Bower Hill Road and Washington Road in Mt. Lebanon, Pennsylvania. Site work and excavation has begun at the site and construction should begin sometime before the end of the fall 2008, with the project lasting until fall 2010. Washington Park Condominiums is the first of two buildings proposed to be built on the site. Building one is a nine-story, 148,000 ft^2 structure which is owned by Zamagias Properties of Pittsburgh, PA. The building was architecturally designed by Indovina Associates Architects and is being constructed by PJ Dick, Inc. for a price of $23,418,000. The building's primary use is residential and it contains 7 stories of condominiums on the 2^{nd} through 8^{th} floors. The first floor of the building is used for retail space and as a location for extra amenities for the residents of Washington Park. The building also contains two below grade levels of parking. The enclosed parking garage contains 78 parking spaces that can be used by the residents. Two elevators and two stairs serve the parking areas that also contain resident storage, a wine room and trash collection along with mechanical and electrical rooms. The ground floor serves primarily as retail space with four separate areas available for possible tenants. Also contained on the floor are a resident exercise room and a private entrance and lobby for the residents.

As the building moves to the second floor, the function changes from primarily retail to one of solely residential with six upscale condominiums located on the floor. These condominiums each have different floor plans and layouts with overall areas ranging from 1523 ft^2 to 2288 ft^2. Each unit contains two or three bedrooms and bathrooms depending on size, along with a living room, dining room, kitchen, study, laundry, entry and in some cases a balcony. This floor layout continues throughout the next four floors, with a total of 30 units on floors 2 through 6. The 7^{th} and 8^{th} floors of the building are the penthouse level. This floor contains five condominiums that range from 1732 ft^2 to 2453 ft^2. These units contain the same amenities and spaces as the units on the below floors do. All of the condominiums floors are served by two elevators and two stairways that are connected by a hallway that runs through the center of the building in the long direction. Finally, the roof contains mechanical spaces that are accessed by using the northern most stairway or elevator.

The typical exterior wall system of the building consists mainly of 4" brick veneer backed by a 2" airspace and 2" of rigid XPS insulation, then containing another 2" layer of rigid spray-foam insulation that is followed by an airspace and then 5/8" gypsum board. This exterior wall system is typical for the first 6 floors of the building. The 7^{th} and 8^{th} floors of the building consist of a similar wall construction except for the exterior façade which is a 5/16" layer of painted fiber-cement siding.

Existing Composite Joist and Precast Concrete Plank System:

Foundations

The foundation system can be best described as a spread footing system with attached concrete piers. The sizes for the spread footings range from the smallest, a 4'-0" x 4'-0" x 2'-0" footing with #8 @ 12" each way, to a 14'-0" x 14-0" x 3'-6" footing with #8 @ 6" each way. These spread footings have a concrete strength of f'_c = 4000 psi, and the deepest of the footings will be 25'-0" below grade. In addition to the spread footings, interior and exterior wall footings were used and are either 2'-0" or 3'-0" wide by 1'-4" deep. The steel reinforcing in these wall footings are (3) #5 continuous bars and #5 x 1'-8" @ 16".

The slab on grade in this system consist of either a 6" or 8" normal weight concrete slab reinforced with 6x6-W2.9xW2.9 welded wire fabric or 6x6-W4xW4 welded wire fabric. The slab on grade is also thickened to a minimum if 1'-0" at non-load bearing walls and (2) #4 bars are added for tensile strength. Connecting the columns to the slab on grade and the spread footings are column piers that range from 16" x 16" with (4) #7 of vertical reinforcement to 40" x 40" w/ (12) #7 of vertical reinforcement. The slab on grade and column piers are both f'_c = 4000 psi concrete.

Floor Systems

There are two separate floors systems that are typical within the structure of Washington Park. The first is a precast concrete plank system that is used in the parking areas as well as the first and second floor framing. The precast concrete plank is 8" thick and also contains a 2" thick structural topping. The reinforcing in the structural topping is 6x6-W1.4xW1.4 welded wire fabric. The precast concrete plank system bears on W shapes which then carry the load to the columns. This system was used in the parking areas because of the systems diaphragm capacity (ability to transfer horizontal loading) and because of its durability and strength. Moreover, the system was utilized on the 1st and 2nd floors due to its weight. It was also useful because of the contractor's need to backfill the building early on to meet the owner's schedule.

The second primary floor system in the building is the VESCOM composite joist floor system. The composite joist system interlocks the top chord of a joist with the concrete producing less deflection, less vibration and greater stiffness. The floor construction consists of a 2 11/16" reduced weight concrete slab that is poured on top of the 1 5/16", 22 Gage galvanized floor decking. The bottom chord acts as the main tension member, and in the composite stage the embedded top chord serves as a continuous shear connection. The concrete is also reinforced with welded wire fabric and compressive strength of the concrete is f'_c = 3500 psi. These floors are also to act as a diaphragm that is able to resist lateral forces of 250 to 350 PLF. Finally, the system was used as an architectural element since the ceiling could be installed directly to the joist bottom chord and the mechanical systems (HVAC, plumbing, fire protection, electrical and telecommunications) could be installed with the joist system, saving space and allowing for higher ceilings and floor to floor height within the apartments. A section of the VESCOM Composite floor system can be found in Appendix B.

Lateral System

The lateral resisting system within the building is mainly moment resisting steel frames made up of wide flange beams. These frames begin on the second floor and continue up through the top of the building. These frames run in the north-south direction and run along column lines A, B, C and D. Rigid connections also occur on these floors along column lines 1 through 9. Since the VESCOM floor system is being used as a diaphragm to transfer shear loading the load path begins at the exterior beams and then continue on through the floor system to joist girders which are to be designed and manufactured by the joist manufacturer. The load is then transferred into the large W14 columns, and finally to the brace frames. There are a total of eleven braced frames located in the basement and sub-basement levels running along column lines 1 through 11 from column lines A.1 to B. The brace frames are 17'-2" in length and they begin at the sub-basement level and connect into the framing for the ground floor. The bracing in the frames consists of HSS 8x8x1/2 up to the basement level, and HSS 6x6x3/8 from the basement level to the ground floor. These frames are used in conjunction with the precast plank system to create a diaphragm that can resist 280 PLF. This plan detail and the detail of the brace frames can be found in Appendix B.

Pro-Con Analysis

The system is extremely innovative and allows for quick erection time and long spans. The system interlocks the top chord of a joist with the concrete producing less deflection, less vibration and greater stiffness. The system also has a fire resistance rating of 3 hours which is above the 2 hour requirement by code. The system is also able to act as a diaphragm, transferring lateral loads to the main lateral resisting elements of the structure. Finally, the all of the mechanical and electrical equipment can be installed in openings in the web of the joists, allowing for maximum floor to ceiling heights and ease of construction and coordination between the different disciplines.

In contrast, the system is relatively new and may require more training for erectors and other tradesmen on the job site. Also, the system requires total floor depth of 23" which could possibly be reduced by using another system.

Overall the composite joist floor system is an extremely viable option that fulfills both the structural and architectural parameters of the building.

Figure 1: Braced Frame Location

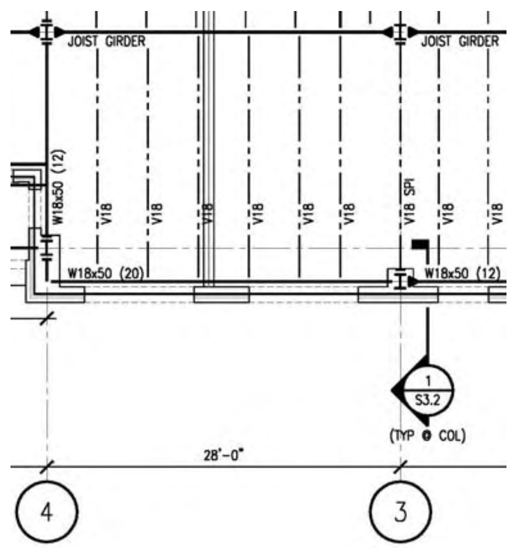


Figure 2: Typical Exterior bay with rigid connections denoted by || and moment connections denoted by ▶.

Alternate Floor System Analysis:

For Technical Report #2, three alternative structural floor systems were researched and analyzed for their perspective usage in Washington Park Condominiums. The typical bay for which these three alternative systems are analyzed is shown on the follow page as Figure 3. The purpose of discussing alternate systems is to attempt to determine if the current system is the most efficient and whether or not it allowed for the most floor to floor space and least amount of used material. The three systems that were analyzed and will be discussed are as follows***:***

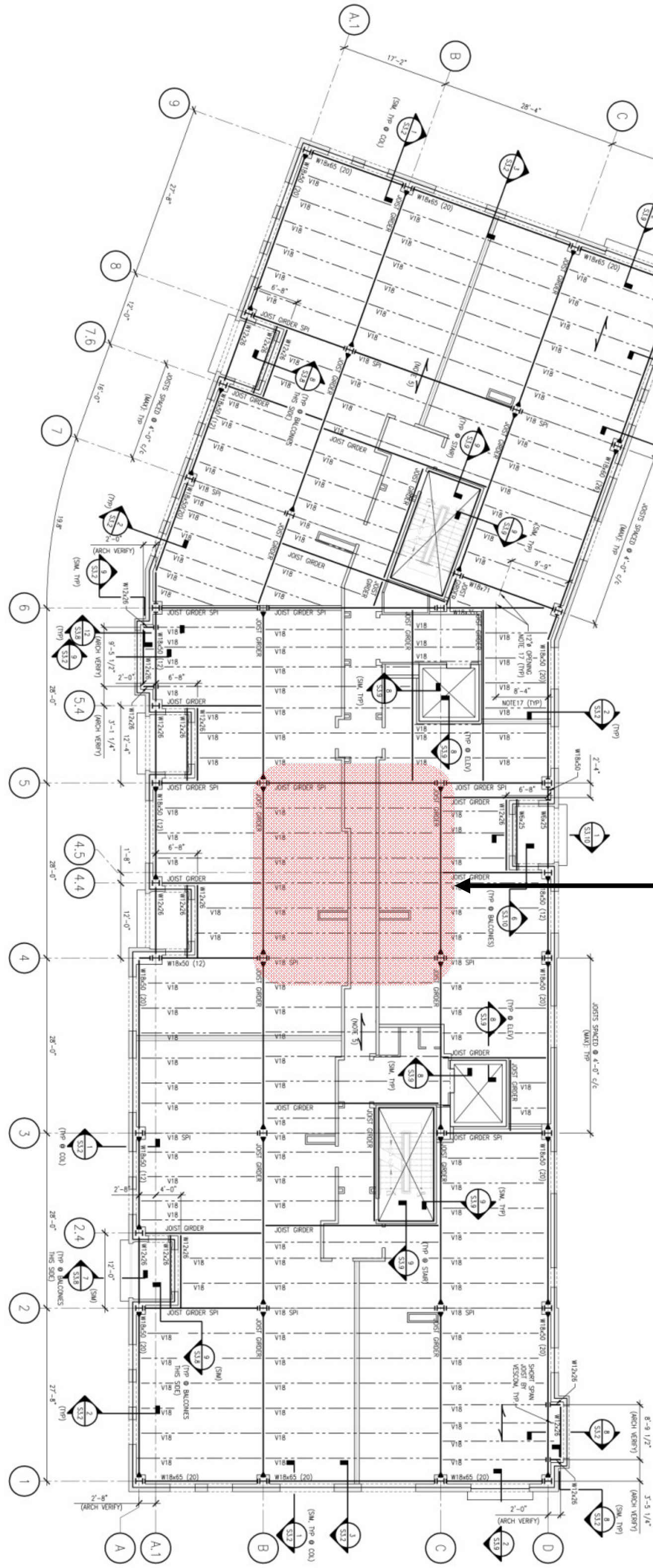
- Girder Slab
- Two Way Flat Slab Concrete
- Composite Steel with Normal Weight Concrete

