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STRUCTURAL TECHNICAL REPORT 2
PRO-CON STRUCTURAL STUDY OF ALTERNATE FLOOR SYSTEMS
EXECUTIVE SUMMARY
OCTOBER 31, 2005

The Academic Villages are located in Orlando, Florida. It is a complex of ten separate dormitories built to accommodate 500 new freshman students. The buildings are various sizes ranging from 14,000 square feet to 22,000 square feet. Each building is 4 stories tall and 44'-8" above the ground. Each floor has between eleven and fifteen 24 ft x 28 ft apartment units.

For this technical assignment, the existing floor system and 4 alternative floor systems were evaluated for the University of Central Florida's Academic Villages. The existing system is a composite deck with a 4" slab. Below are the 4 alternative systems that were analyzed:

1. Post-Tensioned Concrete system in East-West Direction
2. Post-Tensioned Concrete system in North-South Direction
3. Precast Hollow Core Planks
4. Two-Way Flat Plate Slab

The Post-Tensioned Concrete system in the E-W direction is a viable option as a possible floor system for this structure. A thinner slab was found when using the post-tensioned system in this direction which would result in less weight due to concrete. This will produce a much lighter building with less load on the foundation, which can be a benefit in high wind areas such as Florida. Also, the existing system needs additional concrete columns and beams on the first floor to provide additional support for the load bearing stud walls which are not adequate to carry the entire weight of the floors above on their own. Using a Post-tensioned system will provide lighter loads and those extra beams and columns may be able to be eliminated completely upon further analyses. The Post-Tensioned system in the N-S direction requires a 14" slab to support the 62'4" clear span, which is much too large. Using Precast Hollow Core Planks is another feasible alternative floor system. It is a very efficient system since construction time is minimal and is non labor intensive. It's slightly deeper than using a slab on grade but weighs about the same. A Two-Way Flat Plate system, while being very efficient in construction time and labor, requires a 10" slab which is much too deep when compared to some of the other alternatives.

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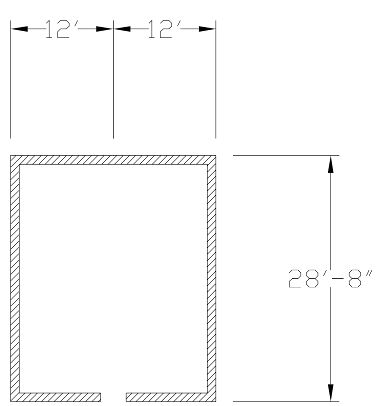
Introduction:

The Academic Villages located in Orlando, Florida. It is a complex of ten separate dormitories built to accommodate 500 new freshman students. The buildings are various sizes ranging from 14,000 square feet to 22,000 square feet. Each building is 4 stories tall and 44'-8" above the ground. Each floor has between eleven and fifteen 24 ft x 28 ft apartment units.

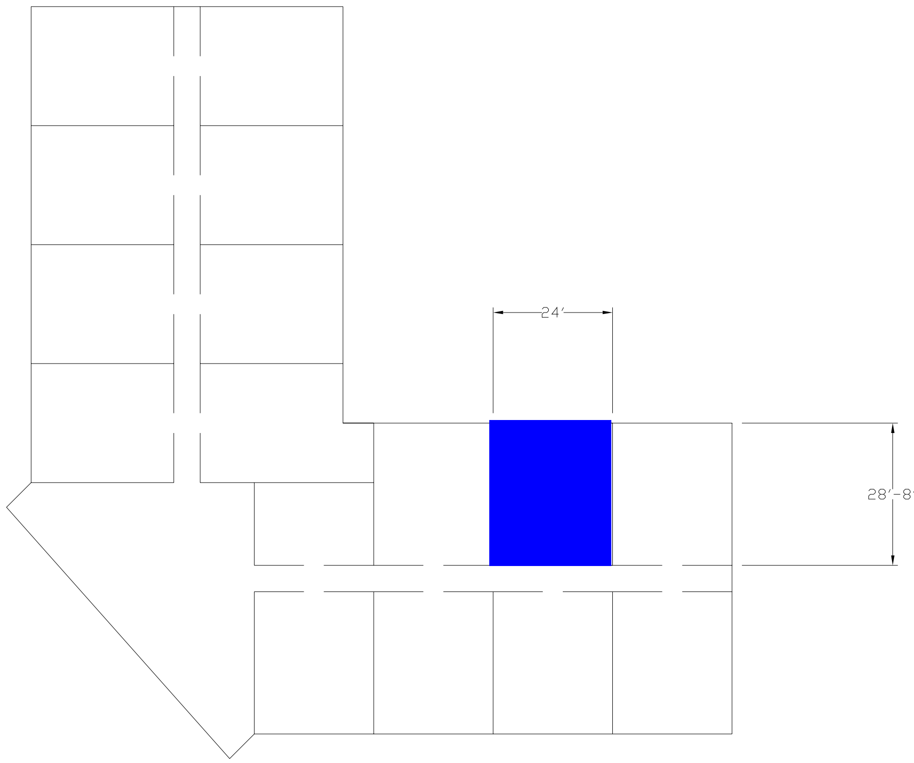
Existing System:

The existing floor system for the University of Central Florida's Academic Villages is called the "Infinity System." This is a composite floor system with 2" 22 GA. Epicore MSR metal decking with a 4 ¼" concrete topping with W6x6 W2.1xW2.1 WWF reinforcement. It spans between interior and exterior load bearing CMU walls in the east-west direction and load bearing metal stud wall panels. Epicore MSR has triangular dovetail shaped ribs spaced 8" on center that allow for longer spans and higher concrete strength. The bottom flutes are completely closed which allows for the deck to have a flat bottom profile. This makes it ideal to combine with load bearing stud walls because it distributes the load evenly over the metal studs eliminating the need for load distribution devices. The typical span in this building is 24 feet. The typical bay that I chose to analyze is 24' x 28'8".

