Drexel University Race Street Dormitory

Technical Report II
Douglas Tower
Structural
10/27/06
Advisor: Parfitt

I. Executive Summary

This report compares the existing structural system with five (5) alternatives that are analyzed and discussed in comparison. The existing system is steel frame and hollow core planks, with two bays horizontally and many longitudinally. The planks are 10” deep with 18” deep beams. For architectural reasons, the column grid will not change, with column to column distances range from 22’ to 30’.

Proposed alternatives are composite deck and steel frame, girder-slabs and steel frame, two way slab with drop panels and concrete columns, post-tensioned two way slab with drop panels and concrete columns, and waffle slab with concrete columns. Each system is spot analyzed for a conservative estimate of system sizing. Each system is compared in a chart on page 11 based on criteria of floor and column thickness, cost, and time for construction. The particular architectural importance of a flat slab vs. beams in this building and time for construction must be analyzed further.

Composite slab and post-tensioned two way slab seem to compete with the existing hollow core planks based on these criteria. Girder slabs probably would as well, but they cannot handle the high spans of the column grid, and therefore fail as an alternative. The composite slab conveniently uses the existing columns and lateral system. The benefits and disadvantages of a new general lateral system for the post-tensioned concrete slab system must be further analyzed, as well as the possibility of unwanted larger concrete column sizes to resist lateral loading. Overall, a post-tensioned two way slab is the best alternative, at a thickness of around 9” and 9” drop panels on 12” square columns.

II. Existing Building and Loading

The Race Street Dormitory is a twelve story, L-shaped dormitory in Philadelphia, PA that resists gravity loads, wind loads, seismic loads, snow loads. Gravity Loads include the weight of steel members, hollow-core concrete planks, mechanical systems, finish conditions, and steel stud partitions and facade, live loads, and snow loads. Table 1 compares design values of live loads, dead loads, and snow loads with those determined in this report. The ground floor and first floor house basic mechanical and administrative facilities for the building, including lobbies, mail, mechanical and electrical rooms, and are thereby subject to higher loads than the other floors of the building as noted in Table 1. Floors two through eleven are typical student residence floors with live loading a uniform 40 psf, or factored load of 64 psf. The first floor live loading is 100 psf, or factored 160 psf. For roof loads, roof snow load will be considered a uniform 27 psf (controls over roof live load of 20 psf), a factored 43.2 psf (See figures 1 and 2).

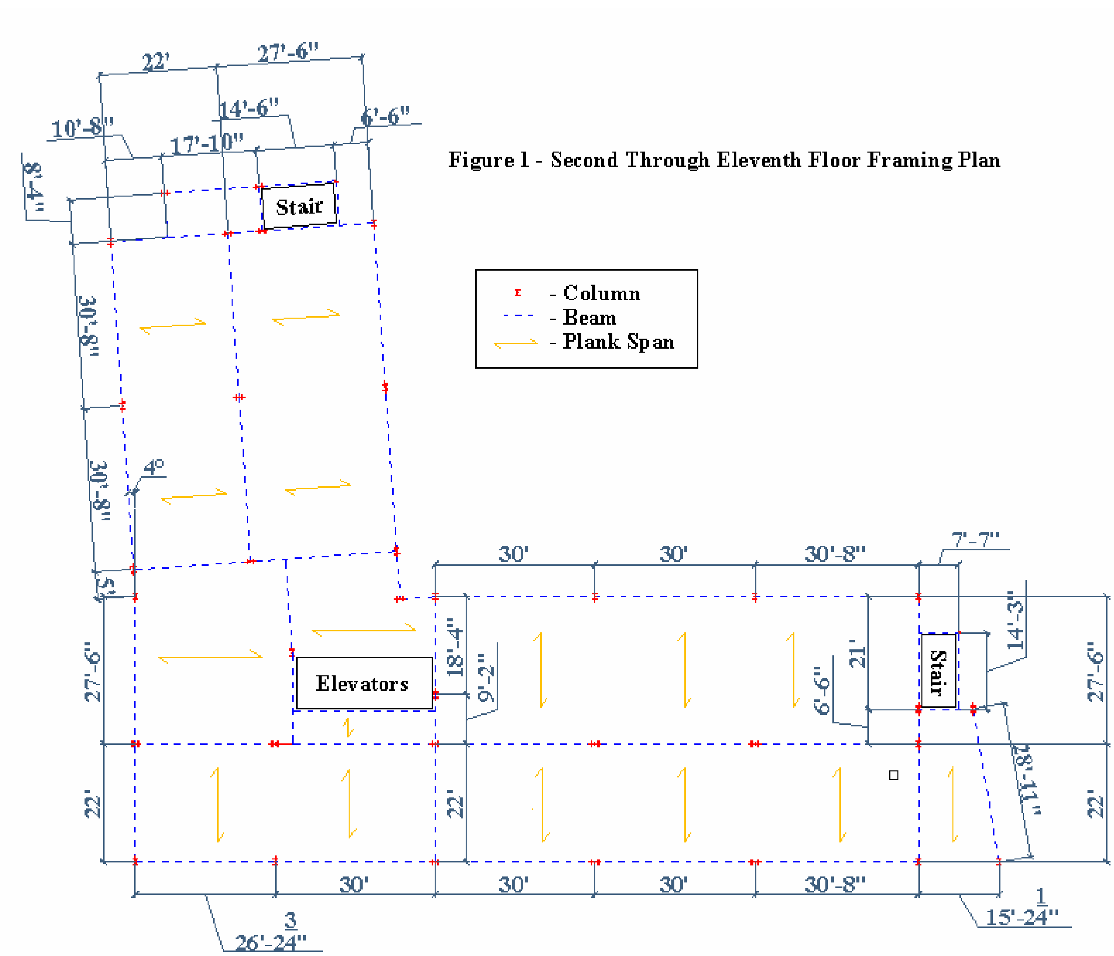
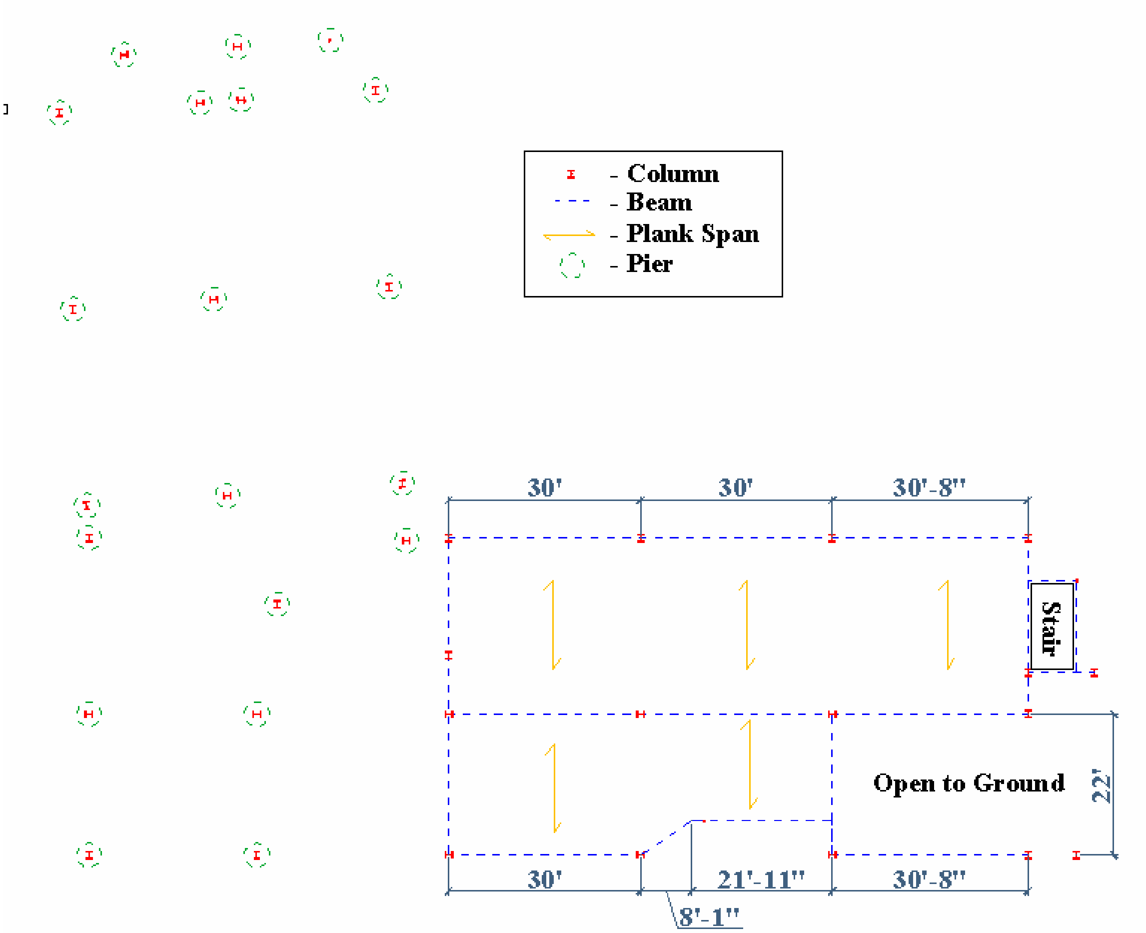