Since three new systems were analyzed there are many reference manuals and materials that were used to complete the design, these are listed as follows:

- IBC 2003 w/ Amendments for Mt. Lebanon
- ASCE 7-05
- Girder-Slab® Design Guide, version 1.4
- D-Beam Reference Calculator (Microsoft Excel Spreadsheet)
- ACI 318-08 Building Code and Commentary
- Design of Concrete Structures Textbook (AE 431)
- AISC Specification for Structural Steel Buildings, 13^{th} Edition
- RAM Structural System
- RS Means Cost Analysis Data

Another aspect of this analysis that is necessary to understand is that there will be changes to the column layout with the changing of the floor systems. Both the two way flat slab concrete system and the composite steel systems use the same floor layout. However, because of span and design deflection restrictions intermediate columns were added when using the Girder Slab system. This will be explained in more detail in the Girder Slab analysis and results on page 10 and Appendix B. Although the column layout was changed for the Girder Slab system, the decision was made to not worry about changing the floor plans since it has not yet been decided if the Girder Slab will be the most efficient system.

Typical Floor Layout



Interior Bay used for alternate system analysis.

Figure 3: Typical Interior Bay

Girder Slab System:

Description

The Girder Slab system is a composite system in which the concrete and steel work together to create an efficient structural system to be used in mid to high rise construction. The lightweight assembly develops composite action enabling it to support residential live loads. This system consists of a special steel beam that is used as an interior girder supporting precast concrete planks on its bottom flange. The web and top flange of the D-Beam are concealed within the precast plank, while the bottom flange is used as the shoring for the precast plank. The system is also efficient because it is assembled-in-place which allows for the support of residential live loads upon the grouting of the D-Beam and the prestressed precast plank because the system develops composite action quickly.

Pro-Con Analysis

The Girder Slab system allows for rapid erection and is also extremely light weight which means, less material and less hassle in erection. The system is also incredibly innovative and interesting because it can develop composite action immediately upon grouting. The system also meets Underwriters Laboratory fire code ratings as well as required sound (STC) ratings, which are important in residential apartment construction. Another benefit of the system is the fact that Washington Park Condominiums currently employs a precast concrete plank system in the parking garage and on the first two floors. With the Girder Slab system, typical precast concrete planks can be used. In this case, 8" planks with a 2" structural topping were used and will allow for less variation in material and erection.

In contrast there are also a few glaring negatives that lead to its ultimate demise as a prospective system for Washington Park Condominiums. First, the system is extremely expensive in comparison to some of the other systems. Also, there are span length limitations with the precast planks and the D-Beam's. In order to analyze the system, changes had to be made to the typical bay size and add an intermediate column halfway between two other columns. This not only will add more columns, but will also add more footings and will change the floor plan of the building. Finally, even though there would be a reduced floor thickness, the overall ceiling cavity would be larger because the current composite joist system allows for mechanical and electrical equipment to be installed within the area of the joist web. These systems would have to be installed below the girder slab system, which would cause a reduced floor to floor height.

Design Results

To complete the Girder Slab design the typical bay length of 28'-4" was used as the span for the precast planks. However, the D-Beam was not able to span 28'-0", so therefore an interior column was added, making the D-Beam span 14'-0". To complete the analysis of the system, a D-Beam Calculator that can be found on the Girder-Slab website was used. This design yielded a floor thickness of 10" which includes 8" Precast Concrete Plank and 2" Structural Topping. The design also includes a girder size of DB9x46 which is 9.625" deep and weighs 45.8 PLF. The design also added 2 columns and footings in each interior bay to achieve the desired deflections and stresses. For more design information and the D-Beam Calculator spreadsheets used in the analysis of the Girder Slab system, see Appendix B. An overall discussion and comparison of all of the systems that are being analyzed can be found in the conclusion found on pages 15 and 16.

Two Way Flat Slab Concrete System:

Description

This system uses a two way reinforced concrete slab, which transfers loads to all supporting columns. The fact that the existing system employs very typical interior square bays makes the two way flat slab system a viable option for analysis. The system uses a flat concrete slab, and in the case of the analysis for Washington Park Condominiums, also uses drop panels around the columns. These drop panels, reduce the effect of punching shear on the system and also reduce the overall slab thickness. Within the slab there is reinforcing placed in both directions and in the top and bottom of the slab. In some design situations, column capitals are considered, but were not in this case because of the desire to have a uniform ceiling cavity with no restrictions. All of the parameters of the system were designed using Design of Concrete Structures Textbook from AE 431 and ACI 318-08, Chapter 13 which is design of two way slabs.

Pro-Con Analysis

The system allows for the retention of the current column layout. However, the columns will obviously have to change from steel W-Shapes to square concrete columns. The slab thickness is less than the Girder Slab system and the existing composite joist system, which will allow for more space in the ceiling cavity for mechanical and electrical equipment.

In contrast the two way concrete slab system adds a significant amount of weight to the system which would then cause the foundations and footings to be resized for the larger load. The drop panels also cause a problem with the layout of the floor plans in the sense that they create an uneven depth to the ceiling cavity. Another issue is the fact that the lateral system on the 2nd through 8th floors would change from steel moment frame system to a shear wall system utilizing the stairways and elevator shafts for these shear walls.

Overall, the system's viability for use in Washington Park Condominiums is one that may be looked at further and will depend largely on the feasibility of changing the main lateral force resisting system of the building.

Design Results

The design of the two way flat slab system yielded a slab thickness of 9" and a drop panel thickness of 12.5". The slab also contains #5 bars at both the top and bottom and in each direction. The design also includes 16"x16" concrete columns that would transfer the gravity loads to the footings. For more design information and Direct Design Method hand calculations please see Appendix C. An overall discussion and comparison of all of the systems that are being analyzed can be found in the conclusion on pages 15 and 16.

Composite Steel System:

Description

The composite steel system uses shear studs and composite decking to transfer load between the concrete and the steel shapes supporting the concrete. The shear studs are welded to the top of the beams and then the concrete is poured on top of the composite decking. This allows the steel and concrete to form a unit to resist the load on the floor. This integration significantly increases the strength of the steel shape being used. Welded wire fabric is used within the slabs and carrying very little load. Ultimately, the benefit of being able to transfer shear between the steel section and the concrete slab, therefore allowing for a higher load capacity, is the main reason for utilizing composite steel construction.

Pro-Con Analysis

The composite steel system is extremely efficient at carrying large loads across long spans, which allows for the system's practicality in mid rise residential design. The floor system also integrates well with the current lateral force resisting system and would require very few changes to make them compatible. The construction of the system is also very efficient and would allow for quick construction. The structure also meets the 2 hour fire rating that is required throughout the building for floor systems. Other than the integration of the steel and concrete to carry the load, the biggest benefit would be the reduced floor deflection. This is obviously important in a building that has constant occupancy and occupant movement. Essentially, the current composite joist system is very similar to the composite steel beam system and therefore the composite steel system would be a viable option to analyze further.

Although, there are many benefits to the composite steel system, there are also a few negatives. First, the W-shapes would add a considerable amount of weight to the overall mass of the structure. This added weight would obviously increase the size of the columns and the footings. There would also be some coordination issues in terms of running the electrical and mechanical equipment within and under than steel beams. Because of this, the ceiling cavity would grow slightly and would ultimately shorten the ceiling height within the apartments.

Overall, the current composite joist system is very similar to the composite steel beam system and therefore the composite steel system would be a viable option for further analysis.

Design Results

The design of the composite steel system was completed using RAM Structural System. This program allows for the imputation of loading, decking, and other conditions relevant to the structure. To complete the analysis and design of the interior bay chosen, a larger portion of the building was laid out so that loads on the supporting girders could be more accurately determined. The other sizes outside of the interior bay being designed, which is shown on page 9 can be disregarded. In doing all of this, the output allowed for the same interior bay size of 28'-0 x 28'-4, while yielding a normal weight concrete slab thickness of 2 ½" above the 1 ½" Vulcraft 1.5VL decking. This design would have a W12x16 beam with 22 shear studs spaced at 7'-0" on center being supported by a W18x40 girder with 38 shear studs. The shear studs are ¾" diameter and are 3 ½" long. (The slab also contains 6x6-W1.4xW1.4 welded wire fabric. For more design information, RAM output, decking catalogs and figures concerning the analysis of the composite steel system, see Appendix D. An overall discussion and comparison of all of the systems that are being analyzed can be found in the conclusion on pages 15 and 16.

System Comparison:

Floor System Comparison for Typical Interior Bay				
Item	**Existing VESCOM Composite Joist System**	**Girder Slab System**	**Two Way Flat Slab System**	**Composite Steel System**
Slab Thickness (in)	4.0	10.0	9.0	4.0
Total Depth (in)	22.0	10.0	12.5	22.0
System Weight (psf)	100	80	118	82
Column Size	W14x120	W12x65	16" x 16"	W12x65
Fire Rating	3 Hours	2 to 3 Hours	2 Hours	2 Hours
Constructability	Easy	Medium	Medium	Medium
Foundation Impact	-	High	Medium	Minimal
Materials Cost per sq. ft.	$20.37	$24.00	$8.00	$12.45
Labor Cost per sq. ft.	$10.17	$12.00	$8.55	$6.35
Column Cost per sq. ft	$8.57	$6.96	$4.49	$6.96
Foundation Cost per sq. ft.	$11.49	$61.24	$30.62	$30.62
Total Cost per sq. ft.	**$50.60**	**$104.20**	**$51.66**	**$56.11**
Possible Alternative	-	No	Yes	Yes

As the above table shows, from a cost standpoint the existing VESCOM Composite Joist system is the most cost effective and viable. The system also provides the architect with the ability to integrate the floor system with the mechanical, electrical, plumbing and other equipment in the ceiling cavity in a way that allows for greater ceiling heights and therefore more vertical space within the apartments. The joist system is also efficient at carrying the gravity loads on the building as well as providing a diaphragm that transfers lateral loads to the moment resisting frames within the structure. Although, this system is the most viable, both the composite steel and two way flat slab system could be used. The composite steel system is common in Pittsburgh and would require very little change in construction for the contractor and workers on the job. The two way flat slab system which is also being used in the new addition to Children's Hospital in Pittsburgh could also be considered but would present possible problems with the mechanical and electrical systems in the ceiling cavity. Overall, both the composite steel system and the two way flat slab system are possible options which deserve more research.