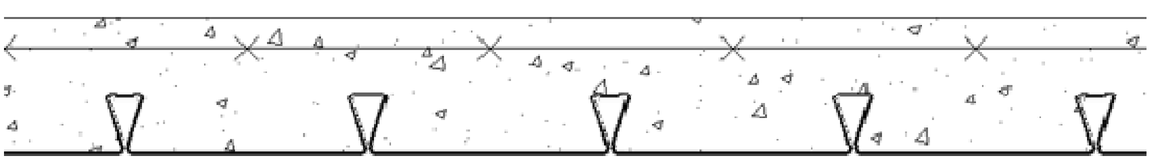
Typical Bay



Building Footprint



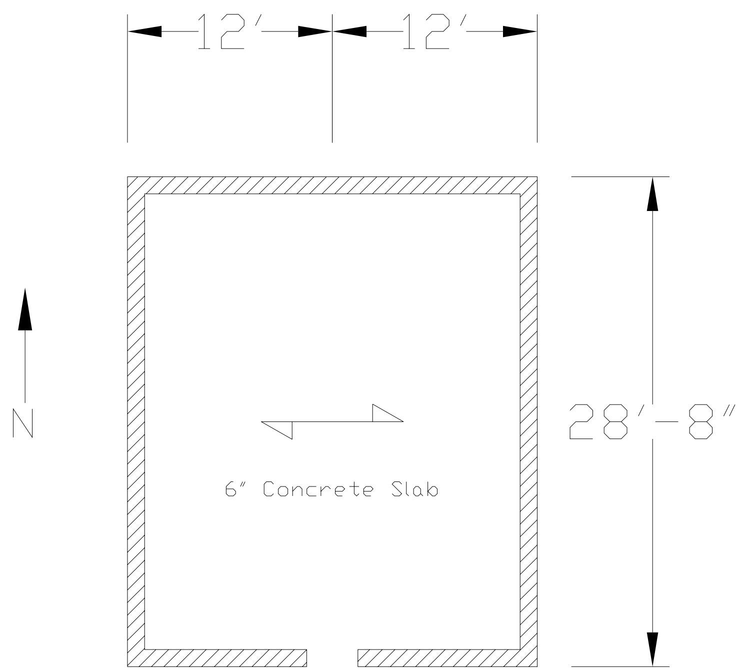
Epicore MSR metal deck Section



Alternative 1: Post-Tensioned Concrete in E-W direction:

A post-tensioned concrete system is a system where the concrete is reinforced with high strength steel stands. These strands are tightened to a specified stress prior to the concrete being poured. Once cured, the strands provide additional tensile stress to the bottom of the concrete slab. A post-tensioned system allows for smaller slab thicknesses, longer clear spans. It is an “active” reinforced system, which means that deflection and cracking are greatly decreased since the steel strands are constantly loaded, unlike “passive” concrete systems where the slab deflects and cracks before the reinforcement provides the additional tension needed. By reducing the slab thickness, the buildings weight is also greatly reduced. This greatly reduces the amount of load the foundation experiences. Post-tensioning provides a great deal of flexibility with the building layout by allowing for longer spans if necessary. Some of the downsides of post-tensioned concrete are that it requires a higher level of construction sophistication. A highly skilled labor force should be present to be sure that the strands are installed correctly. Buildings which are constantly being structurally modified should not use this system since the high stress steel strands make it very dangerous to cut into the slab. Shrinkage is also an issue with post-tensioned concrete since it is enhanced to the axial stresses acting on the side.

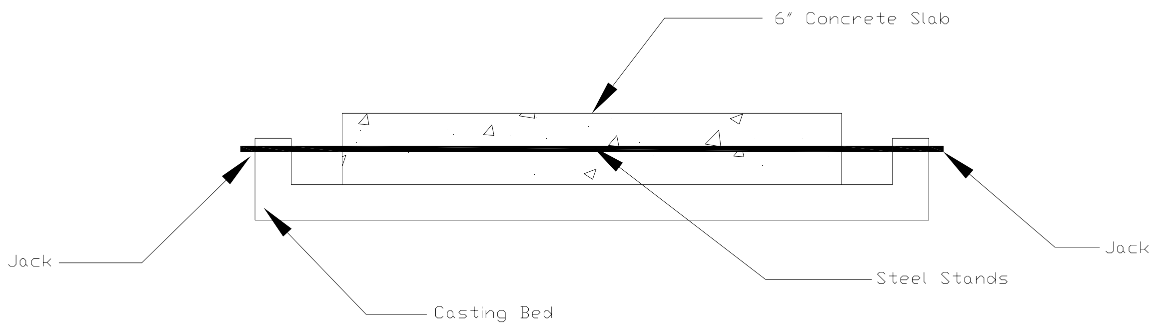
Typical Bay Post-Tensioned Concrete Slab (E-W)