Figure 1 - Second Through Eleventh Floor Framing Plan

Figure 2 - First Floor Framing Plan



III. Existing Structural System

The residence hall is a steel W-shaped column and beam frame with moment connections and braced frames. The floor heights (column un-braced lengths) are 9'4" for floors two through eleven, 14' for level one, and 10' for ground level. Beams tend to run predominately longitudinally along the building, as floor planks span two horizontal bays. Beam sizes range from W12 to W18 (most common), and span up to 30'8". The third through eleventh floors have identical beam systems, while the beams at the first and second floors are unique and generally larger.

The roof is flat and consists of mainly W12 purlins spaced 6' on center and Grade 33 structural galvanized steel decking supporting EPDM single-ply membrane roofing over rigid insulation.

Each floor consists of pre-stressed pre-cast hollow core concrete planks 8" deep, typically 8' wide with 2" cast-in-place concrete topping. They are typically 22'8 or 28'2" long (8" overhang, typ.). The maximum depth of the floors is about 26" (roughly 18" beams and 8" decking), but, as noted before, beams do not frame each bay of the system, and are not intermediately placed within bays. This allows for long (up to 90') spans of 10" deep flooring (see fig. 1). **In general, the existing floor system is 10" deep and 28" deep over columns.**

IV. Design Goals/Criteria

The design goals of a new structural system are:

- Thin Floor- The thinner the floor, the greater the floor to floor height which can either make the building more attractive to residents, decrease the building height, or increase space and long runs for mechanical and electrical systems. Floor depths are usually not uniform, so other factors such as number of beams or beam depths are taken into account.
- Thin Columns- Columns interrupt the interior space if not concealed within the walls, and can be an architectural problem.
- Cost- Cheaper is often better.
- Construction time- slower construction means losing money, and more likelihood of delays.

V. Proposed Structural Systems and Analysis

The following four structural systems will be analyzed in place of the existing steel frame and pre-cast hollow-core concrete plank system. They include:

a) Steel frame with composite slab
b) Steel frame with girder-slab system
c) Concrete columns and flat slab with drop panels
d) Concrete columns and post-tensioned flat slab with drop panels
e) Concrete columns and waffle slab

The roofing system for options a) and b) will stay the existing system, while roofing for options c), d) and e) will match the typical flooring respectively.

Note: For a composite slab (part a) and girder-slab (part b) alternative flooring structure will be spot designed for a typical bay in floors two through eleven (see fig. 4). Column sizing is not particularly important.

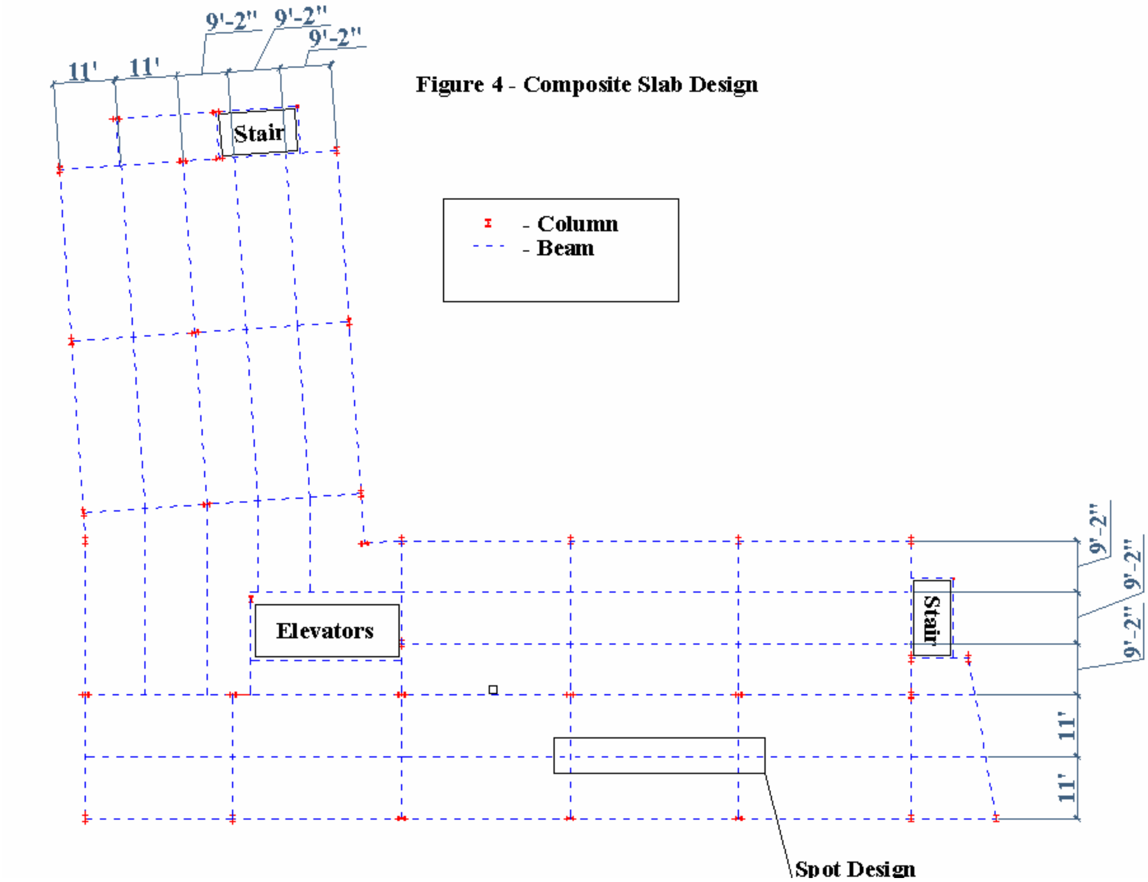


Figure 4 - Composite Slab Design

a) To design for steel frame and composite slab, the footprint of the existing steel frame is to be used, and columns and lateral bracing are to be the same. Composite slabs can only span up to 15', so in order to account for this, beams must be placed intermediately within the framing grid and existing beam sizes must be changed (see fig. 4). Based on a maximum unshored span of 11' (see fig. 4), A 16 gage 2" x 12" Steel Deck (2" Lok-Floor) with 5" deep f'c = 3 ksi and 145 pcf concrete can carry 210 psf Live Load, well over the 160 psf required for the first floor, and 64 psf for consecutive floors. With a suspended ceiling, the fire rating is about 2.5 hours for this system. For floors two through eleven, the spot checked beam (see fig. 4) is required to carry 190 ft-k and is sized at W12x26 with a depth of 12.2". This beam is representative of a beam that carries one of the larger loads over one of the longest spans of this floor plan, thereby a conservative estimate for most other beams in the plan for simple gravity loading. **In conclusion, a composite steel system will have a deck thickness of 5" with a depth of around 17.2" under beams that are far more prevalent than in the existing system.**

b) According to design aids on the Girder-Slab Technologies website, Steel members for the girder-slabs are only up to DB9x48 (9" depth), which is a far insignificant size to carry 30' spans under the given loading conditions. The system would work if these spans were half as long, but this would complicate the column grid severely. **In conclusion, girder-slab is not a viable choice.**

Note: For two way slabs (part c and d) and waffle slabs (part e) slab and drop panel sizes are estimated using CRSI design charts with 12’ ceilings and either 30’x30’ bays or 31’x31’ bays. This is due to the dormitory’s typical bay size of [30’ or 30’8”] x [22’ or 27’6”] and because the Direct Design Method cannot be used since there are not three continuous bays in either direction of the building. In order to maintain the same column grid, the dormitory will have two bays its least direction. Furthermore, concrete column sizes are important to impacting architectural requirements of the building, and although sized by gravity loads in this section, will probably become larger to resist lateral loads.