Conclusion:

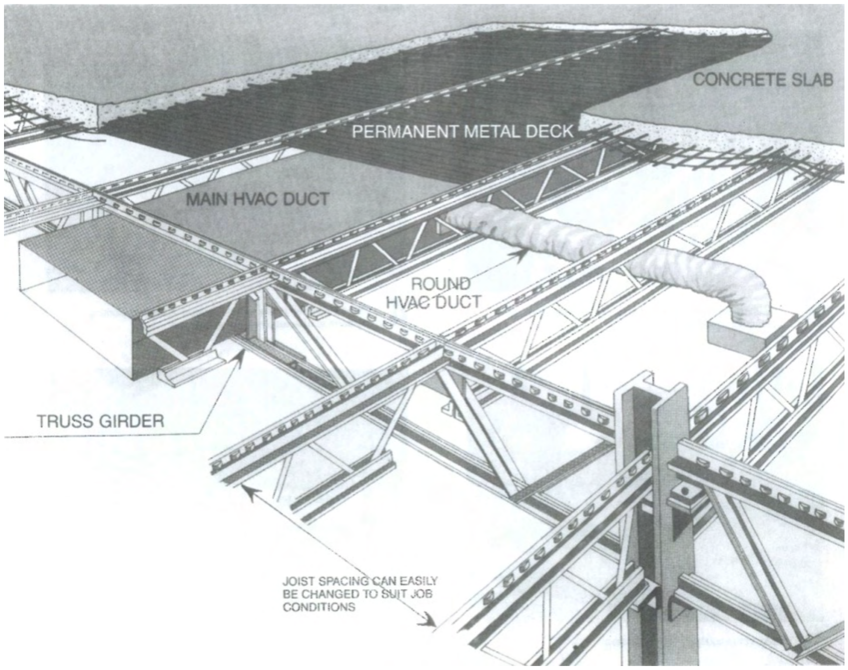
The alternative designs as well as the existing design for Washington Park Condominiums were presented so that consideration could be given to the situation and issues practicing structural engineers face when determining the best and most efficient structure for a given project. So many times, structural design classes in college present students with a problem which essentially has a given right or wrong answer in terms of the final design of the structure at hand. Technical Report #2 allows for the analysis and design of alternative solutions of the project so that either the existing design is verified as being the most efficient, or so that another system can be discussed and proposed as a possible substitute.

Throughout the report a basic analysis was presented for each of the three alternative systems chosen. All three of the analyses were then used to create a schematic design of the structure for that given system. These designs led to an overall system comparison and furthermore, conclusions that can be used to propose further study of possible alternative.

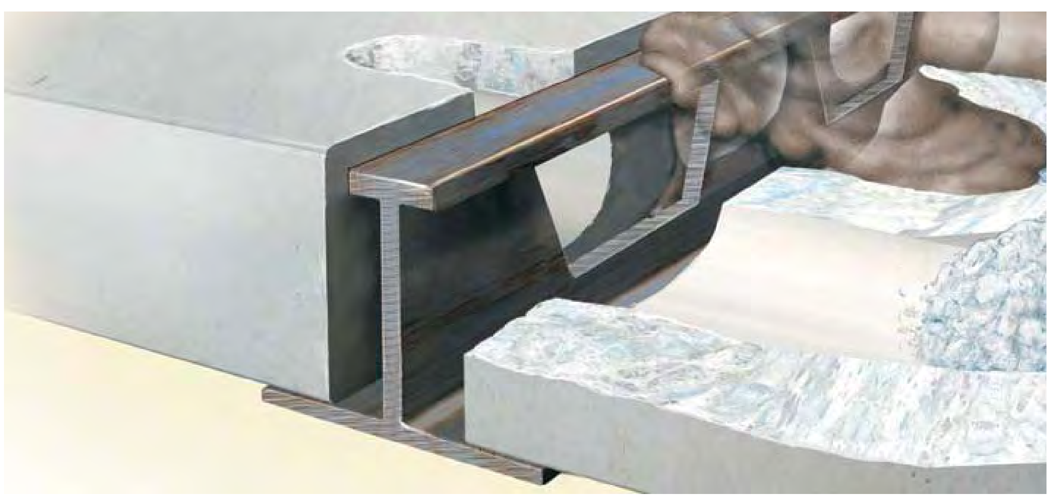
In doing the design and research for the other systems, it became obvious that the Girder-Slab system was not a possible solution for this project. The fact that the bay size needed to be cut in half, therefore adding more columns and footings significantly increased the cost of the system. However, the two way flat slab and composite steel system seem to be viable options to the current VESCOM composite joist system. Both systems utilize the same basic column layout as the existing system and therefore would have minimum impact on the foundations. Another benefit is the fact that the cost of each system is also close to that of the existing system. One disadvantage of these systems is their integration with the ceiling cavity and all of the equipment that is located there. Another issue is concerning the lateral systems that would be used for both alternatives. Although current lateral system could most likely be used with the composite steel system, it would have to be changed in order to accommodate the two way flat slab design. These factors will be the focus of Technical Report #3 and from there a more detailed and definite decision can be made on the feasibility of each system as a design alternative.

Appendix A: Structural System Details

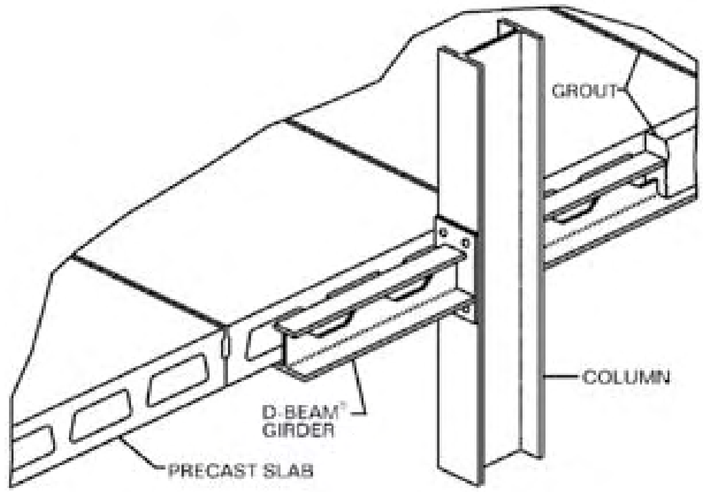
Perspective Section of Existing VESCOM Composite Joist System



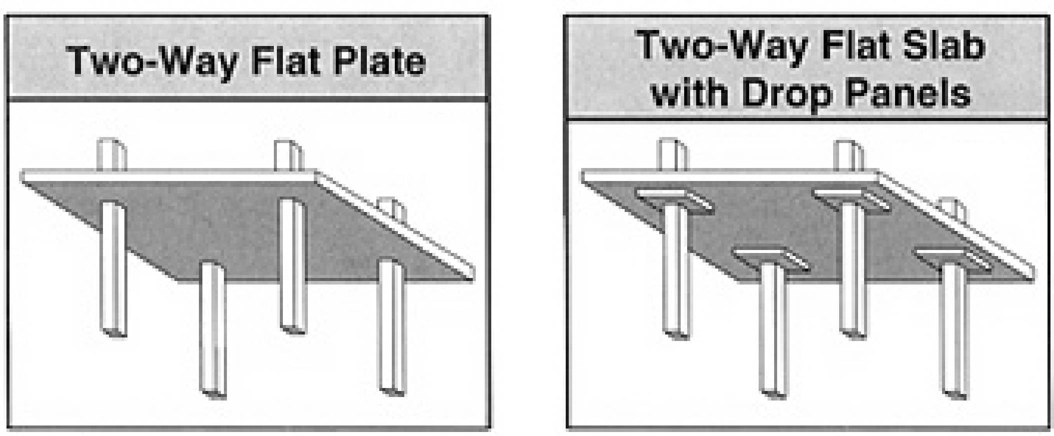
Perspective Section of Girder Slab D-Beam and Precast Plank



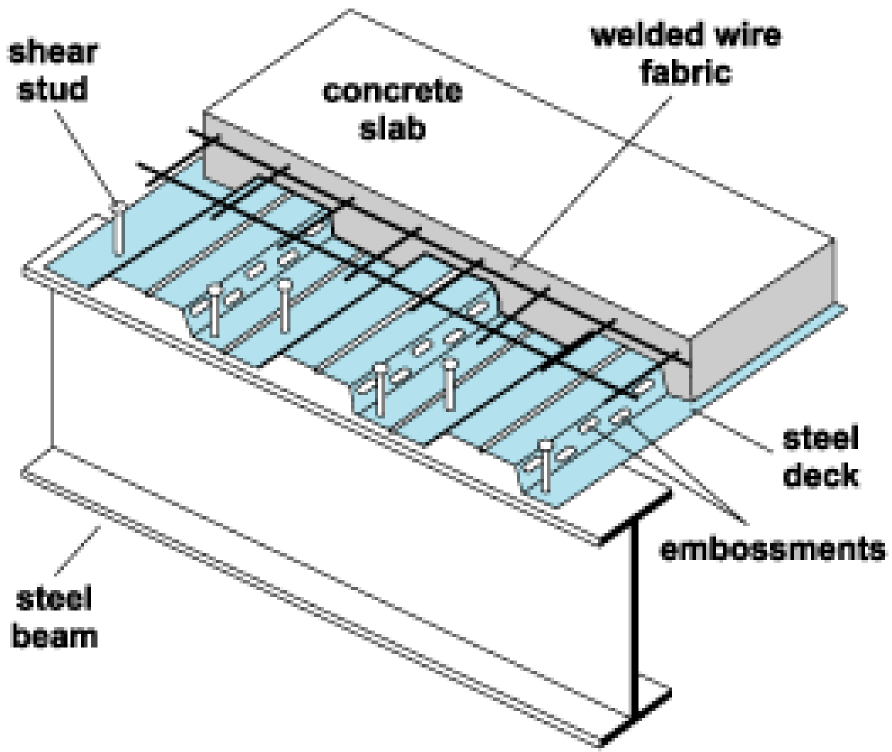
Perspective Section of Girder Slab System