Assumptions:

- Superimposed Load, w = 125 psf
- F'_c = 4000 psi
- F_y = 60,000 psi
- Cross section is homogenous
- Strand stress f_{py} = 270 ksi
- Strand area A_{ps} = 0.153 in^2
- Concrete is uncracked → Class U → $f_{tallowable}$ = 474 psi
- Fiber stress in compression is due to prestress plus total load → $f_{callowable}$ = 2400 psi
- Span = 24'0"
- Length = 28'8"

Post-Tensioned Concrete Detail



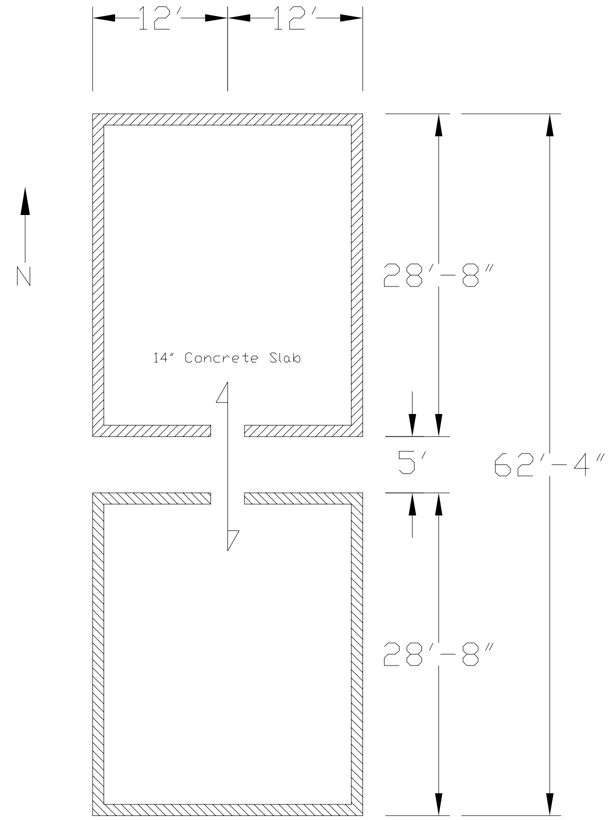
Results:

Using the allowable stresses of $f_{tallowable}$ = 474 psi and $f_{callowable}$ = 2400 psi calculated from ACI 318-02 sections 18.3.3 and 18.4.2 and setting them equal to the actual stresses and the force in the steel stands; I found that P_e = 24.6 kips. This was based on a 6" slab with a 2" eccentricity. The strands need to be spaced a maximum of 12" apart. (See appendix for calculations)

Alternative 2: Post-Tensioned Concrete in N-S direction:

When using post-tensioned concrete in the east west direction, the largest span is 62'4" and the length is 24'0". All other assumptions are the same as Alternative 1.

Typical Bay Post-Tensioned Concrete Slab (N-S)



Assumptions:

- Superimposed Load, w = 125 psf
- F'_c = 4000 psi
- F_y = 60,000 psi
- Cross section is homogenous
- Strand stress f_{py} = 270 ksi
- Strand area $A_{ps} = 0.153\ in^2$
- Concrete is uncracked → Class U → $f_{tallowable}$ = 474 psi
- Fiber stress in compression is due to prestress plus total load → $f_{callowable}$ = 2400 psi
- Span = 62'4"
- Length = 24'0"

Results:

Since this was a much longer span than the E-W direction, a much thicker slab was required. After finding out that a 12” slab with a 3” eccentricity did not have sufficient compressive strength, I assumed a 14” slab with a 5” eccentricity. This satisfied the compressive and tensile allowable stresses specified in ACI 318-02. The maximum spacing in this direction is a strand every 4”. (See appendix for calculations)

Alternative 3: Precast Hollow Core Plank System

Precast hollow core planks can range anywhere between 6 inches thick to 16 inches thick depending on how long a span is desired. A 6” hollow core plank with a 100 psf superimposed load can usually support a 20-22 foot span while 16” planks can support up to 50 foot spans under the same load. The hollow core allows for a reduction of the weight by approximately 60% compared to a solid section. Construction time is greatly reduced when using precast panels since the concrete has already been cured. Precast panels can also be erected any time of the year unlike cast in place concrete, which needs certain conditions to cure properly. Precast panels also have an excellent fire rating. Depending on the thickness, up to 4 hour endurance can be achieved. Precast panels are much deeper than cast in place concrete system since the smallest thickness available is 6”. Many use an additional 2” concrete topping which further reduces the amount space available. The system that will be looked at here was designed using the Nitterhouse Concrete Products Manual. Based on the 24’ span in the typical bay, a trial 8”x 4’ panel was selected.

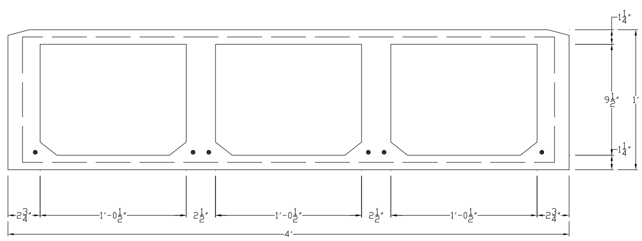
Assumptions:

- F’c =5000 psi at 28 days
- Maximum tensile stress = 6 * (f’c)$^{0.5}$ = 424 psi
- Span = 24 ft
- No concrete cover used at this time
- Precast wt = 57.5 psf (8”x 4’)
- M/E/P = 10 psf
- Partitions = 20 psf
- Live load = 40 psf

Results:

Using the Nitterhouse Concrete Products Manual, the 8”x 4’ Spandeck –UL–J917 with no concrete topping and 6 strands was sufficient to carry the 127.4 superimposed load.