Figure 5 - Two Way Slab with Drop Panels

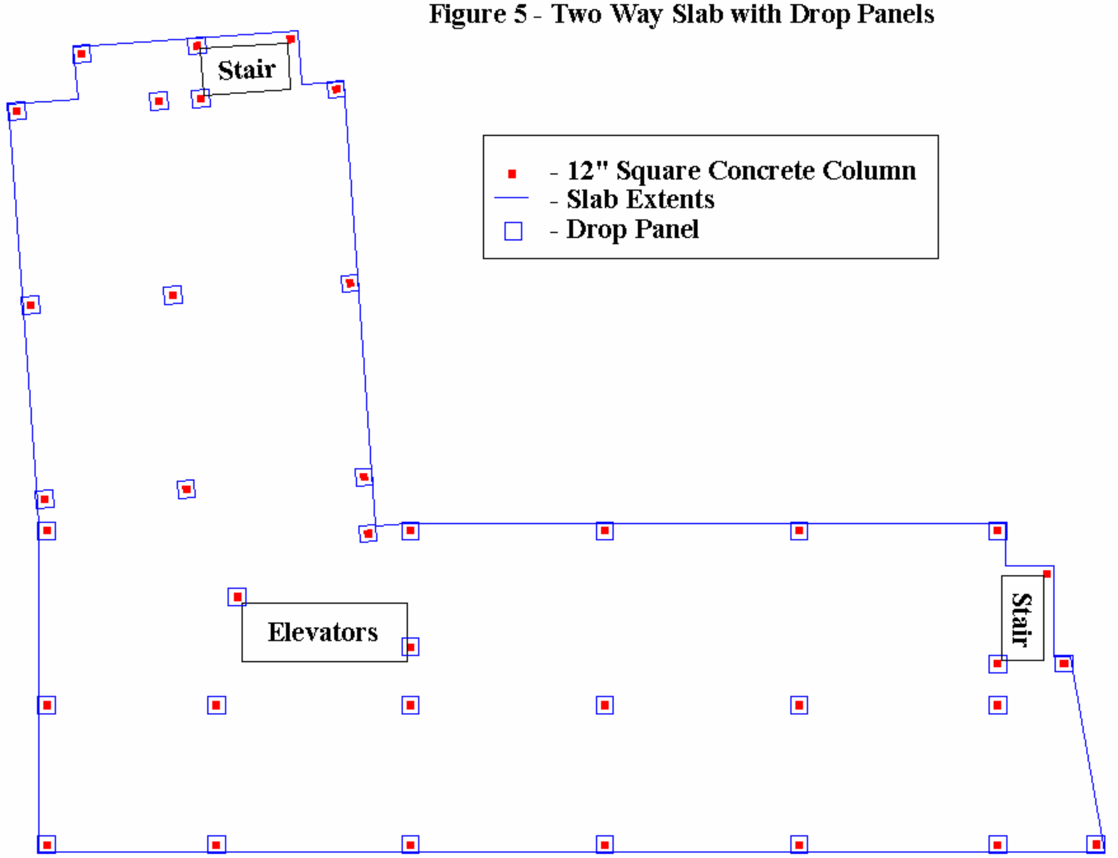
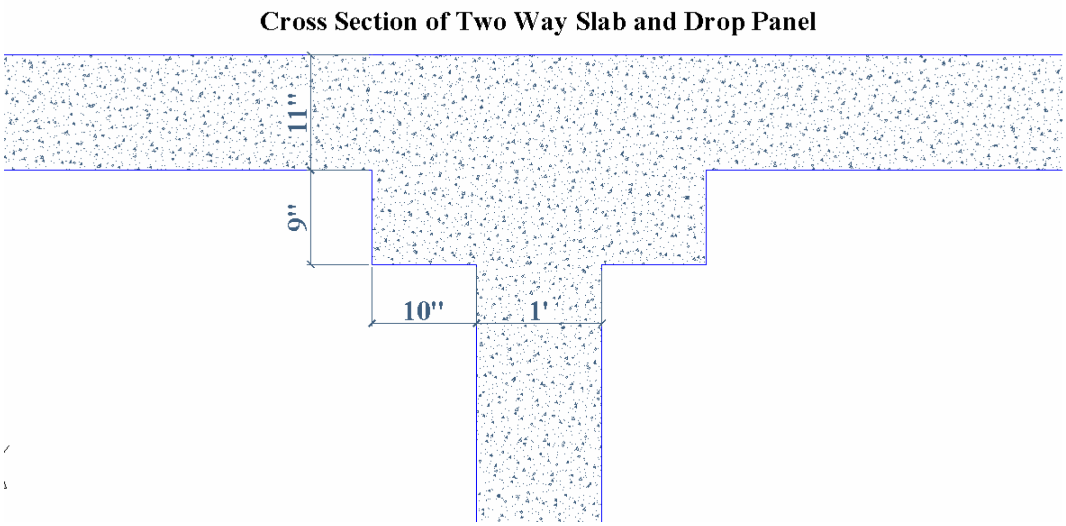


Figure 5b



c) Refer to figure 5. According to the CRSI manual, drop panels must be used for a slab over 28’ span. An 11” deep slab will be used due to it being the thinnest slab that can carry 31’ square bays. According to pg. 10-24 of the design manual, an 11” deep two way slab with 9” deep drop panels on 12” square columns (as shown in fig. 5b) can carry 100 psf factored live load in a 31’ x 31’ bay, more than the required 64 psf factored load. For a 30’ x 30’ bay, the drop panels decrease to 7”. These depths can also hold a 200 psf load with increased reinforcement, which satisfies the required 160 psf of the first floor. Drop panels are 10” to 10.33” larger than columns. Steel reinforcement weighs from 3.40 to 3.42 psf for edge panels, and 2.77 to 2.75 psf for interior panels. Concrete volumes range from 0.981 to 1.000 ft^3 per square foot of floors two through eleven. According to axial compression, a 12” square column is acceptable with this structural configuration (based on ground floor column axial load, see Table 2). **In conclusion, for this design the maximum required flooring design depth is 11” for the two way slab and 7”-9” deep for drop panels. The minimum design concrete column size is 12” square.**

d) With a post-tensioned slab, the design chart on page 121 of The Architect’s Studio Companion shows the slab thickness cut down from 11” to 9” for a 30’ span. Column sizes and drop panels remain the same size as with non post-tensioned slabs. This looks to be a much more reasonable thickness. The non-post-tensioned slabs, however, were based on a bay size larger than actual bays. For without post-tensioning, RS Means notes a 9.5” deep slab for a more accurate 25’x30’ bay estimation, which might suggest post tensioning is not needed to achieve this depth. More investigation is needed. **In conclusion, for post-tensioned two way slabs, the maximum required flooring design depth is 9” for the two way slab and 9” deep for drop panels. The minimum design concrete column size is 12” square.**