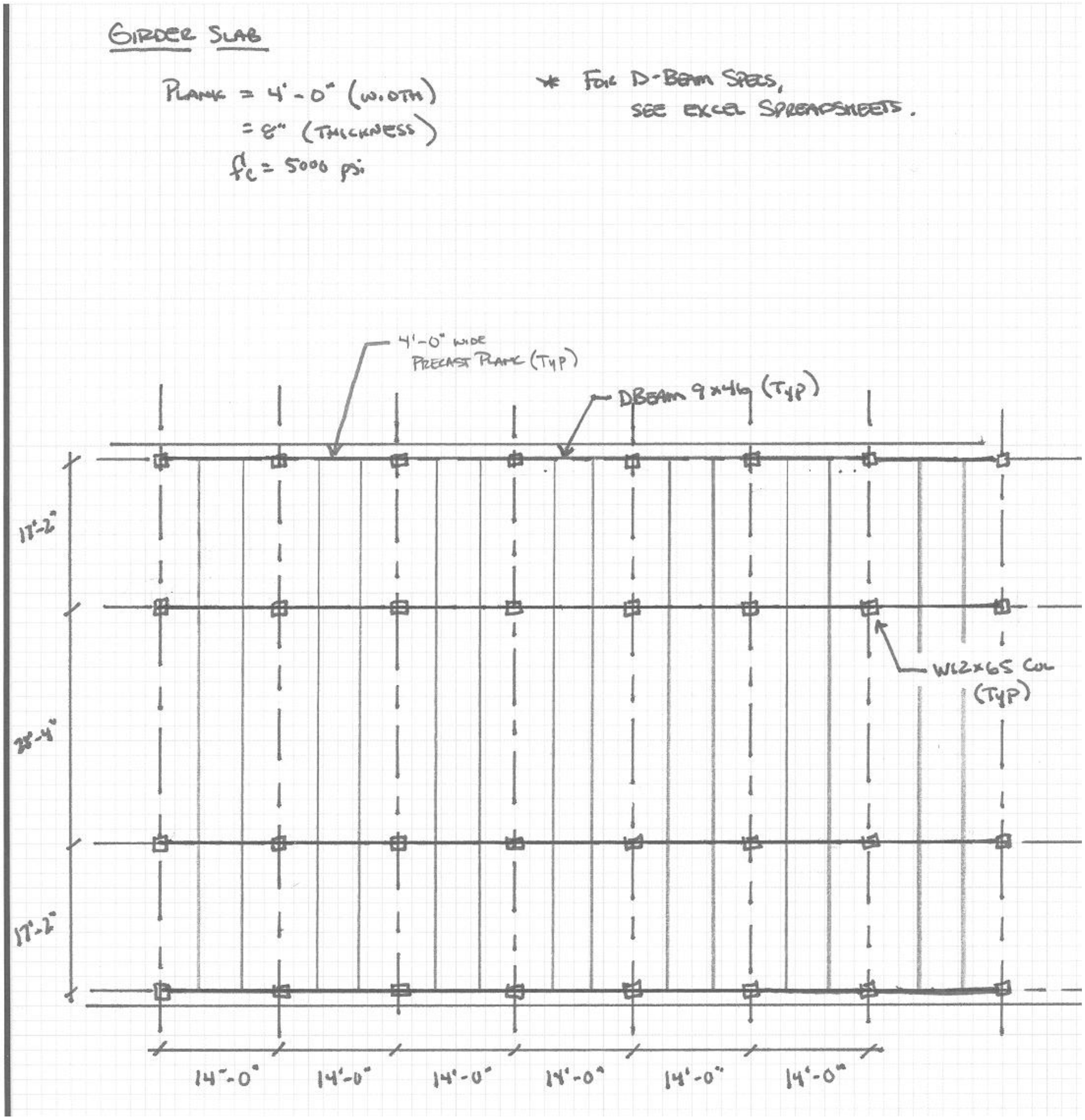
Two Way Flat Slab Details



Composite Steel Floor Detail



Appendix B: Girder Slab Analysis


GIRDER SLAB
PLANK = 4'-0" (WIDTH)
= 8" (THICKNESS)
f'c = 5000 psi
* FOR D-BEAM SPECS, SEE EXCEL SPREADSHEETS.
4'-0" WIDE PRECAST PLANK (TYP)
DBEAM 9x46 (TYP)
W12x65 COL (TYP)
17'-2"
28'-4"
17'-2"
14'-0"
14'-0"
14'-0"
14'-0"
14'-0"
14'-0"

D-Beam® Calculator Reference Tool						Project Name:	Washington Park Condominiums
10/20/2008						Job Number:	BLF-2009

Design Information

Dead Load =	79	psf
Partition Load =	20	psf
Live Load =	40	psf
Topping Load =	25	psf
DB Span =	14	ft
Plank Span =	28.3333	ft
Grout f'c =	4000	psi
Allowable Δ_{LL} = L /	360	
Allowable Δ_{LL} =	0.47	in

DB Properties

DB Size ------------> DB 9 x 46

Steel Section			Transformed Section		
I_s =	195	in^4	I_t =	356	in^4
S_t =	33.7	in^3	S_t =	68.6	in^3
S_b =	50.8	in^3	S_b =	80.6	in^3
M_{scap} =	84.0	ft-k			
t_w =	0.375	in			
b =	5.75	in			

Live Load Reduction (IBC 00/03/06)

Include LLR	☐	(Check for Yes)
% Reduction =	N/A	
Reduced Load =	N/A	

Initial Load - Precomposite

M_{DL} =	54.8	ft-k	<	84.0	ft-k	OK
Δ_{DL} =	0.34	in				
Δ Ratio = L /	491					
Camber D-Beam	☐	(Check for Yes)				
D-Beam Camber	1	in				

Total Load - Composite

M_{sup} =	59.0	ft-k				
M_{TL} =	113.8	ft-k				
S_{REQ} =	45.5	in^3	<	68.6	in^3	OK
Δ_{SUP} =	0.20	in	<	0.47	in	OK
Δ_{TOT} =	0.54	in	= L/	309		

Superimposed Compressive Stress on Concrete

N value =	8.04					
S_{tc} =	552	in^3				
f_c =	1.28	ksi				
F_c =	1.80	ksi	>	1.28	ksi	OK

Bottom Flange Tension Stress (Total Load)

f_b =	21.7	ksi				
F_b =	45	ksi	>	21.7	ksi	OK

Shear Check

Total Load =	164	psf				
w =	4.65	klf				
R =	32.5	k				
f_v =	15.1	ksi				
Fv =	20	ksi	>	15.1	ksi	OK

D-Beam® Calculator Reference Tool

10/20/2008

Project Name: Washington Park Condominiums
Job Number: BLF-2009

Design Information

Dead Load =	79	psf
Partition Load =	20	psf
Live Load =	40	psf
Topping Load =	25	psf
DB Span =	14	ft
Plank Span =	17.1667	ft
Grout f'c =	4000	psi
Allowable Δ_{LL} = L /	360	
Allowable Δ_{LL} =	0.47	in

DB Properties

DB Size ------------> DB 9 x 46

Steel Section			Transformed Section		
I_s =	195	in^4	I_t =	356	in^4
S_t =	33.7	in^3	S_t =	68.6	in^3
S_b =	50.8	in^3	S_b =	80.6	in^3
M_{scap} =	84.0	ft-k			
t_w =	0.375	in			
b =	5.75	in			

Live Load Reduction (IBC 00/03/06)

Include LLR	☐	(Check for Yes)
% Reduction =	N/A	
Reduced Load =	N/A	

Initial Load - Precomposite

M_{DL} =	33.2	ft-k	<	84.0	ft-k	OK
Δ_{DL} =	0.21	in				
Δ Ratio = L /	810					
Camber D-Beam	☐	(Check for Yes)				
D-Beam Camber		in				

Total Load - Composite

M_{sup} =	35.7	ft-k				
M_{TL} =	69.0	ft-k				
S_{REQ} =	27.6	in^3	<	68.6	in^3	OK
Δ_{SUP} =	0.12	in	<	0.47	in	OK
Δ_{TOT} =	0.33	in	= L/	510		

Superimposed Compressive Stress on Concrete

N value =	8.04					
S_{tc} =	552	in^3				
f_c =	0.78	ksi				
F_c =	1.80	ksi	>	0.78	ksi	OK

Bottom Flange Tension Stress (Total Load)

f_b =	13.2	ksi				
F_b =	45	ksi	>	13.2	ksi	OK

Shear Check

Total Load =	164	psf				
w =	2.82	klf				
R =	19.7	k				
f_v =	9.1	ksi				
Fv =	20	ksi	>	9.1	ksi	OK

Appendix C: Two Way Flab Slab Analysis

TWO WAY FLAT SLAB

ASSUMPTIONS:

$f'_c = 4000$ psi $f_y = 60,000$ psi

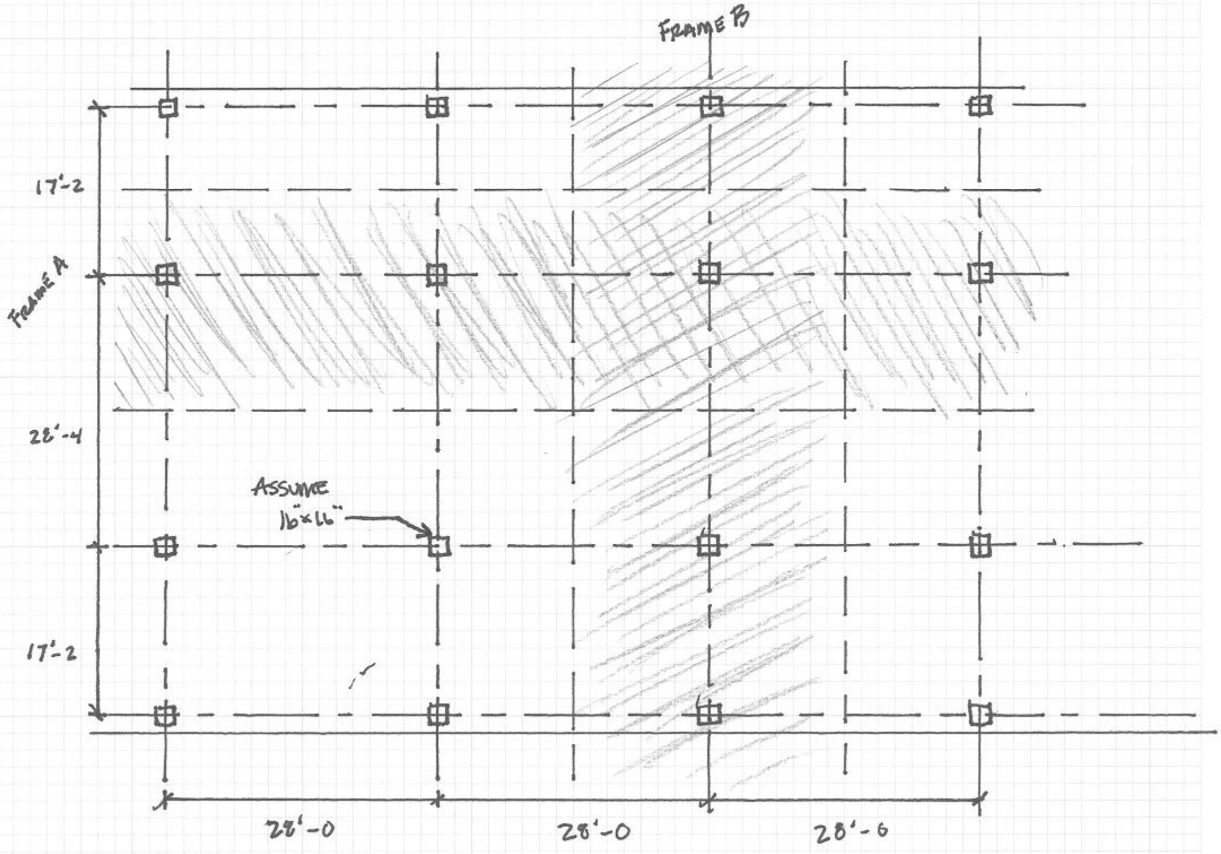
LOADING:

LIVE = 40 PSF

DEAD LOAD = 20 PSF (PARTITIONS)

SUPERIMPOSED DEAD LOAD = 19 PSF
(INCLUDES MEP, CEILING, SPRINKLERS, FINISHES)

TYPICAL INTERIOR BAY:



SLAB THICKNESS: BASED ON SHEAR w/ NO DROP PANEL

USING ACI 318-08, TABLE 9.5(c)

INT. PANEL

$t = \ell_n/33$; $\ell_n = 28'\text{-}4" - 10"/12 = 27.0\text{ ft}$

$$t_{min} = \frac{(27.0\text{ ft})(12\text{ in}/1\text{ FT})}{33} = 9.82" = 10" \Rightarrow \text{CONTROLS.}$$

$$W_u = 1.2\left[(10"/12)(145\text{ PCF}) + 39\text{ PSF}\right] + 1.6(40\text{ PSF}) = \underline{255.8\text{ PSF}}$$

SLAB THICKNESS: BASED ON SHEAR w/ NO DROP PANEL

USING ACI 318-08, TABLE 9.5(c)

EXT. PANEL

$t = \ell_n/30$; $\ell_n = 17.1667 - 10"/12 = 15.833'$

$$t_{min} = \frac{(15.833\text{ ft})(12\text{ in}/1\text{ FT})}{30}(1.1) = 6.966" = 7.0"$$

CHECK SHEAR:

$V_u = W_u \cdot \text{AREA}$

$$V_u = (255.8\text{ PSF})\left[(28\text{ ft})(28.333\text{ ft}) - \left(\frac{16 \times 16}{144}\right)\right]$$

$$V_u = 202.5^k = 203^k$$

PUNCHING SHEAR:

$b_o = 16"(4) = 64"$

* ASSUME THAT d IS 1" LESS THAN t_{min} $\therefore d = 9\text{ in}$.

$$\frac{b_o}{d} = \frac{64"}{9"} = 7.11$$

$\alpha_s = 40$, FOR INTERIOR COLUMNS

$$V_c = \text{MIN OF} \begin{cases} 4\sqrt{f'_c}\, b_o d = 4\sqrt{4100}(64")(9") = 145.7^k \\ (2 + 4/\beta_c)\sqrt{f'_c}\, b_o d = (2 + \frac{4}{1})(\sqrt{4000})(64")(9") = 218.6^k \\ \left(\frac{\alpha_s}{b_o/d} + 2\right)\sqrt{f'_c}\, b_o d = \left(\frac{40}{7.11} + 2\right)\sqrt{4000}(64")(9") = 277.8^k \end{cases}$$

$$\phi V_c = 0.75(145.7^k) = 109.3^k < 203^k$$

$\therefore$ NO GOOD, FIND NEW t_{min}.

FIND NEW t_{min} FOR CONTROLLING SHEAR:

$$V_u = \phi V_c = 4\sqrt{f'_c}\, b_o d =$$

$$\left(2 + {}^{4}/_{\beta_c}\right)\sqrt{f'_c}\, b_o d =$$

$$\left(\frac{\alpha_s}{\frac{b_o}{d}} + 2\right)\sqrt{f'_c}\, b_o d =$$

$$203^{k} = 0.75\,(4)\sqrt{4000}\,(64'')\,(d)$$

$$d_{max} = 16.8''$$

$$203^{k} = 0.75\,(2+4)\sqrt{4000}\,(64'')\,d$$

$$d_{max} = 11.15''$$

$$203^{k} = 0.75\left(\frac{40}{7.11} + 2\right)\sqrt{4000}\,(64'')\,d$$

$$d_{max} = 8.8''$$

* USING MAXIMUM d, WE FIND $d_{max} = 16.8''$ OR 17". THIS IS NOT ECONOMICAL THEREFORE LOOK INTO DROP PANELS.

<u>SLAB DESIGN USING DROP PANELS</u>:

USING ACI - 318-08, TABLE 9.5(c)

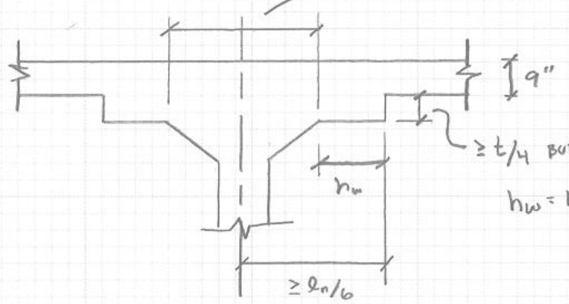
$$t_{min} = \ell_n/36$$

$$t_{min} = \frac{(27.0)(12^{in}/1FT)}{36} = 9'' \Rightarrow \underline{\text{CONTROLS}}.$$

SIZE DROP PANELS:

ACI 318-08
13.2.5, 13.3.7

0.20 to 0.25 of $\ell_{AVG} = (0.23)(28.1667)(12'')$
$= 78$ in $\Rightarrow$ 39 in ON EACH SIDE



$\geq t/4$ BUT $\leq h_w/4 = 3.5'' = t_d$

$h_w = 17$ in

$$\geq \ell_n/6 = \frac{(28^{ft})(12^{in}/ft)}{6} = 56 \text{ in}$$

FRAME A:

$$M_o = (1/8)(256\ PSF)(22.75')(28'\text{-}0 - 16/12)^2$$

$$M_o = 517.67\ k.ft$$

FRAME B:

$$M_o = (1/8)(256\ PSF)(28'\text{-}0)(22.75 - 16/12)^2$$

$$M_o = 411\ k.ft$$

PER ACI 318-08, 13.6.3.2

	FRAME A	FRAME B
M^-	$(0.65)(517.67) = 336.5\ k.ft$	$(0.65)(411) = 267.2\ k.ft$
M^+	$(0.35)(517.67) = 181.2\ k.ft$	$(0.35)(411) = 143.8\ k.ft$

MOMENT DISTRIBUTION

$\alpha_f = 0$ ∴ PER 13.6.4.1 & 13.6.4.4

$0.75 M^-$ to C.S & $0.25 M^-$ to M.S.

$0.60 M^+$ to C.S. & $0.40 M^+$ to M.S.

FRAME A

	M^-	M^+
M_{TOTAL}	-336.5	181.2
$M_{c.s.}$	-252.4	135.9
$M_{m.s}$	-84.1	45.3

FRAME B

	M^-	M^+
M_{TOTAL}	-267.2	143.8
$M_{c.s.}$	-200.4	107.9
$M_{m.s}$	-66.8	35.9

* ASSUMING #5 BARS AS REINFORCEMENT;

$$d_s = 9'' - 0.75'' - 0.625'' = 7.625'' - \left(\frac{0.625''}{2}\right) = 7.31''$$

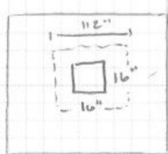
$$d_{DP} = 12.5'' - 0.75'' - 0.625'' = 11.125'' - \left(\frac{0.625''}{2}\right) = 10.81''$$

Item	Description	Frame A C.S. M^-	Frame A C.S. M^+	Frame A M.S. M^-	Frame A M.S. M^+	Frame B C.S. M^-	Frame B C.S. M^+	Frame B M.S. M^-	Frame B M.S. M^+
1	Moment	-252.4	135.9	-84.1	45.3	-200.4	107.9	-66.8	35.9
2	$d_{effective}$	11.125"	7.625"	7.625"	7.625"	10.81"	7.31"	7.31"	7.31"
3	b (Drop or Strip)	112"	136.5"	136.5"	136.5"	112"	136.5"	199.5"	199.5"
4	$M_n = M_u/\phi$	-280.4	151	-93.4	50.3	-222.7	119.9	-74.2	39.9
5	$R = M_n/bd^2\,(12000)$	-242.8	228.3	-141.2	76.1	-204.2	197.3	-83.5	44.9
6	Table A.5a ρ =	.0042	.0039	0.0024	.0013	.0035	.0034	.0014	.00074
7	$A_s = \rho b d$	5.23	4.06	2.50	1.35	4.24	3.39	2.04	1.10
8	$A_{s\,min} = 0.002bt$	5.26	2.46	2.46	2.46	5.26	2.46	3.6	3.6
9	$N = \frac{> \text{ of } 7 \text{ or } 8}{0.31}$	17	13	8	8	17	11	12	12
10	$N_{min} = \frac{\text{Width}}{2t}$	5	8	8	8	5	8	11	11