12” SpanDeck Cross Section



Alternative 4: Two-Way Flat Plate Slab

Since the typical bays for this structure are relatively square, a two-way flat plate system was analyzed to be an alternative structural system. Flat plate construction is very efficient process given that it minimizes both time and labor due to the very simple formwork and steel layout. It is very practical for layouts that need flexibility such as hotels, hospitals, and apartments/dormitories. In addition, flat plates allow for minimum story height for required clear headroom. Using a span of 24 feet, this analysis was done without the use of capitals or drop panels, although it is possible that they might be necessary since the span is almost 25 feet. This system was analyzed using CRSI 2002.

Assumptions:

- F'c = 4000 psi
- All reinforcement bars are Grade 60
- Superimposed load rounded up to 100 psf (LL = 40 psf, DL = 30 psf)
- 24' clear span

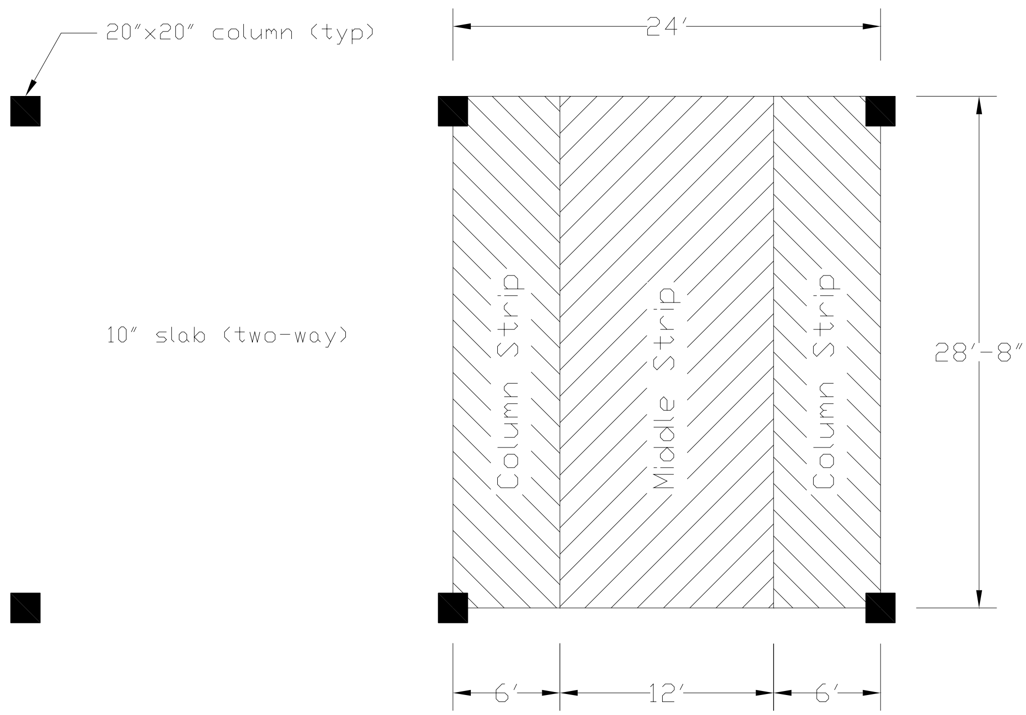
CRSI Results:

- Minimum slab thickness = 10"
- Minimum square column width = 20"
- Exterior Panel Reinforcement
    - Column strip
        - Top Exterior → 11-#5
        - Bottom → 8-#6
        - Top Interior → 11-#7
    - Middle strip
        - Bottom → 9-#5
        - Top Interior → 9-#5
- Interior Panel Reinforcement
    - Column strip
        - Top → 13-#6
        - Bottom → 9-#5
    - Middle strip
        - Top → 9-#5
        - Bottom → 9-#5

Results:

According to CRSI 2002, 20"x 20" square columns are required due to the 24' span. If the widths of these columns needs to be further reduced, drop panels can be used to help distribute the load to the columns. The thinnest slab available for this span was 10" thick. See diagram below for column layout.

Two-Way Flat Plate Concrete Slab



Conclusion

In conclusion to the analysis of these 5 structures, it has been determined that the existing structure while a good choice for the structural floor system may not be the best. The Post-Tensioned Concrete system in the E-W direction is a viable option as a possible floor system for this structure. A thinner slab was found when using the post-tensioned system in this direction which would result in less weight due to concrete. This will produce a much lighter building with less load on the foundation, which can be a benefit in high wind areas such as Florida. Also, the existing system needs additional concrete columns and beams on the first floor to provide additional support for the load bearing stud walls which are not adequate to carry the entire weight of the floors above on their own. Using a Post-tensioned system will provide lighter loads and those extra beams and columns may be able to be eliminated completely upon further analyses. The Post-Tensioned system in the N-S direction requires a 14” slab to support the 62’4” clear span, which is much too large. Using Precast Hollow Core Planks is another feasible alternative floor system. It is a very efficient system since construction time is minimal and is non labor intensive. It’s slightly deeper than using a slab on grade but weighs about the same. A Two-Way Flat Plate system, while being very efficient in construction time and labor, requires a 10” slab which is much too deep when compared to some of the other alternatives. Further analysis will be taken to decide if a post-tensioned concrete system is a better choice than the existing system. The following chart shows the results of this report.