Figure 6 - Waffle Slab Design

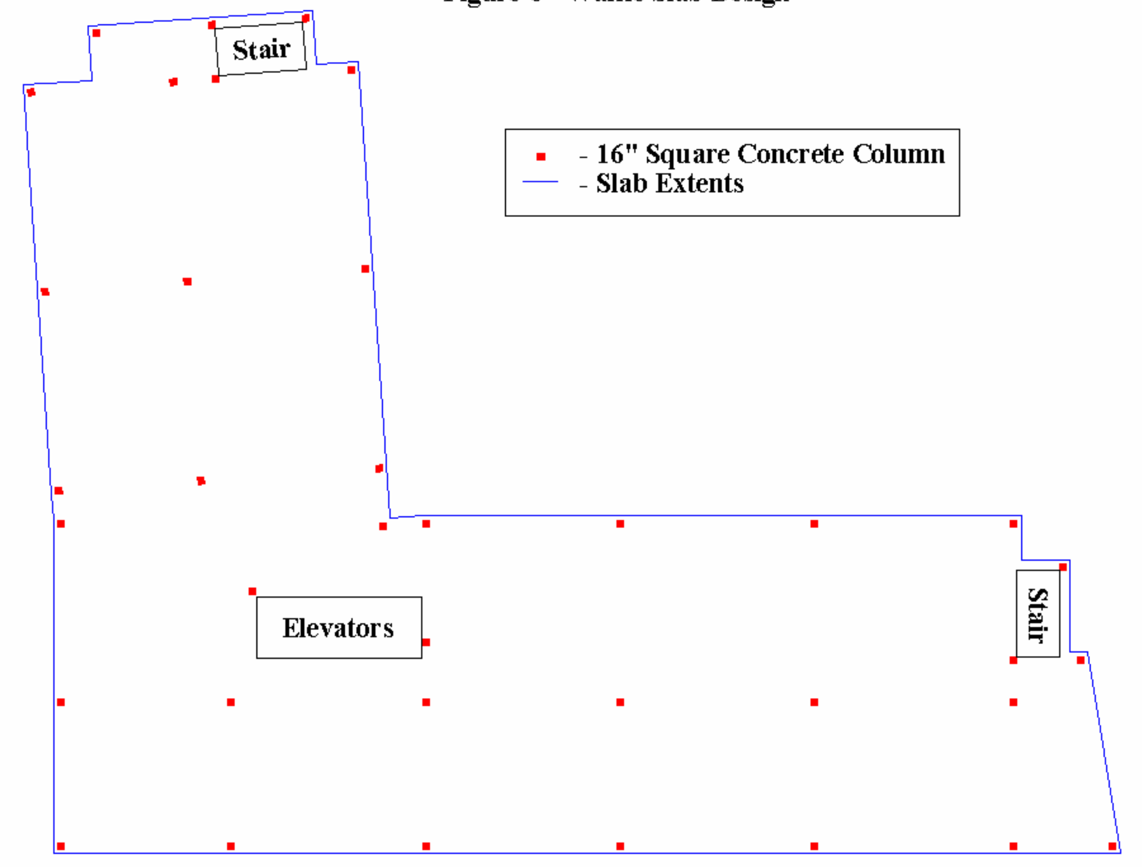
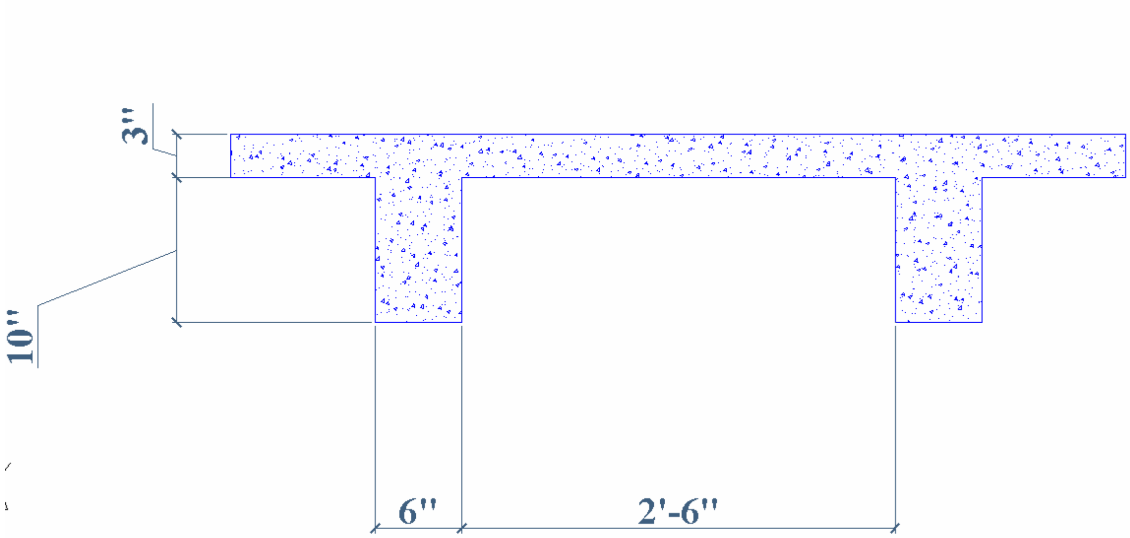


Figure 6b

Cross Section of Waffle Slab



e) Refer to figure 6. According to the CRSI manual, the waffle slab shown in cross section in fig. 6b can carry a 100 psf load over a 30' x 30' bay with 2.29 psf of steel weight and 15" square columns. For spans just over 30', this waffle slab and the 19" x 19" void waffle slab of the same depth both have punching shear problems at columns and require much larger column sizes. For the first floor with a factored load of 160 psf, waffle slabs jump to 15" deep and minimum 16" square columns. According to axial compression, a 16" square column can hold the gravity loads of the building (based on ground floor column axial load, see Table 3). This is the deepest flooring (sans beam depth) and the heaviest. Due to the thin top layer of 3" of concrete, the fire protection is also poor at only an up to 1 hr rating. **Overall, for a waffle slab the maximum required flooring design depth is 13" for the 2nd through 11th floor waffle slabs and 15" for the 1st floor. The minimum design concrete column is 16" square.**

VI. Summary of Alternative Systems

The four functioning alternative floor systems- composite slab, two way slab, post tensioned two way slab, and waffle slab differ in various ways. Each system costs roughly the same per square foot. The composite slab utilizes the existing columns and lateral system, but requires more beams and larger girders. The floor itself is thinner than the hollow core planks, and probably involves only slightly longer installment time than the existing due to the added 2" cover on the hollow core planks. Because of the added under floor space within bays, and since it is a time proven system, the composite slab should be considered as an alternative. This system was, however, however ruled out in the initial design due to the speed of plank construction. Further analysis is necessary. The waffle slab is probably an unwise choice for an alternative. The slab is slightly more expensive, much more complex to form on site, and much deeper than the other systems. A post tensioned two way slab is probably the most effective alternative at reaching the design goals, despite a longer time period for construction than hollow core planks. It is a thinner option with better fire protection. A new lateral system of shear walls and thicker columns will probably be necessary. At this stage in design, 12" square columns do not interrupt the interior space. Larger columns may be a problem and shear walls will be tricky to fit into the plan layout. This concrete system will not require any foundation changes, although the ground level exterior wall is pre-cast concrete that could be incorporated into a concrete structure better. Concrete can be left exposed throughout the building, unlike steel, which is covered in this building for aesthetic reasons.

VII. Comparison Chart

Comparison of Structural Systems						
	Existing Hollow Core Planks w/ Steel Frame	a) Composite Slab w/ Steel Frame	b) Girder Slab w/ Steel Frame	c) Two Way Slab w/ Drop Panels and Concrete Columns	d) Post-Tensioned Two Way Slab w/ Drop Panels and Concrete Columns	e) Waffle Slab w/ Concrete Columns
Floor Depth	10", 28" at beams	6", 24" at beams, deeper at girders	---------------	11", 20" at drop panels	9", 18" at drop panels	13"
Column Size Required (not considering lateral loads)	Mainly W12	Same as existing- mainly W12	Same as existing- mainly W12	12" square	12" square	16" square
Beams Required	mainly W18	Girders around each column bay with intermediate beams spaced 11' or 9'2"	FAILURE TO SPAN REQUIRED 30' TO MAINTAIN COLUMN GRID	none	none	none
Average Concrete Volume per ft^2	0.550 ft^3	0.333 ft^3	---------------	1.000 ft^3	1.000 ft^3	0.500 ft^3
Fire Rating	1 hr (4.5" net thickness)	2.5 hr	---------------	3 hr	3 hr	1 hr
Cost (per ft^2), assuming 25'x30' bays	$9.23 + steel members	$12.70	---------------	$11.36	$11.36 + post-tensioning	$13.50
Strengths	-planks easy/quick to erect	-thinnest system	---------------	-no beams	-no beams, relatively thin	-poor fire protection
	-relatively thin, few beams	- good fire protection	---------------	- excellent fire protection	-excellent fire protection	

	-poor fire protection		---------------			
Weaknesses	-depth could be slightly lower -beams	-cast in place is time consuming -need for many more framing members	--------------- ---------------	-cast in place and shoring is time consuming -depth	-cast in place and shoring is time consuming -tensioning is time consuming and requires further engineering	-cast in place is time consuming -depth

VIII. Conclusion

In conclusion, after reviewing the pros and cons of each system, the traditional composite slab with steel frame and the post-tensioned two way concrete slab with concrete columns are the two systems that are worthy of being further investigated. Construction time and further cost analysis will be further considered for each alternative in relation to the existing system. More accurate calculations of post-tensioned slab thickness will also follow this report for a more concise estimate.