Check Shear:

$$d_{AVG} = \frac{(11.125 + 10.81)}{2} = 10.97 \text{ in @ Panel}$$

$$\text{Critical Section} = d/2 = \frac{10.97}{2} = 5.49''$$



28"

$$V_u = (256\text{ PSF})(28' \times 22.75' - 105.03)$$

$$V_u = 136.2^k$$

$$b_o = 491.92''$$

$$\frac{b_o}{d} = \frac{491.92}{10.97} = 44.84''$$

$$V_c = 4\sqrt{f'_c}\, b_o d = 4\sqrt{4000}\,(491.92)(10.97) = 1363.3^k$$

$$V_c = (2 + 4/\beta_c)\sqrt{f'_c}\, b_o d = (6)(\sqrt{4000})(491.92)(10.97) = 2047.8^k$$

$$V_c = \left(\frac{\alpha_s}{\frac{b_o}{d}} + 2\right)\sqrt{f'_c}\, b_o d = (2.89)\sqrt{4000}\,(491.92)(10.97) = 986.35^k$$

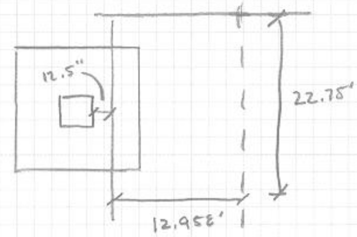
$$\phi V_c = 0.75(986.35^k) = 739.8^k > 136.2^k \quad \therefore \text{ OK!}$$

Beam Shear:

$V_u = w_u \cdot \text{Area}$

$= (256\ \text{psf})(294.80)$

$V_u = 75.5^k$

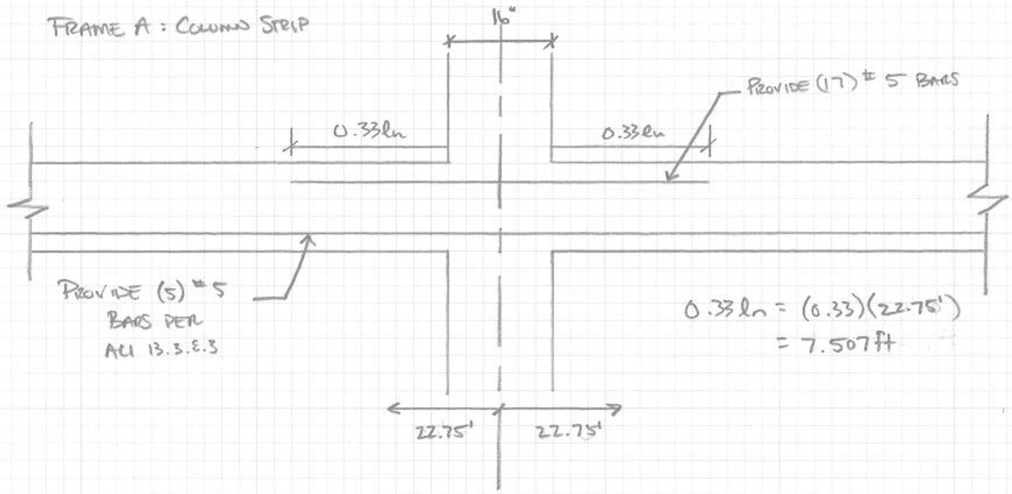


$\phi V_c = 0.75(2)\sqrt{4000}(22.75)(12)(7.625")$

$\phi V_c = 197.5^k > 75.5^k \quad \therefore$ OK!

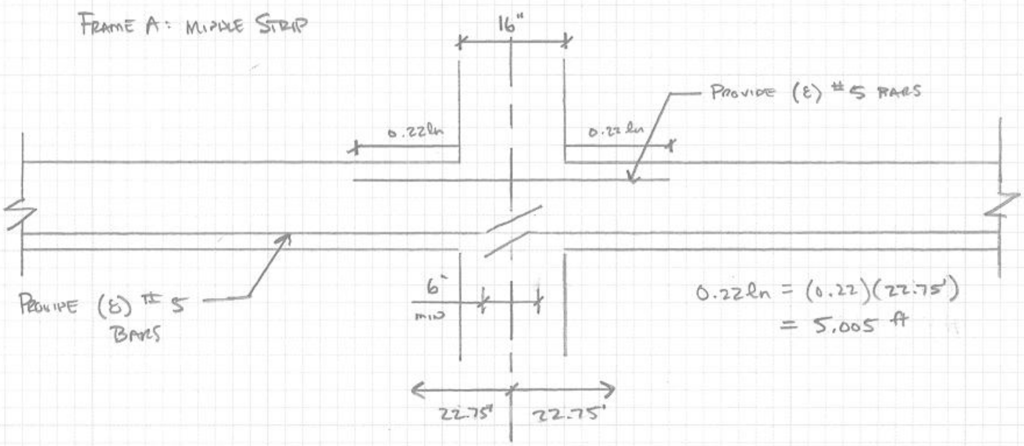
Sections cut through slab showing reinf. layout:

Frame A: Column Strip

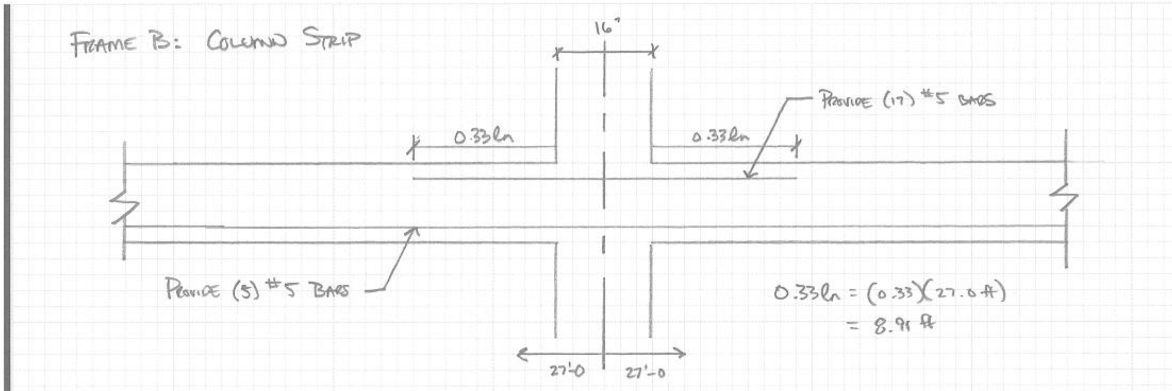


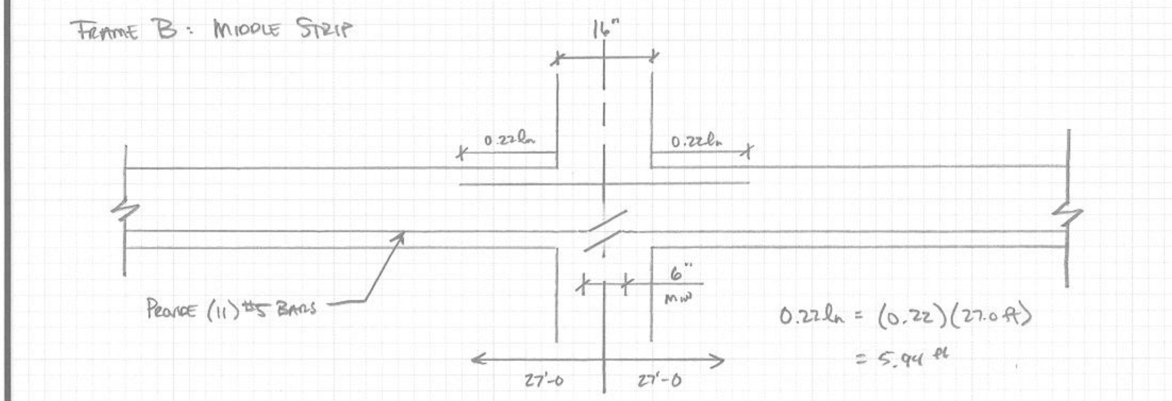
$0.33 l_n = (0.33)(22.75')$
$= 7.507 \text{ ft}$

Frame A: Middle Strip

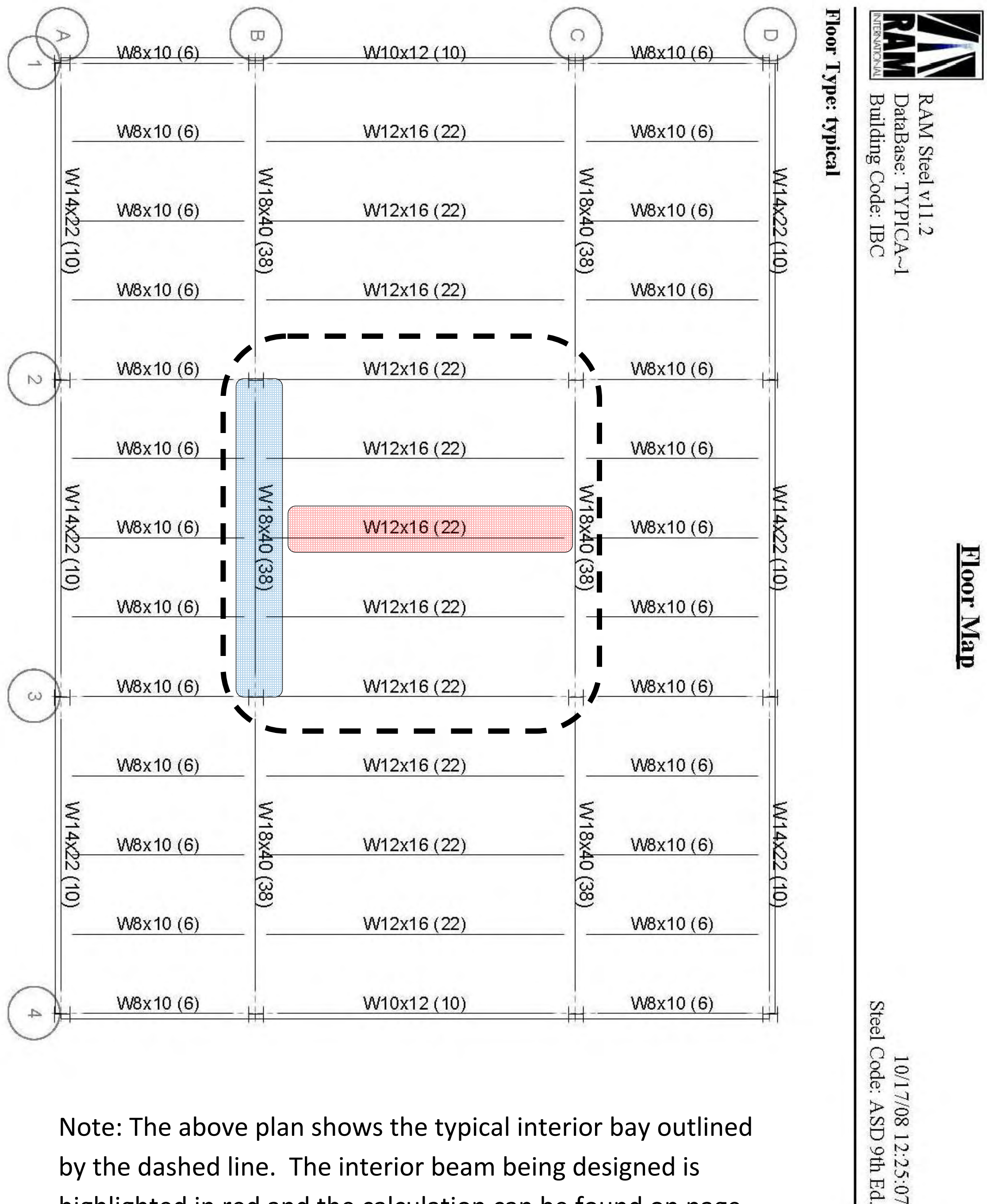


$0.22 l_n = (0.22)(22.75')$
$= 5.005 \text{ ft}$


FRAME B: COLUMN STRIP
16"
PROVIDE (17) #5 BARS
0.33ln
0.33ln
PROVIDE (5) #5 BARS
0.33ln = (0.33)(27.0 ft)
= 8.91 ft
27'-0
27'-0