Compare/Contrast

System	Depth	Advantages	Disadvantages	Potential
Existing: Composite deck with slab	4"	Works well with steel studs Relatively low cost Long spans Good fire rating	Construction time Heavy building Addition supports needed	N/A
Post-tensioned Concrete (E-W)	6"	Long spans Thin slabs/less weight Fewer deflections Less cracking	Shrinkage Complex construction Need additional fire protection Construction time	YES
Post-tensioned Concrete (E-W)	14"	Long spans Fewer deflections Less cracking	Shrinkage Complex construction Need additional fire protection Construction time	NO
Precast Hollow Core Planks	8"	Lightweight Fast construction Weather not a problem Allows for floor conduit	High cost Lead time for fabrication Deep system	YES
Two-Way Flat Plate Slab	10"	Long Spans Fast construction Not Labor intensive Reusable formwork	Deep system Heavy system Need additional fire protection	YES

Post-Tensioned Concrete (E-W)

From ACI 318-02

18.3.3 $\Rightarrow f_t \leq 7.5\sqrt{f'_c} \leq 7.5\sqrt{4000} \leq 474$ psi ← class U

18.4.1 $\Rightarrow$ assume for MAX service loads

$\Rightarrow f_c \leq 0.6 f'_c = 0.6(4000) = 2400$ psi

$w = 75$ psf $+ 10$ psf $+ 40$ psf $= 125$ psf (superimposed)

slab thickness $= 6''$

$L = 24'$ assume $e = 2''$

$$M = \frac{wL^2}{8} = \frac{(125)(24)^2}{8} = 9 \text{ ft k/ft}$$

$$S = \frac{bd^2}{6} = \frac{(12)(6)^2}{6} = 72 \text{ in}^3$$

$$A = b \times d = 12'' \times 6'' = 72 \text{ in}^2$$

stress @ top

$$f_{top} = -\frac{M}{S} - \frac{P_e}{A} + \frac{P_e e}{S} = -\frac{9 \text{ ft k}}{72 \text{ in}^3} - \frac{P_e}{72 \text{ in}^2} + \frac{P_e(2'')}{72 \text{ in}^3} = -2.4 \text{ ksi} \quad (f_c)$$

$$-1.5 + \frac{P_e}{72} = -2.4 \Rightarrow P_e = -64.8^k$$

stress @ bottom

$$f_{bot} = \frac{M}{S} - \frac{P_e}{A} - \frac{P_e e}{S} = \frac{9 \text{ ft k}}{72 \text{ in}^3} - \frac{P_e}{72 \text{ in}^2} - \frac{P_e(2)}{72 \text{ in}^3} = 0.474 \text{ ksi} \quad (f_t)$$

$$= 1.5 - \frac{P_e}{24} = .474 \Rightarrow P_e = 24.6^k < 65^k \Rightarrow \text{use } 24.6^k/\text{ft}$$

check top again

$$f_{top} = -\frac{M}{S} - \frac{P_e}{A} + \frac{P_e e}{S}$$

$$= -1.5 + \frac{24.6}{72}$$

$$= -1.16 < -2.4 \text{ ok}$$

Spacing

$A_{ps} = 0.153$ in^2

$f_{py} = 270$ ksi

$f_{strand} = 60\% \times f_{py} \times A_{ps} = 24.8^k/\text{ft}$

$$\text{Spacing} = \frac{24.8'}{24.6} \times 12 = \text{every } 12''$$

Post-Tentioned Concrete (N-S)

$f_t = 474$ psf (class U)
$f_c = 2400$ psf (max service loads)
} ACI 318-02

$\omega = 125$ psf (superimposed)

$L = 28'8" + 28'8" + 5' = 62'4"$

Try slab thickness = 12"

assume $e = 3"$

$$M = \frac{wL^2}{8} = \frac{(125)(62.33)^2}{8} = 60.71 \text{ ft k/ft}$$

$$S = \frac{bd^2}{6} = \frac{(12")(12")^2}{6} = 288 \text{ in}^3$$

$$A = 12" \times 12" = 144 \text{ in}^2$$

Stress @ top

$$f_{top} = -\frac{M}{S} - \frac{P_e}{A} + \frac{P_e e}{S} = -\frac{(60.71)(12)}{288} - \frac{P_e}{144} + \frac{P_e(3)}{288} = -2.4 \Rightarrow P_e = 37.32^K$$

Stess @ bottom

$$f_{bot} = \frac{M}{S} - \frac{P_e}{A} - \frac{P_e e}{S} = \frac{(60.71)(12)}{288} - \frac{P_e}{144} - \frac{P_e(3)}{288} = .474 \Rightarrow P_e = 118.4^K$$