IX. Tables

--Table 1

LOADING	Existing Design	This Design (IBC 2003)
Service Level Live Loads (psf)		
All floors, u.n.o.	40	40
Lobbies	100	100
Mechanical Rooms	250	250
Mechanical Penthouse Floor	250	250
Storage Rooms	200	250
Roof	20	20
Corridors	None	100
Elevator Machine Room Floor	125 + Machine Reactions	250
Dead Loads (psf)		
Partitions	15	15
Finish	Not noted	5
Mechanical	Not noted	5
Concrete Plank Weight	Not noted	82.5*
Steel Member Weight	Not noted	10
Roof Snow Load		
Ground Snow Load, Pg	20 psf	30 psf
Terrain Category	B	B
Exposure of Roof	Fully Exposed	Fully Exposed
Snow Exposure Factor, Ce	1	0.9

Thermal Factor, Ct	1	1
Snow Importance Factor, I	1	1
Flat Roof Snow Load, P	20 psf	27 psf

* - Changed from Technical Report 1 based on 2" concrete topping (Nitterhouse Concrete Products)

--Table 2

Two Way Slab- Ground Level Column Check		
Floor	Live Load (psf)	Dead Load (psf)
First Floor	100	175
Second Through Eleventh Floor	400	1750
Roof (snow controls)	27	180
Total Factored Load		3369.2
Maximum tributary area (ft^2)	30'x24.75'=	142.5
Load Carried (k)		480.11
Column Weight Above (k)	110ft*1ft^2*150 pcf=	16.5
Total Load (k)		496.61
Concrete compressive strength- f'c (psi)		4000
Uniform Load on Column (psi)		3448.69

ok

--Table 3

Waffle Slab- Ground Level Column Check		
Floor	Live Load (psf)	Dead Load (psf)
First Floor	100	100.7
Second Through Eleventh Floor	400	1007
Roof (snow controls)	27	105.7
Total Factored Load		2299.28
Maximum tributary area (ft^2)	30'x24.75'=	142.5
Load Carried (k)		327.65
Column Weight Above (k)	110ft*1.33ft^2*150 pcf=	22
Total Load (k)		349.65
Concrete compressive strength- f'c (psi)		4000
Uniform Load on Column (psi)		2428.11

ok

X. References

1) Chapters 10 and 11, Concrete Reinforcement Steel Institute (CRSI)

2) Nitterhouse Concrete Products
www.nitterhouse.com

3) Girder-Slab Technologies, LLC
www.girder-slab.com

4) Allen, Edward; Iano, Joseph, *The Architects Studio Companion*, 3rd Edition

5) RS Means Company, *Square Foot Costs*, 23rd Edition, 2002

XI. Calculations

Girder-Slab® System

D-Beam® Calculator Reference Tool

10/26/2006

Design Information

Dead Load =	60	psf
Partition Load =	0	psf
Live Load =	40	psf
Topping Load =	25	psf
DB Span =	30	ft
Plank Span =	28.17	ft
Grout f'c =	4	psi
Allowable Δ_{LL} = L /	360	
Allowable Δ_{LL} =	1.00	in

DB Properties

DB 9 x 46

DB Size ------------>

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	**b =**	5.75	in
t_w =	0.375	in			

Live Load Reduction (BOCA 96/99)

☐

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

Initial Load - Precomposite

M_{DL} =	190.1	ft-k	**>**	84.0	ft-k	**NO GOOD**
Δ_{DL} =	5.45	in				

Δ Ratio = L /	☐	66	
Camber D-Beam			(Check for Yes)
D-Beam Camber		0	

Total Load - Composite

M_{sup} =	206.0	ft-k				
M_{TL} =	396.1	ft-k				
S_{REQ} =	158.5	in^3	**>**	68.6	ft-k	**NO GOOD**
Δ_{SUP} =	3.23	in	**>**	1.00	in	**NO GOOD**
Δ_{TOT} =	8.68	in	= L/	41		

Superimposed Compressive Stress on Concrete

N value =	254.39	
S_{tc} =	17451	in^3

f_c =	0.14	ksi				
F_c =	0.00	ksi	**<**	0.14	ksi	**NO GOOD**

Bottom Flange Tension Stress (Total Load)

f_b =	75.6	ksi				
F_b =	45	ksi	**<**	75.6	ksi	**NO GOOD**

Shear Check

Total Load =	125	psf				
w =	3.52	klf				
R =	52.8	k				
f_v =	24.5	ksi				
Fv =	20	ksi	**<**	24.5	ksi	**NO GOOD**

Notice of Disclaimer:

Prestressed Concrete

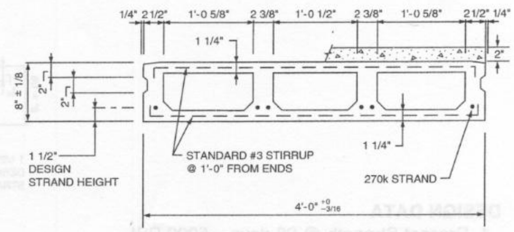
8" x 4' SpanDeck – U.L. – J917

(2" C.I.P. TOPPING)

PHYSICAL PROPERTIES

Composite

A' = 254 in.^{2}	S'$_b$ = 547 in.^{3}
I' = 2944 in.^{4}	S'$_t$ = 1124 in.^{3} (At Top of SpanDeck)
Y$_{b'}$ = 5.38 in.	S'$_{tt}$ = 637 in.^{3} (At Top of Topping)
Y$_t$' = 2.62 in. (To Top of SpanDeck)	Wt.' = 330 PLF
Y'$_{tt}$ = 4.62 in. (To Top of Topping)	Wt.' = 82.5 PSF



8" SPANDECK CROSS SECTION

UL FIRE RATED J917

DESIGN DATA

1. Precast Strength @ 28 days = 5000 PSI.
2. Precast Density = 150 PCF.
3. Strand = 1/2"ø, 270K Lo-Relaxation.
4. Composite Strength = 3000 PSI.
5. Composite Density = 150 PCF.
6. Strand Height = 1.5 in.
7. Ultimate moment capacities (when fully developed) . . .
   4 – 1/2"ø, 270K = 94.6'K
   6 – 1/2"ø, 270K = 133.3'K
8. Maximum bottom tensile stress is $6\sqrt{f'c}$ = 424 PSI.
9. All superimposed load is treated as live load in the strength analysis of flexure and shear.
10. Flexural strength capacity is based on stress/strain strand relationships.
11. Load values to the left of the solid line are controlled by ultimate strength. Load values to the right are controlled by service stress.
12. Shear values are the maximum allowable before shear reinforcement is required.
13. Deflection limits were not considered when determining allowable loads in this table.
14. All loads shown refer to allowable loads applied after topping has hardened.

8" SPANDECK W/2" TOPPING			ALLOWABLE SUPERIMPOSED LOAD (PSF)																					
STRAND PATTERN			SPAN (FEET)																					
			10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Flexure	4 –	1/2"ø	795	718	650	590	500	426	366	317	275	240	210	184	162	142	125	110	96	84	73	60	49	39	X
Shear	4 –	1/2"ø	571	509	458	415	378	347	320	296	275	257	240	222	199	178	160	145	133	126	115	103	93	84	X
Flexure	6 –	1/2"ø	1155	1040	945	859	732	629	544	474	416	366	324	287	256	228	204	183	164	147	132	118	103	90	77
Shear	6 –	1/2"ø	589	525	472	428	391	360	331	308	286	266	249	235	220	207	195	184	175	160	145	132	120	110	100