FRAME B: MIDDLE STRIP
16"
0.22ln
0.22ln
6" MIN
PROVIDE (11) #5 BARS
0.22ln = (0.22)(27.0 ft)
= 5.94 ft
27'-0
27'-0

Appendix D: Composite Steel Floor Analysis



Note: The above plan shows the typical interior bay outlined by the dashed line. The interior beam being designed is highlighted in red and the calculation can be found on page 35. The interior girder is highlighted in blue and the design can be found on page 37.

Interior Gravity Beam (Denoted above in Red)

Gravity Beam Design

RAM Steel v11.2
DataBase: TYPICA~1
Building Code: IBC

10/17/08 12:25:07
Steel Code: ASD 9th Ed.

Floor Type: typical **Beam Number = 91**

SPAN INFORMATION (ft): I-End (70.00,45.50) J-End (70.00,73.83)

Beam Size (Optimum) = W12X16 Fy = 50.0 ksi
Total Beam Length (ft) = 28.33

COMPOSITE PROPERTIES (Not Shored):

	Left	Right
Concrete thickness (in)	2.50	2.50
Unit weight concrete (pcf)	145.00	145.00
f'c (ksi)	4.00	4.00
Decking Orientation	perpendicular	perpendicular
Decking type	VULCRAFT 1.5VL	VULCRAFT 1.5VL

beff (in)	=	84.00	Y bar(in)	=	13.42
Seff (in3)	=	30.99	Str (in3)	=	31.49
Ieff (in4)	=	411.65	Itr (in4)	=	422.74
Stud length (in)	=	3.50	Stud diam (in)	=	0.75

Stud Capacity (kips) q = 10.0
\# of studs: Full = 24 Partial = 22 Actual = 22
Number of Stud Rows = 1 Percent of Full Composite Action = 93.18

LINE LOADS (k/ft):

Load	Dist	DL	CDL	LL	Red%	Type	CLL
1	0.000	0.546	0.000	0.280	---	NonR	0.000
	28.333	0.546	0.000	0.280			0.000
2	0.000	0.016	0.016	0.000	---	NonR	0.000
	28.333	0.016	0.016	0.000			0.000

SHEAR: Max V (DL+LL) = 11.93 kips fv = 4.52 ksi Fv = 20.00 ksi

MOMENTS:

Span	Cond	Moment	@	Lb	Cb	Tension Flange		Compr Flange	
		kip-ft	ft	ft		fb	Fb	fb	Fb
Center	PreCmp+	1.6	14.2	0.0	1.00	1.13	33.00	1.13	33.00
	Max +	84.5	14.2	---	---				
	Mmax/Seff					32.72	33.00	---	---
	Mconst/Sx+Mpost/Seff					33.22	45.00	---	---
Controlling		84.5	14.2	---	---	32.72	33.00	---	---

fc (ksi) = 0.76 Fc = 1.80

REACTIONS (kips):

	Left	Right
Initial reaction	0.23	0.23
DL reaction	7.96	7.96
Max +LL reaction	3.97	3.97
Max +total reaction	11.93	11.93

DEFLECTIONS:

Initial load (in)	at	14.17 ft	=	-0.078	L/D	=	4370
Live load (in)	at	14.17 ft	=	-0.340	L/D	=	1000

Gravity Beam Design

RAM Steel v11.2
DataBase: TYPICA~1
Building Code: IBC

Page 2/2
10/17/08 12:25:07
Steel Code: ASD 9th Ed.

Post Comp load (in)	at	14.17 ft	=	-1.003	L/D	=	339
Net Total load (in)	at	14.17 ft	=	-1.081	L/D	=	314

Interior Gravity Girder (Denoted above in Blue)

Gravity Beam Design

RAM Steel v11.2
DataBase: TYPICA~1 10/17/08 12:25:07
Building Code: IBC Steel Code: ASD 9th Ed.

Floor Type: typical **Beam Number = 5**

SPAN INFORMATION (ft): I-End (56.00,73.83) J-End (84.00,73.83)

Beam Size (Optimum) = W18X40 Fy = 50.0 ksi
Total Beam Length (ft) = 28.00

COMPOSITE PROPERTIES (Not Shored):

	Left	Right
Concrete thickness (in)	2.50	2.50
Unit weight concrete (pcf)	145.00	145.00
f'c (ksi)	4.00	4.00
Decking Orientation	parallel	parallel
Decking type	VULCRAFT 1.5VL	VULCRAFT 1.5VL

beff (in)	= 84.00	Y bar(in)	=	17.25
Seff (in3)	= 99.29	Str (in3)	=	101.78
Ieff (in4)	= 1670.25	Itr (in4)	=	1755.39
Stud length (in)	= 3.50	Stud diam (in)	=	0.75

Stud Capacity (kips) q = 13.3
\# of studs: Full = 46 Partial = 38 Actual = 38
Number of Stud Rows = 1 Percent of Full Composite Action = 85.66

POINT LOADS (kips):

Dist	DL	CDL	RedLL	Red%	NonRLL	StorLL	Red%	RoofLL	Red%	CLL
7.000	4.77	0.09	0.00	0.0	2.40	0.00	0.0	0.00	Snow	0.00
7.000	7.96	0.23	0.00	0.0	3.97	0.00	0.0	0.00	Snow	0.00
14.000	4.77	0.09	0.00	0.0	2.40	0.00	0.0	0.00	Snow	0.00
14.000	7.96	0.23	0.00	0.0	3.97	0.00	0.0	0.00	Snow	0.00
21.000	4.77	0.09	0.00	0.0	2.40	0.00	0.0	0.00	Snow	0.00
21.000	7.96	0.23	0.00	0.0	3.97	0.00	0.0	0.00	Snow	0.00

LINE LOADS (k/ft):

Load	Dist	DL	CDL	LL	Red%	Type	CLL
1	0.000	0.040	0.040	0.000	---	NonR	0.000
	28.000	0.040	0.040	0.000			0.000

SHEAR: Max V (DL+LL) = 29.22 kips fv = 5.18 ksi Fv = 20.00 ksi

MOMENTS:

Span	Cond	Moment	@	Lb	Cb	Tension Flange		Compr Flange	
		kip-ft	ft	ft		fb	Fb	fb	Fb
Center	PreCmp+	8.3	14.0	7.0	1.13	1.46	30.00	1.46	28.94
	Max +	271.4	14.0	---	---				
	Mmax/Seff					32.80	33.00	---	---
	Mconst/Sx+Mpost/Seff					33.25	45.00	---	---
Controlling		271.4	14.0	---	---	32.80	33.00	---	---

fc (ksi) = 1.05 Fc = 1.80

REACTIONS (kips):

Gravity Beam Design

RAM Steel v11.2
DataBase: TYPICA~1
Building Code: IBC

Page 2/2
10/17/08 12:25:07
Steel Code: ASD 9th Ed.

	Left	Right
Initial reaction	1.03	1.03
DL reaction	19.66	19.66
Max +LL reaction	9.55	9.55
Max +total reaction	29.22	29.22

DEFLECTIONS:

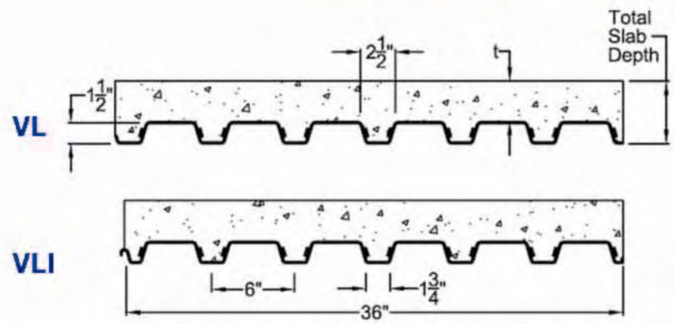
Initial load (in)	at	14.00 ft	=	-0.064	L/D	=	5214
Live load (in)	at	14.00 ft	=	-0.247	L/D	=	1361
Post Comp load (in)	at	14.00 ft	=	-0.728	L/D	=	461
Net Total load (in)	at	14.00 ft	=	-0.793	L/D	=	424

Vulcraft Composite Steel Deck Properties

VULCRAFT

1.5 VL, VLI

Maximum Sheet Length 42'-0
Extra Charge for Lengths Under 6'-0
ICBO Approved (N0. 3415)



Interlocking side lap is not drawn to show actual detail.