Not Good!
Try 14" slab

t=14" (assume e=5)

$$S = \frac{bd^2}{6} = \frac{12(14)^2}{6} = 392 \text{ in}^3$$

$$A = b \times d = 12 \times 14 = 168 \text{ in}^2$$

top

$$f_{top} = -\frac{(60.71)(12)}{392} - \frac{P_e}{168} + \frac{P_e(5)}{392} = -2.4 \Rightarrow P_e = -79.6^K$$

bottom

$$f_b = \frac{(60.71)(12)}{392} - \frac{P_e}{168} - \frac{P_e(5)}{392} = .474 \Rightarrow P_e = 73.8^K < 79.6^K$$

Check top

$$f_{top} = -\frac{60.71(12)}{392} - \frac{73.8}{168} + \frac{73.8(5)}{392} = -1.35 < -2.4 \quad \underline{ok}$$

Spacing

$A_{ps} = 0.153 \text{ in}^2$

$f_{py} = 270$ ksi

$f_{strand} = 24.8$ k/ft

$$\text{Spacing} = \frac{24.8}{73.8} \times 12 = \text{every } 4''$$

Precast Hollow Core System (Nitterhouse)

Try 8" x 4' Span Deck U.L. J917
(no topping)

WT = 57.5 psf

Dead Loads

M/E/P = 10 psf
Partitions = 20 psf
30 psf

Live Loads

L = 40 psf
(residential)

$w = 57.5 + 30 + 40$
$= 127.4$ psf

Longest span for this system = 26'

$w_{flexure} = 136$ psf
$w_{shear} = 139$ psf

⇒ use 8" x 4" without topping and 6 strands

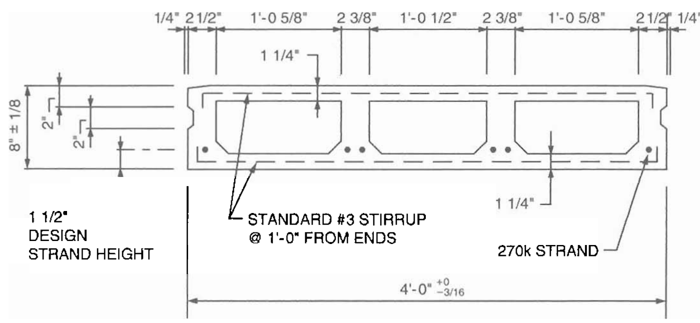
Prestressed Concrete

8" x 4' SpanDeck – U.L. – J917

(NO TOPPING)

PHYSICAL PROPERTIES
Precast

A =	180 in.^{2}	S_b =	397 in.^{3}
I =	1543 in.^{4}	S_t =	375 in.^{3}
Y_b =	3.89 in.	Wt. =	230 PLF
Y_t =	4.11 in.	Wt. =	57.5 PSF
e =	2.39 in.		



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, 270 K Lo-Relaxation.
4. Strand Height = 1.50 in.
5. Ultimate moment capacities (when fully developed) . . .
   4 – 1/2"ø, 270K = 74.3'K
   6 – 1/2"ø, 270K = 105.6'K
6. Maximum bottom tensile stress is $6\sqrt{f'c}$ = 424 PSI.
7. All superimposed load is treated as live load in the strength analysis of flexure and shear.
8. Flexural strength capacity is based on stress/strain strand relationships.
9. All values in this table are based on ultimate strength and are not governed by service stress.
10. Shear values are the maximum allowable before shear reinforcement is required.
11. Deflection limits were not considered when determining allowable loads in this table.

8" SPANDECK W/O 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	610	550	499	457	399	341	294	255	222	195	171	151	133	117	103	92	82	72	66	56	49	43	X
Shear 4 – 1/2"ø	441	393	354	321	294	270	249	231	215	201	188	177	160	145	132	120	110	101	95	90	82	75	X
Flexure 6 – 1/2"ø	885	800	726	667	586	509	437	382	334	296	263	234	208	187	168	151	136	122	111	100	90	81	73
Shear 6 – 1/2"ø	459	411	370	337	308	283	262	243	226	211	197	185	174	164	155	147	139	131	120	111	102	94	87

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.

NITTERHOUSE
CONCRETE PRODUCTS

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

REVISED 12/93

FLAT PLATE SYSTEM
(WITHOUT SHEARHEADS)