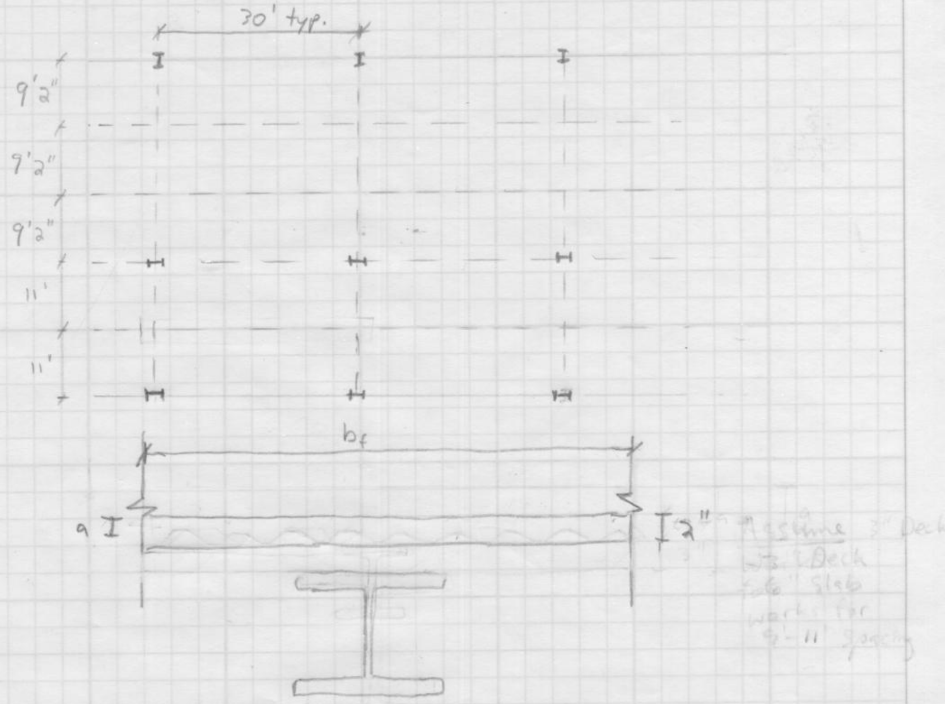
NITTERHOUSE
CONCRETE PRODUCTS

This table is for simple spans and uniform loads. Design data for any of these span-load conditions is available on request. Individual designs may be furnished to satisfy unusual conditions of heavy loads, concentrated loads, cantilevers, flange or stem openings and narrow widths.

2655 Molly Pitcher Hwy. South, Box N
Chambersburg, PA 17201-0813
717-267-4505 • FAX: 717-267-4518

REVISED 12/93

Composite Slab



Effective Width

$\frac{b_{eff}}{2} \le \frac{1}{8}(30) = 3'9" \rightarrow b_f = 7'6"$

$\frac{b_{eff}}{2} \le \frac{1}{2}(11) = 6'$

$F_y = 50$ ksi
$f'_c = 3$ ksi

~~$C_c = 0.85 f'_c b_{eff} t = 0.85(3)(90)(2) = 688.5^k$~~

~~$T_s = F_y A_s = 60 A_s \rightarrow A_s \ge 11.5 \text{ in}^2 \rightarrow W16\times40 \quad A_s = 11.8 \text{ in}^2$~~

$w = 1.2(.333(150) + 25) + 1.6(40) = 154$ psf

$M = \frac{w \, l_2 l_1^2}{8} = \frac{154(11)(30)^2}{8} = 190.5'^k$

$W12\times26 \rightarrow 197'^k \qquad \Sigma Q_N = 95.6^k$

Assume 1 weak stud per rib

$3/4''$ Studs

$Q_n = 17.2$

$\frac{95.6}{17.2} = 5.56$ Studs

Check a

$a = \frac{\Sigma Q_n}{0.85 f'_c b} = \frac{95.6}{0.85(3)(90)} = 0.42 < 2''$

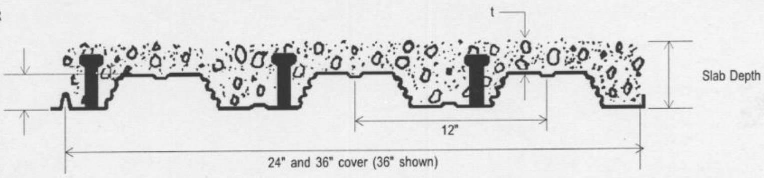
OK ✓

2 x 12" DECK F_y = 33ksi f'_c = 3 ksi 145 pcf concrete

USD United Steel Deck, Inc.

LRFD

2" LOK-FLOOR



The **Deck Section Properties** are per foot of width. The **I** value is for positive bending (in.[4]); **t** is the gage thickness in inches; **w** is the weight in pounds per square foot; S_p and S_n are the section moduli for positive and negative bending (in.[3]); R_b and ϕV_n are the interior reaction and the shear in pounds (per foot of width); studs is the number of studs required per foot in order to obtain the full resisting moment, ϕM_{nf}.

DECK PROPERTIES									
Gage	t	w	As	I	S_p	S_n	R_b	ϕV_n	studs
22	0.0295	1.5	0.440	0.338	0.284	0.302	714	1990	0.36
20	0.0358	1.8	0.540	0.420	0.367	0.387	1010	2410	0.43
19	0.0418	2.1	0.630	0.490	0.445	0.458	1330	2810	0.51
18	0.0474	2.4	0.710	0.560	0.523	0.529	1680	3180	0.57
16	0.0598	3.1	0.900	0.700	0.654	0.654	2470	3990	0.72

The **Composite Properties** are a list of values for the composite slab. The **slab depth** is the distance from the bottom of the steel deck to the top of the slab in inches as shown on the sketch. U.L. ratings generally refer to the cover over the top of the deck so it is important to be aware of the difference in names. ϕM_{nf} is the factored resisting moment provided by the composite slab when the "full" number of studs as shown in the upper table are in place; inch kips (per foot of width). A_c is the area of concrete available to resist shear, in.[2] per foot of width. **Vol.** is the volume of concrete in ft.[3] per ft.[2] needed to make up the slab; no allowance for frame or deck deflection is included. **W** is the concrete weight in pounds per ft.[2]. S_c is the section modulus of the "cracked" concrete composite slab; in.[3] per foot of width. I_{av} is the average of the "cracked" and "uncracked" moments of inertia of the transformed composite slab; in.[4] per foot of width. The I_{av} transformed section analysis is based on steel; therefore, to calculate deflections the appropriate modulus of elasticity to use is 29.5 x 10^6 psi. ϕM_{no} is the factored resisting moment of the composite slab if there are no studs on the beams (the deck is attached to the beams or walls on which it is resting) inch kips (per foot of width). ϕV_{nt} is the factored vertical shear resistance of the composite system; it is the sum of the shear resistances of the steel deck and the concrete but is not allowed to exceed $\phi 4(f'_c)^{1/2} A_c$; pounds (per foot of width). The next three columns list the **maximum unshored spans** in feet; these values are obtained by using the construction loading requirements of the SDI; combined bending and shear, deflection, and interior reactions are considered in calculating these values. A_{wwf} is the minimum area of welded wire fabric recommended for temperature reinforcing in the composite slab; square inches per foot.