STEEL SECTION PROPERTIES

Deck Type	Design Thickness in	Deck Weight psf	Section Properties I_p in^4/ft	S_p in^3/ft	I_n in^4/ft	S_n in^3/ft	V_a lbs/ft	F_y ksi
1.5VL22	0.0295	1.78	0.143	0.169	0.177	0.179	2754	50
1.5VL20	0.0358	2.14	0.186	0.224	0.222	0.231	3322	50
1.5VL19	0.0418	2.49	0.230	0.271	0.260	0.282	3857	50
1.5VL18	0.0474	2.82	0.272	0.311	0.295	0.324	4350	50
1.5VL16	0.0598	3.54	0.373	0.404	0.373	0.411	4336	40

(N=9.35) NORMAL WEIGHT CONCRETE (145 PCF)

TOTAL SLAB DEPTH	DECK TYPE	SDI Max. Unshored Clear Span 1 SPAN	2 SPAN	3 SPAN	Superimposed Live Load, PSF Clear Span (ft.-in.) 5'-0	5'-6	6'-0	6'-6	7'-0	7'-6	8'-0	8'-6	9'-0	9'-6	10'-0	10'-6	11'-0	11'-6	12'-0
3.50 (t=2.00) 33 PSF	1.5VL22	5'-10	7'-10	7'-10	314	279	230	206	186	169	154	141	130	120	111	100	87	76	67
	1.5VL20	7'-0	9'-4	9'-6	345	306	275	249	227	187	171	157	144	133	124	108	94	82	73
	1.5VL19	7'-11	10'-3	10'-8	372	330	296	268	244	224	186	171	157	145	134	116	101	88	78
	1.5VL18	8'-8	11'-0	11'-2	385	351	315	285	260	238	220	204	168	156	142	123	107	94	82
	1.5VL16	8'-10	11'-0	11'-4	397	353	316	286	261	239	221	205	169	156	145	135	119	105	92
4.00 (t=2.50) 39 PSF	1.5VL22	5'-6	7'-5	7'-5	366	325	267	239	216	196	179	164	151	139	129	119	111	103	96
	1.5VL20	6'-7	8'-10	8'-11	400	356	319	289	239	217	198	182	167	155	143	133	124	115	108
	1.5VL19	7'-5	9'-9	10'-1	400	383	344	311	283	235	215	197	182	168	156	145	135	126	115
	1.5VL18	8'-1	10'-5	10'-7	400	400	365	330	301	276	254	211	194	180	167	156	145	136	122
	1.5VL16	8'-3	10'-5	10'-9	400	400	365	330	301	276	255	211	194	180	167	155	145	136	127
4.50 (t=3.00) 45 PSF	1.5VL22	5'-3	7'-1	7'-1	400	345	307	275	248	225	205	188	173	159	147	136	127	118	109
	1.5VL20	6'-3	8'-5	8'-6	400	400	366	303	274	249	227	208	192	177	164	152	142	132	123
	1.5VL19	7'-1	9'-3	9'-7	400	400	383	356	325	269	246	226	208	192	179	166	155	144	135
	1.5VL18	7'-8	9'-11	10'-1	400	400	400	378	344	316	262	241	222	206	191	178	166	155	145
	1.5VL16	7'-10	9'-11	10'-3	400	400	400	377	344	315	262	240	222	205	190	177	165	155	145
5.00 (t=3.50) 51 PSF	1.5VL22	5'-0	6'-9	6'-9	400	391	347	311	280	254	232	213	195	180	167	154	143	133	124
	1.5VL20	6'-0	8'-1	8'-2	400	400	400	343	310	281	257	236	217	200	186	172	160	149	139
	1.5VL19	6'-9	8'-11	9'-2	400	400	400	400	335	304	278	255	235	218	202	188	175	163	153
	1.5VL18	7'-3	9'-6	9'-8	400	400	400	400	389	324	297	272	251	233	216	201	187	175	164
	1.5VL16	7'-5	9'-6	9'-10	400	400	400	400	388	323	295	271	250	232	215	200	187	175	164
5.50 (t=4.00) 57 PSF	1.5VL22	4'-10	6'-6	6'-6	400	400	388	348	314	285	260	238	219	202	186	173	160	149	138
	1.5VL20	5'-9	7'-9	7'-10	400	400	400	383	346	314	287	263	243	224	208	193	179	167	156
	1.5VL19	6'-5	8'-6	8'-9	400	400	400	400	374	340	311	286	263	243	226	210	196	183	171
	1.5VL18	7'-0	9'-1	9'-4	400	400	400	400	400	363	331	305	281	260	241	225	210	196	183
	1.5VL16	7'-1	9'-2	9'-5	400	400	400	400	400	361	330	303	279	259	240	224	209	195	183
6.00 (t=4.50) 63 PSF	1.5VL22	4'-8	6'-4	6'-4	400	400	400	385	347	315	288	263	242	223	206	191	178	165	153
	1.5VL20	5'-6	7'-5	7'-6	400	400	400	400	383	348	318	292	269	248	230	213	199	185	173
	1.5VL19	6'-2	8'-2	8'-5	400	400	400	400	400	377	344	316	291	270	250	232	217	202	189
	1.5VL18	6'-8	8'-9	9'-0	400	400	400	400	400	400	367	337	311	288	267	249	232	217	203
	1.5VL16	6'-10	8'-10	9'-1	400	400	400	400	400	399	365	335	309	286	266	248	231	216	202

VULCRAFT

FLOOR-CEILING ASSEMBLIES WITH COMPOSITE DECK

Vulcraft Decks have been tested by Underwriters Laboratories Inc. for their Fire Resistance Ratings. In as much as new listings are continually being added, please contact the factory if your required design is not listed below. The cellular decks listed comply with U.L. 209 for use as Electrical Raceways.

Restrained Assembly Rating	Type of Protection	Concrete Thickness & Type (1)	U.L. Design No. (2,3,4)	Classified Deck Type: Fluted Deck	Classified Deck Type: Cellular Deck (5)	Unrestrained Beam Rating
¾ Hr.	Unprotected Deck	2 ½" LW	D914 #	1.5VL,1.5VLI,2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1 Hr.
			D916 #	1.5VL,1.5VLI,2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1,1.5,2,3 Hr.
1 Hr.	Exposed Grid	2 ½" NW	D216 +	1.5VL,1.5VLI,2VLI,3VLI	2VLP, 3VLP	2,3 Hr.
	Cementitious	2" NW&LW	D743 *	2VLI,3VLI	2VLP, 3VLP	1,1.5,2,3 Hr.
		2 ½" NW&LW	D703 *	1.5VLI,2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1.5 Hr.
			D712 *	3VLI	3VLP	2 Hr.
			D722 *	2VLI,3VLI	2VLP, 3VLP	1,1.5,2 Hr.
			D739 *	1.5VLI,2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1,1.5,2,3,4 Hr.
			D759	1.5VL,1.5VLI,2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1,1.5,2,3 Hr.
	Sprayed Fiber	2" NW&LW	D859 *	2VLI,3VLI	2VLP, 3VLP	1,1.5,2,3 Hr.
		2 ½" NW&LW	D832 *	1.5VLI,2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1,1.5,2,3 Hr.
			D847 *	2VLI,3VLI	3VLP	1,1.5,3 Hr.
			D858 *	2VLI,3VLI	2VLP, 3VLP	1,1.5,2,4 Hr.
			D871 *	2VLI,3VLI	2VLP, 3VLP	1,1.5,2,3 Hr.
	Unprotected Deck	2 ½" LW	D902 #	1.5VL,1.5VLI,2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1,1.5 Hr.
			D914 #	1.5VL,1.5VLI,2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1 Hr.
			D916 #	1.5VL,1.5VLI,2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1,1.5,2,3 Hr.
			D918 #	1.5VL,1.5VLI,2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1,1.5 Hr.
			D919 #	1.5VL,1.5VLI,2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1,1.5 Hr.
		3 ½" NW	D902 #	1.5VL,1.5VLI,2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1,1.5 Hr.
			D916 #	1.5VL,1.5VLI,2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1,1.5,2,3 Hr.
			D918 #	1.5VL,1.5VLI,2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1,1.5 Hr.
			D919 #	1.5VL,1.5VLI,2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1,1.5 Hr.
1½ Hr.	Gypsum Board	2 ½" NW	D502 *	1.5VL,1.5VLI,2VLI,3VLI	2VLP, 3VLP	1.5,2 Hr.
	Cementitious	2" NW&LW	D743 *	2VLI,3VLI	2VLP, 3VLP	1,1.5,2,3 Hr.
		2 ½" NW&LW	D703 *	1.5VLI,2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1.5 Hr.
			D712 *	3VLI	3VLP	2 Hr.
			D722 *	2VLI,3VLI	2VLP, 3VLP	1,1.5,2 Hr.
			D739 *	1.5VLI,2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1,1.5,2,3,4 Hr.
			D759	1.5VL,1.5VLI,2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1,1.5,2,3 Hr.
	Sprayed Fiber	2" NW&LW	D859 *	2VLI,3VLI	2VLP, 3VLP	1,1.5,2,3 Hr.
		2 ½" NW&LW	D832 *	1.5VLI,2VLI,3VLI	3VLP	1,1.5,2,3 Hr.
			D847 *	2VLI,3VLI	3VLP	1,1.5,3 Hr.
			D858 *	2VLI,3VLI	2VLP, 3VLP	1,1.5,2,4 Hr.
			D871 *	2VLI,3VLI	2VLP, 3VLP	1,1.5,2,3 Hr.
	Unprotected Deck	3" LW	D902 #	1.5VL,1.5VLI,2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1,1.5 Hr.
			D916 #	1.5VL,1.5VLI,2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1,1.5,2,3 Hr.
			D919 #	1.5VL,1.5VLI,2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1,1.5 Hr.
		4" NW	D902 #	1.5VL,1.5VLI,2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1,1.5 Hr.
			D916 #	1.5VL,1.5VLI,2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1,1.5,2,3 Hr.
			D918 #	1.5VL,1.5VLI,2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1,1.5 Hr.
			D919 #	1.5VL,1.5VLI,2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1,1.5 Hr.
2 Hr.	Exposed Grid	2 ½" NW	D216 +	1.5VL,1.5VLI,2VLI,3VLI	2VLP, 3VLP	2,3 Hr.
	Gypsum Board	2 ½" NW	D502 +	1.5VL,1.5VLI,2VLI,3VLI	2VLP, 3VLP	1.5,2 Hr.
	Cementitious	2" NW&LW	D743 *	2VLI,3VLI	2VLP, 3VLP	1,1.5,2,3 Hr.
		2 ½" LW	D746 *	1.5VLI		1,1.5,2,3 Hr.
			D752 *	1.5VLI,2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1,1.5,2, Hr.
		2 ½" NW&LW	D703 *	1.5VLI,2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1.5 Hr.
			D712 *	3VLI	3VLP	2 Hr.
			D716 *	1.5VLI,2VLI,3VLI	2VLP, 3VLP	1.5,2 Hr.
			D722 *	2VLI,3VLI	2VLP, 3VLP	1,1.5,2 Hr.
			D739 *	1.5VLI,2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1,1.5,2,3,4 Hr.
			D745 *	2VLI,3VLI		1,1.5,2, Hr.
			D750 *	1.5VLI,2VLI,3VLI		1.5,2 Hr.
			D755	1.5VLI,2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1,1.5,2,3 Hr.
			D759	1.5VL,1.5VLI,2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1,1.5,2,3 Hr.
			D760 *	2VLI,3VLI		1,1.5,2,3,4 Hr.
		2 ½" NW	D730 *	2VLI,3VLI	2VLP, 3VLP	1.5,2 Hr.
			D742 *	1.5VLI,2VLI,3VLI		1,1.5 Hr.

NUCOR VULCRAFT GROUP