f'_c = 4,000 psi
Grade 60 Bars

SQUARE EDGE PANEL

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

SPAN c.-c. Cols. $\ell_1 = \ell_2$	Factored Superimposed Load	(1) Min. Square Column		Total Panel Moments			Reinforcing Bars						End Panel Steel (psf) Location of Panel		
				−M Ext.	+M Int.	−M 1st. int.	Each Column Strip				Each Middle Strip				
(ft)	(psf)	(in.)	γ_f	(ft-kip)	(ft-kip)	(ft-kip)	Top Ext.	+	Bottom	Top Int.	Bottom	Top Int.	E	EC	C
20	50	10	0.840	54	107	145	9-# 5	1	7-# 5	10-# 5	7-# 5	7-# 5	2.23	2.24	2.24
20	100	12	0.837	65	130	175	9-# 5	2	7-# 5	12-# 5	7-# 5	7-# 5	2.32	2.33	2.30
20	150	15	0.804	75	149	201	9-# 5	3	8-# 5	13-# 5	7-# 5	7-# 5	2.46	2.46	2.49
20	200	17	0.784	84	168	227	9-# 5	3	9-# 5	11-# 6	7-# 5	7-# 5	2.61	2.62	2.64
20	250	20	0.726	93	187	251	9-# 5	3	7-# 6	9-# 7	7-# 5	7-# 5	2.78	2.80	2.81
20	300	22	0.725	103	206	277	9-# 5	4	8-# 6	10-# 7	7-# 5	7-# 5	2.96	2.98	2.95
20	350	24	0.702	112	223	300	10-# 5	3	12-# 5	20-# 5	8-# 5	7-# 5	3.09	3.12	3.30
21	50	11	0.845	62	124	167	10-# 5	1	8-# 5	11-# 5	8-# 5	8-# 5	2.34	2.35	2.33
21	100	14	0.816	75	150	202	10-# 5	2	8-# 5	10-# 6	8-# 5	8-# 5	2.51	2.52	2.49
21	150	17	0.769	86	172	232	10-# 5	2	9-# 5	11-# 6	8-# 5	8-# 5	2.66	2.66	2.58
21	200	20	0.737	97	194	261	10-# 5	3	10-# 5	10-# 7	8-# 5	8-# 5	2.78	2.83	2.82
21	250	22	0.719	108	216	291	10-# 5	3	8-# 6	11-# 7	8-# 5	8-# 5	2.98	3.02	2.96
21	300	25	0.662	118	235	316	11-# 5	2	7-# 7	15-# 6	8-# 5	8-# 5	3.22	3.22	3.28
21	350	27	0.666	127	254	342	11-# 5	3	7-# 7	10-# 8	9-# 5	8-# 5	3.37	3.41	3.50
22	50	13	0.821	71	142	192	10-# 5	2	8-# 5	13-# 5	8-# 5	8-# 5	2.34	2.36	2.36
22	100	16	0.780	86	171	231	10-# 5	2	9-# 5	11-# 6	8-# 5	8-# 5	2.53	2.53	2.47
22	150	19	0.753	99	198	266	10-# 5	3	8-# 6	10-# 7	8-# 5	8-# 5	2.75	2.78	2.76
22	200	22	0.705	111	222	298	10-# 5	3	12-# 5	11-# 7	8-# 5	8-# 5	2.87	2.90	3.04
22	250	25	0.676	123	245	330	11-# 5	3	13-# 5	12-# 7	9-# 5	8-# 5	3.11	3.12	3.18
22	300	27	0.662	134	267	360	12-# 5	2	10-# 6	10-# 8	10-# 5	8-# 5	3.35	3.40	3.48
22	350	30	0.675	144	288	388	13-# 5	4	8-# 7	11-# 8	10-# 5	9-# 5	3.58	3.62	3.74
23	50	15	0.813	81	162	218	11-# 5	3	9-# 5	11-# 6	9-# 5	9-# 5	2.56	2.59	2.54
23	100	18	0.791	97	194	261	11-# 5	4	10-# 5	17-# 5	9-# 5	9-# 5	2.69	2.70	2.69
23	150	21	0.738	111	223	300	11-# 5	3	12-# 5	20-# 5	9-# 5	9-# 5	2.94	2.95	2.99
23	200	24	0.696	126	251	338	11-# 5	3	13-# 5	12-# 7	9-# 5	9-# 5	3.08	3.10	3.07
23	250	27	0.709	138	277	373	12-# 5	5	8-# 7	11-# 8	10-# 5	9-# 5	3.45	3.49	3.49
23	300	30	0.669	150	301	405	13-# 5	4	16-# 5	12-# 8	8-# 6	9-# 5	3.69	3.73	3.78
23	350	33	0.627	162	325	437	14-# 5	3	9-# 7	13-# 8	8-# 6	10-# 5	3.96	4.02	4.15
24	50	16	0.817	92	184	247	11-# 5	4	10-# 5	16-# 5	9-# 5	9-# 5	2.55	2.56	2.49
24	100	20	0.773	109	218	293	11-# 5	5	8-# 6	11-# 7	9-# 5	9-# 5	2.78	2.79	2.75
24	150	23	0.704	125	251	338	11-# 5	3	13-# 5	12-# 7	9-# 5	9-# 5	2.94	2.96	2.98
24	200	27	0.691	140	281	378	13-# 5	4	8-# 7	11-# 8	10-# 5	9-# 5	3.34	3.36	3.37
24	250	30	0.655	155	310	417	14-# 5	3	9-# 7	12-# 8	8-# 6	9-# 5	3.62	3.66	3.71
24	300	33	0.637	169	337	454	15-# 5	3	8-# 8	13-# 8	12-# 5	10-# 5	3.96	4.01	4.14
24	350	36	0.612	182	364	490	16-# 5	2	8-# 8	14-# 8	9-# 6	8-# 6	4.19	4.25	4.45
25	50	18	0.796	103	206	278	12-# 5	4	11-# 5	13-# 6	9-# 5	9-# 5	2.60	2.61	2.61
25	100	22	0.755	122	244	329	12-# 5	5	9-# 6	12-# 7	9-# 5	9-# 5	2.84	2.85	2.88
25	150	26	0.697	140	280	377	12-# 5	5	11-# 6	14-# 7	10-# 5	9-# 5	3.19	3.21	3.24
25	200	29	0.683	158	315	425	14-# 5	4	9-# 7	12-# 8	11-# 5	9-# 5	3.44	3.49	3.55
25	250	33	0.619	173	346	465	15-# 5	3	10-# 7	13-# 8	12-# 5	10-# 5	3.79	3.83	3.96
25	300	36	0.623	188	376	507	12-# 6	2	20-# 5	14-# 8	13-# 5	11-# 5	4.15	4.18	4.35
25	350	41	0.611	199	397	535	13-# 6	1	9-# 8	15-# 8	10-# 6	12-# 5	4.50	4.55	4.67