COMPOSITE PROPERTIES													
	Slab Depth	ϕM_{nf} in.k	A_c in²	Vol. ft³/ft²	W psf	S_c in³	I_{av} in³	ϕM_{no} in.k	ϕV_{nt} lbs.	Max. unshored spans, ft. 1span	2span	3span	A_{wwf}
22 gage	4.50	40.27	32.6	0.292	42	1.05	5.9	29.40	5030	5.82	7.83	7.92	0.023
	5.00	46.44	37.5	0.333	48	1.23	8.0	34.53	5480	5.54	7.47	7.56	0.027
	5.25	49.53	40.0	0.354	51	1.32	9.2	37.16	5720	5.41	7.31	7.39	0.029
	5.50	52.61	42.6	0.375	54	1.42	10.5	39.81	5960	5.30	7.16	7.24	0.032
	6.00	58.78	48.0	0.417	60	1.61	13.5	45.21	6460	5.09	6.89	6.97	0.036
	6.25	61.87	50.8	0.438	63	1.71	15.3	47.95	6720	5.03	6.76	6.84	0.038
	6.50	64.95	53.6	0.458	66	1.81	17.1	50.70	6980	4.97	6.65	6.72	0.041
	7.00	71.12	59.5	0.500	73	2.01	21.2	56.26	7530	4.85	6.43	6.51	0.045
	7.25	74.21	61.9	0.521	76	2.11	23.5	59.07	7750	4.79	6.32	6.41	0.047
	7.50	77.29	64.3	0.542	79	2.21	26.0	61.88	7970	4.74	6.22	6.31	0.050
20 gage	4.50	48.60	32.6	0.292	42	1.26	6.3	35.43	5450	6.81	8.97	9.27	0.023
	5.00	56.18	37.5	0.333	48	1.48	8.6	41.65	5900	6.47	8.55	8.83	0.027
	5.25	59.96	40.0	0.354	51	1.60	9.8	44.84	6140	6.32	8.36	8.63	0.029
	5.50	63.75	42.6	0.375	54	1.71	11.3	48.07	6380	6.18	8.18	8.45	0.032
	6.00	71.32	48.0	0.417	60	1.95	14.5	54.63	6880	5.94	7.85	8.11	0.036
	6.25	75.11	50.8	0.438	63	2.07	16.3	57.96	7140	5.86	7.70	7.95	0.038
	6.50	78.90	53.6	0.458	66	2.19	18.2	61.31	7400	5.79	7.56	7.80	0.041
	7.00	86.47	59.5	0.500	73	2.43	22.6	68.09	7950	5.65	7.29	7.53	0.045
	7.25	90.26	61.9	0.521	76	2.55	25.0	71.50	8170	5.58	7.17	7.41	0.047
	7.50	94.05	64.3	0.542	79	2.67	27.6	74.93	8390	5.52	7.05	7.28	0.050
19 gage	4.50	55.85	32.6	0.292	42	1.45	6.7	40.69	5850	7.65	9.76	10.08	0.023
	5.00	64.68	37.5	0.333	48	1.71	9.0	47.87	6300	7.26	9.30	9.61	0.027
	5.25	69.10	40.0	0.354	51	1.84	10.4	51.56	6540	7.09	9.09	9.39	0.029
	5.50	73.52	42.6	0.375	54	1.97	11.9	55.30	6780	6.93	8.90	9.19	0.032
	6.00	82.35	48.0	0.417	60	2.24	15.2	62.90	7280	6.65	8.54	8.83	0.036
	6.25	86.77	50.8	0.438	63	2.38	17.1	66.76	7540	6.56	8.38	8.66	0.038
	6.50	91.19	53.6	0.458	66	2.52	19.2	70.65	7800	6.48	8.23	8.50	0.041
	7.00	100.03	59.5	0.500	73	2.80	23.8	78.50	8350	6.32	7.94	8.20	0.045
	7.25	104.44	61.9	0.521	76	2.94	26.3	82.46	8570	6.24	7.81	8.07	0.047
	7.50	108.86	64.3	0.542	79	3.08	29.0	86.45	8790	6.17	7.68	7.94	0.050
18 gage	4.50	62.08	32.6	0.292	42	1.62	7.0	45.34	6080	8.42	10.48	10.83	0.023
	5.00	72.04	37.5	0.333	48	1.90	9.5	53.36	6670	7.98	9.99	10.32	0.027
	5.25	77.02	40.0	0.354	51	2.05	10.9	57.48	6910	7.79	9.77	10.10	0.029
	5.50	82.00	42.6	0.375	54	2.20	12.4	61.66	7150	7.61	9.56	9.88	0.032
	6.00	91.95	48.0	0.417	60	2.50	15.9	70.18	7650	7.30	9.18	9.49	0.036
	6.25	96.93	50.8	0.438	63	2.66	17.9	74.50	7910	7.20	9.01	9.31	0.038
	6.50	101.91	53.6	0.458	66	2.81	20.0	78.85	8170	7.11	8.85	9.14	0.041
	7.00	111.87	59.5	0.500	73	3.13	24.8	87.66	8720	6.93	8.54	8.82	0.045
	7.25	116.85	61.9	0.521	76	3.28	27.4	92.10	8940	6.85	8.40	8.68	0.047
	7.50	121.83	64.3	0.542	79	3.44	30.2	96.57	9160	6.77	8.26	8.54	0.050
16 gage	4.50	62.08	32.6	0.292	42	1.99	7.7	45.34	6080	9.58	11.63	12.02	0.023
	5.00	72.04	37.5	0.333	48	2.35	10.4	53.36	6980	9.08	11.10	11.47	0.027
	5.25	77.02	40.0	0.354	51	2.53	11.9	57.48	7450	8.85	10.85	11.22	0.029
	5.50	82.00	42.6	0.375	54	2.72	13.6	61.66	7940	8.65	10.63	10.98	0.032
	6.00	91.95	48.0	0.417	60	3.10	17.4	70.18	8460	8.29	10.21	10.55	0.036
	6.25	96.93	50.8	0.438	63	3.29	19.5	74.50	8720	8.17	10.02	10.35	0.038
	6.50	101.91	53.6	0.458	66	3.48	21.8	78.85	8980	8.07	9.84	10.17	0.041
	7.00	111.87	59.5	0.500	73	3.88	27.0	87.66	9530	7.86	9.50	9.82	0.045
	7.25	116.85	61.9	0.521	76	4.08	29.8	92.10	9750	7.77	9.35	9.66	0.047
	7.50	121.83	64.3	0.542	79	4.28	32.8	96.57	9970	7.67	9.20	9.50	0.050

2" LOK-FLOOR

2 x 12" DECK F_y = 33ksi f'_c = 3 ksi   145 pcf concrete

			L_r Uniform Live Loads, psf *												
	Slab Depth	φMn in.k	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	12.00
22 gage	4.50	40.27	400	365	310	265	230	200	175	155	135	120	105	95	85
	5.00	46.44	400	400	360	305	265	230	200	175	155	140	125	110	95
	5.50	52.61	400	400	400	350	300	260	230	200	175	155	140	125	110
	6.00	58.78	400	400	400	390	335	295	255	225	200	175	155	140	125
	6.50	64.95	400	400	400	400	370	325	285	250	220	195	175	155	135
	7.00	71.12	400	400	400	400	400	355	310	275	240	215	190	170	150
	7.25	74.21	400	400	400	400	400	370	325	285	250	225	200	175	155
	7.50	77.29	400	400	400	400	400	385	340	295	260	230	205	185	165
20 gage	4.50	48.60	400	400	380	325	285	245	215	190	170	150	135	120	110
	5.00	56.18	400	400	400	380	330	285	250	220	195	175	155	140	125
	5.50	63.75	400	400	400	400	375	325	285	250	225	200	175	160	140
	6.00	71.32	400	400	400	400	400	365	320	285	250	225	200	180	160
	6.50	78.90	400	400	400	400	400	400	355	315	280	245	220	195	175
	7.00	86.47	400	400	400	400	400	400	390	345	305	270	240	215	195
	7.25	90.26	400	400	400	400	400	400	400	360	320	285	255	225	205
	7.50	94.05	400	400	400	400	400	400	400	375	330	295	265	235	210
19 gage	4.50	55.85	400	400	400	380	330	290	255	225	200	180	160	145	130
	5.00	64.68	400	400	400	400	385	335	295	260	230	205	185	165	150
	5.50	73.52	400	400	400	400	400	380	335	295	265	235	210	190	170
	6.00	82.35	400	400	400	400	400	400	375	335	295	265	235	215	190
	6.50	91.19	400	400	400	400	400	400	400	370	330	295	265	235	210
	7.00	100.03	400	400	400	400	400	400	400	400	360	320	290	260	235
	7.25	104.44	400	400	400	400	400	400	400	400	375	335	300	270	245
	7.50	108.86	400	400	400	400	400	400	400	400	395	350	315	280	255
18 gage	4.50	62.08	400	400	400	400	370	325	285	255	225	200	180	160	145
	5.00	72.04	400	400	400	400	400	375	335	295	260	235	210	190	170
	5.50	82.00	400	400	400	400	400	400	380	335	300	265	240	215	195
	6.00	91.95	400	400	400	400	400	400	400	375	335	300	270	245	220
	6.50	101.91	400	400	400	400	400	400	400	400	375	335	300	270	245
	7.00	111.87	400	400	400	400	400	400	400	400	400	365	330	295	270
	7.25	116.85	400	400	400	400	400	400	400	400	400	385	345	310	280
	7.50	121.83	400	400	400	400	400	400	400	400	400	400	360	325	290
16 gage	4.50	62.08	400	400	400	400	370	325	285	255	225	200	180	160	145
	5.00	72.04	400	400	400	400	400	375	335	295	260	235	210	190	170
	5.50	82.00	400	400	400	400	400	400	380	335	300	265	240	215	195
	6.00	91.95	400	400	400	400	400	400	400	375	335	300	270	245	220
	6.50	101.91	400	400	400	400	400	400	400	400	375	335	300	270	245
	7.00	111.87	400	400	400	400	400	400	400	400	400	365	330	295	270
	7.25	116.85	400	400	400	400	400	400	400	400	400	385	345	310	280
	7.50	121.83	400	400	400	400	400	400	400	400	400	400	360	325	290
22 gage	4.50	29.40	305	255	215	185	160	135	120	105	90	80	70	60	50
	5.00	34.53	360	305	255	220	185	160	140	120	105	95	80	70	65
	5.50	39.81	400	350	295	255	215	190	165	140	125	110	95	85	75
	6.00	45.21	400	400	340	290	250	215	185	160	140	125	110	95	85
	6.50	50.70	400	400	380	325	280	240	210	185	160	140	125	110	95
	7.00	56.26	400	400	400	360	310	270	235	205	180	155	140	120	105
	7.25	59.07	400	400	400	380	325	285	245	215	190	165	145	130	115
	7.50	61.88	400	400	400	400	345	295	260	225	200	175	155	135	120
20 gage	4.50	35.43	375	315	270	230	200	170	150	130	115	100	90	80	70
	5.00	41.65	400	375	315	270	235	205	175	155	135	120	105	95	85
	5.50	48.07	400	400	365	315	270	235	205	180	160	140	125	110	95
	6.00	54.63	400	400	400	360	310	270	235	205	180	160	140	125	110
	6.50	61.31	400	400	400	400	350	300	265	230	205	180	160	140	125
	7.00	68.09	400	400	400	400	390	335	295	260	230	200	180	160	140
	7.25	71.50	400	400	400	400	400	355	310	270	240	210	190	165	150
	7.50	74.93	400	400	400	400	400	370	325	285	250	225	200	175	155
19 gage	4.50	40.69	400	370	315	270	230	200	175	155	135	120	105	95	85
	5.00	47.87	400	400	370	315	275	240	210	185	160	145	125	115	100
	5.50	55.30	400	400	400	365	320	275	240	215	190	165	150	130	120
	6.00	62.90	400	400	400	400	365	315	275	245	215	190	170	150	135
	6.50	70.65	400	400	400	400	400	355	310	275	245	215	190	170	155
	7.00	78.50	400	400	400	400	400	395	350	305	270	240	215	190	170
	7.25	82.46	400	400	400	400	400	400	365	320	285	255	225	200	180
	7.50	86.45	400	400	400	400	400	400	385	340	300	265	235	210	190
18 gage	4.50	45.34	400	400	350	300	260	230	200	175	155	140	125	110	100
	5.00	53.36	400	400	400	355	310	270	235	210	185	165	145	130	115
	5.50	61.66	400	400	400	400	360	315	275	240	215	190	170	150	135
	6.00	70.18	400	400	400	400	400	360	315	275	245	220	195	175	155
	6.50	78.85	400	400	400	400	400	400	355	310	275	245	220	195	175
	7.00	87.66	400	400	400	400	400	400	395	350	310	275	245	220	195
	7.25	92.10	400	400	400	400	400	400	400	365	325	290	260	230	210
	7.50	96.57	400	400	400	400	400	400	400	385	340	305	270	245	220
16 gage	4.50	45.34	400	400	350	300	260	230	200	175	155	140	125	110	100
	5.00	53.36	400	400	400	355	310	270	235	210	185	165	145	130	115
	5.50	61.66	400	400	400	400	360	315	275	240	215	190	170	150	135
	6.00	70.18	400	400	400	400	400	360	315	275	245	220	195	175	155
	6.50	78.85	400	400	400	400	400	400	355	310	275	245	220	195	175
	7.00	87.66	400	400	400	400	400	400	395	350	310	275	245	220	195
	7.25	92.10	400	400	400	400	400	400	400	365	325	290	260	230	210
	7.50	96.57	400	400	400	400	400	400	400	385	340	305	270	245	220

LRFD

1 STUD/FT.

NO STUDS

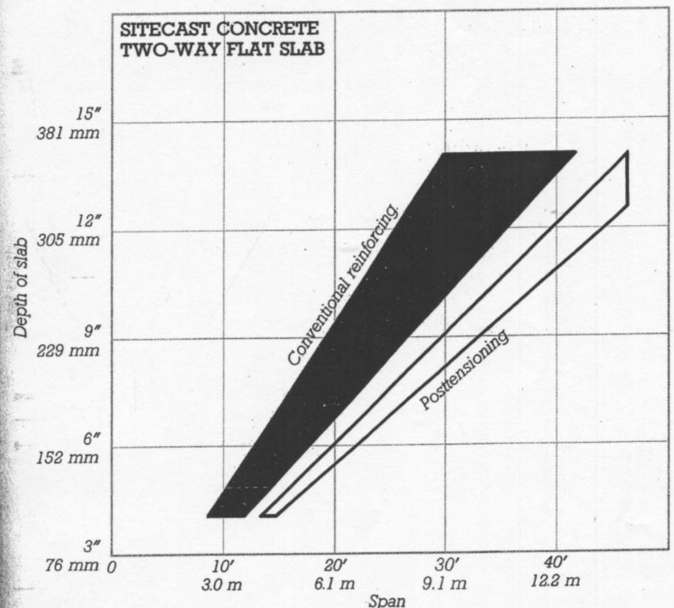
* The **Uniform Live Loads** are based on the LRFD equation $\phi M_n = (1.6L + 1.2D)l^2/8$. Although there are other load combinations that may require investigation, this will control most of the time. The equation assumes there is no negative bending reinforcement over the beams and therefore each composite slab is a single span. Two sets of values are shown; ϕM_{nf} is used to calculate the uniform load when the full required number of studs is present; ϕM_{no} is used to calculate the load when no studs are present. A straight line interpolation can be done if the average number of studs is between zero and the required number needed to develop the "full" factored moment. The tabulated loads are checked for shear controlling (it seldom does), and also limited to a live load deflection of 1/360 of the span.

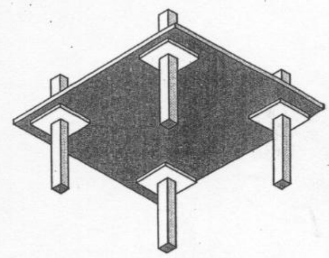
An upper limit of 400 psf has been applied to the tabulated loads. This has been done to guard against equating large concentrated to uniform loads. Concentrated loads may require special analysis and design to take care of servicibility requirements not covered by simply using a uniform load value. On the other hand, for any load combination the values provided by the composite properties can be used in the calculations.

Welded wire fabric in the required amount is assumed for the table values. If welded wire fabric is not present, deduct 10% from the listed loads.

Refer to the example problems for the use of the tables.

SITECAST CONCRETE TWO-WAY FLAT SLAB





This chart is for concrete two-way flat slab construction, either conventionally reinforced or posttensioned. For light loads, read toward the right in the indicated areas. For heavy loads, read toward the left.

- For rectangular column bays, use the span of the longer of the two sides of the bay in reading from this chart.
- Size slab depth to the nearest ½ in. (10 mm).

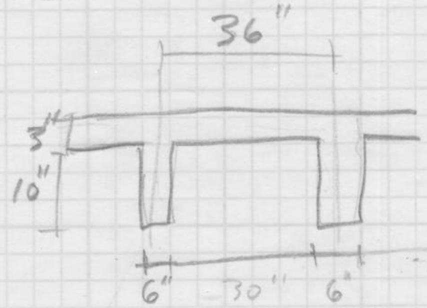
COLUMN SIZES AND LAYOUTS FOR FLAT SLAB CONSTRUCTION

For light to moderate loads, use a minimum square column size of 12 in. (300 mm) for preliminary design. For heavier loads, larger columns or the addition of column caps may be required. Column size may be increased by 4 to 12 in. (100 to 300 mm) for extremely heavy loads.

For rectangular columns, use a column whose area is equal to that of the recommended square column size. For round columns, use a column diameter one-third greater than the recommended square column size. Column sizes may also need to be increased in multistory buildings or for columns taller than 12 ft (3.7 m). See pages 108–109 for checking column sizes for these conditions.

For maximum economy and efficiency of the two-way structural system, column layouts for flat slab construction should adhere to the same guidelines as those described for flat plate construction. Column bays should be approximately square, and column offsets from regular lines should be minimized. See page 118 for a complete discussion of these guidelines.

Waffle Slab



Floor Unfactored Dead Load

Area of Concrete in 3' cubed section

$3'' \times 36'' \times 36$

$+ \; 3 \times 10 \times 36 \times 2$

$+ \; 3 \times 10 \times 30 \times 2$

$$\frac{7848 \text{ in}^3}{(12 \frac{\text{in}}{\text{ft}})^3 (3')^3} = 0.505 \frac{\text{ft}^3}{\text{ft}^2}$$

$0.505(150 \text{ lb/ft}^3) = 75.7 \text{ psf}$

$+ \; 25 \text{ psf}$ (Other Dead, see Table 1)

100.7 psf

Roof Unfactored Dead Load

<u>assume</u> 5 psf more for roofing materials