SQUARE INTERIOR PANEL

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

(2) Span c.-c.	(3) Load	(1) Min. Sq. Col.	Reinforcing Bars				Steel (psf) Location of Panel		
			Column Strip		Middle Strip				
(ft)	(psf)	(in.)	Top	Bottom	Top	Bottom	I	IE	IC
20	50	10	9-# 5	7-# 5	7-# 5	7-# 5	2.21	2.22	2.24
20	100	10	11-# 5	7-# 5	7-# 5	7-# 5	2.33	2.35	2.36
20	150	14	9-# 6	7-# 5	7-# 5	7-# 5	2.48	2.48	2.48
20	200	17	10-# 6	7-# 5	7-# 5	7-# 5	2.58	2.61	2.63
20	250	19	11-# 6	7-# 5	7-# 5	7-# 5	2.69	2.71	2.74
20	300	20	17-# 5	8-# 5	7-# 5	7-# 5	2.84	2.89	2.93
20	350	22	10-# 7	8-# 5	7-# 5	7-# 5	3.03	3.03	3.04
21	50	10	10-# 5	8-# 5	8-# 5	8-# 5	2.35	2.36	2.38
21	100	10	13-# 5	8-# 5	8-# 5	8-# 5	2.53	2.55	2.57
21	150	14	11-# 6	8-# 5	8-# 5	8-# 5	2.72	2.72	2.72
21	200	17	16-# 5	8-# 5	8-# 5	8-# 5	2.75	2.80	2.86
21	250	19	10-# 7	8-# 5	8-# 5	8-# 5	2.98	3.01	3.04
21	300	22	11-# 7	9-# 5	8-# 5	8-# 5	3.22	3.22	3.21
21	350	25	12-# 7	9-# 5	8-# 5	8-# 5	3.36	3.39	3.42
22	50	10	12-# 5	8-# 5	8-# 5	8-# 5	2.36	2.37	2.39
22	100	11	11-# 6	8-# 5	8-# 5	8-# 5	2.59	2.58	2.58
22	150	14	12-# 6	8-# 5	8-# 5	8-# 5	2.68	2.72	2.75
22	200	18	10-# 7	8-# 5	8-# 5	8-# 5	2.84	2.86	2.89
22	250	21	11-# 7	9-# 5	8-# 5	8-# 5	3.06	3.09	3.12
22	300	25	12-# 7	10-# 5	8-# 5	8-# 5	3.27	3.30	3.33
22	350	28	10-# 8	10-# 5	8-# 5	8-# 5	3.41	3.46	3.51
23	50	10	14-# 5	9-# 5	9-# 5	9-# 5	2.59	2.61	2.64
23	100	13	16-# 5	9-# 5	9-# 5	9-# 5	2.71	2.72	2.74
23	150	17	11-# 7	9-# 5	9-# 5	9-# 5	3.04	3.02	2.99
23	200	20	15-# 6	9-# 5	9-# 5	9-# 5	3.06	3.08	3.11
23	250	24	13-# 7	10-# 5	9-# 5	9-# 5	3.37	3.40	3.44
23	300	28	11-# 8	8-# 6	9-# 5	9-# 5	3.66	3.70	3.73
23	350	31	12-# 8	12-# 5	9-# 5	9-# 5	3.87	3.91	3.96
24	50	11	11-# 6	9-# 5	9-# 5	9-# 5	2.58	2.58	2.58
24	100	15	13-# 6	9-# 5	9-# 5	9-# 5	2.75	2.79	2.82
24	150	19	15-# 6	9-# 5	9-# 5	9-# 5	2.92	2.95	2.97
24	200	23	13-# 7	10-# 5	9-# 5	9-# 5	3.22	3.25	3.29
24	250	27	11-# 8	8-# 6	9-# 5	9-# 5	3.50	3.53	3.57
24	300	31	12-# 8	12-# 5	10-# 5	9-# 5	3.74	3.78	3.81
24	350	34	13-# 8	13-# 5	10-# 5	9-# 5	3.99	4.04	4.09
25	50	12	13-# 6	9-# 5	9-# 5	9-# 5	2.63	2.63	2.62
25	100	17	15-# 6	9-# 5	9-# 5	9-# 5	2.79	2.82	2.84
25	150	21	13-# 7	10-# 5	9-# 5	9-# 5	3.08	3.10	3.12
25	200	25	19-# 6	12-# 5	9-# 5	9-# 5	3.34	3.38	3.42
25	250	30	12-# 8	9-# 6	10-# 5	9-# 5	3.66	3.70	3.73
25	300	34	17-# 7	10-# 6	11-# 5	9-# 5	3.95	3.99	4.02
25	350	41	14-# 8	10-# 6	11-# 5	10-# 5	4.19	4.23	4.28

(1) Columns same above and below plate.
(2) Center-to-center of columns; $\ell_1 = \ell_2$.
(3) Superimposed factored load (factored dead load has been deducted).