Overlook Towers

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Technical Assignment 2

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Executive Summary

This technical assignment will focus on the flooring system for Overlook Towers. The existing system is described in detail along with the design considerations and loading calculations. Four alternate flooring systems are also analyzed and considered a potential system for the building. Through rough calculations, computer models and economic considerations the systems will be compared and a conclusion will be made whether the chosen system is a viable option for the building conditions.

The existing floor system for Overlook Towers is a composite deck supported by A992 wide-flange steel frames. The deck is composed of 3 ¼” lightweight concrete (115 pcf) and a 3” 18 gauge composite steel deck. The following are the four alternate systems:

Open-web Steel Joist
Pre-cast hollow-core plank
Pre-cast Double-T plank
Post-tensioned slab

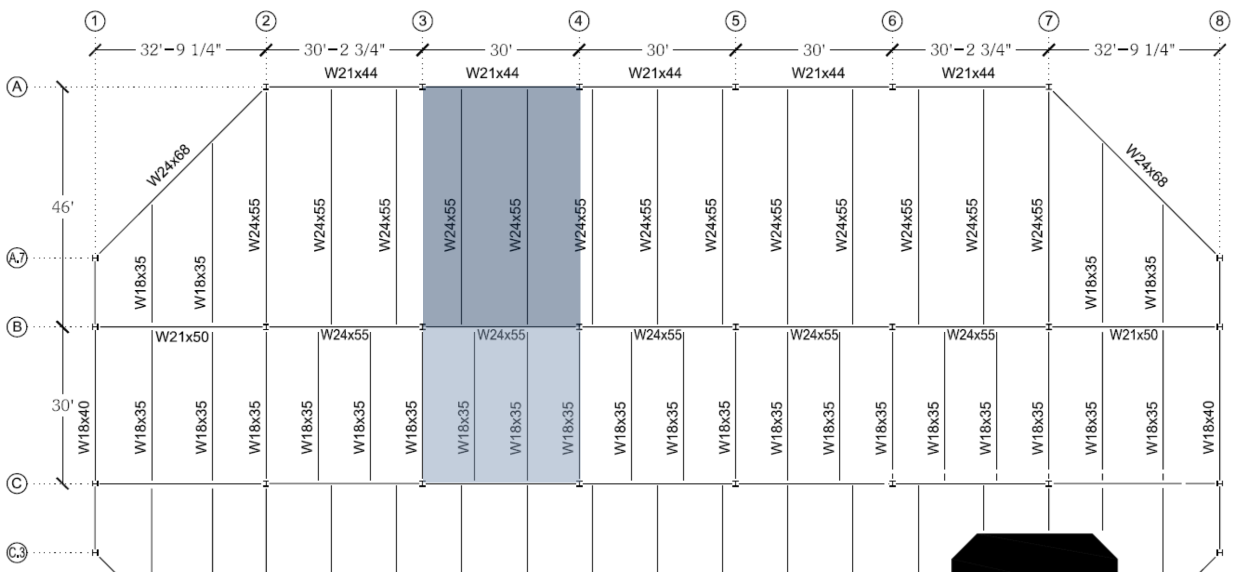
The option that can be ruled out immediately is the open-web steel joist system. It is just not practical for an office building. Vibrations would be too much of a problem. Another problem with the system is its difficulty to fireproof. This may be a possible roofing system, but not for a flooring system. The pre-cast hollow core planks can also be eliminated; the self weight alone is enough for disqualification. This system may allow for a quicker erection time and easier fireproofing than steel joists; however, it is still not practical when compared to the last two alternatives.

The existing system is one of the better options. This is a common system to work with and relatively cheap to construct. Post-tensioning and the double-T plank were found to be viable alternatives to the current system. Both systems have smaller depth and roughly weigh the same. The double-T, in all probability, will require a larger foundation but may reduce construction time, considering it is pre-cast. The complexity of post-tensioning concrete may be reason enough to exclude this option. Although the system would cost more, the 46’ span is easily achieved.

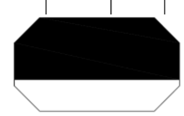
Existing Conditions

Building Summary

Overlook Towers is a nine story, 260,000 square foot steel office building. The floor plan is open with only a few columns interfering with the office space. The majority of the supporting structure is along the perimeter of the building and around the central core. The two typical bay sizes are highlighted below in the partial framing plan. The typical beam sizes are also noted on the drawing, actual sizes vary depending on level. Each bay is spaced approximately thirty feet. The longest span in the building is a distance of forty-six feet, which runs from the exterior wall to the interior core. Since this will be the determining factor in the design of the system, I will be concentrating on a bay size of 46' x 30'. The flooring system will be designed considering only live load and dead load. Loads due to wind and seismic forces are omitted.



Partial Framing Plan (typ.)



Key Plan

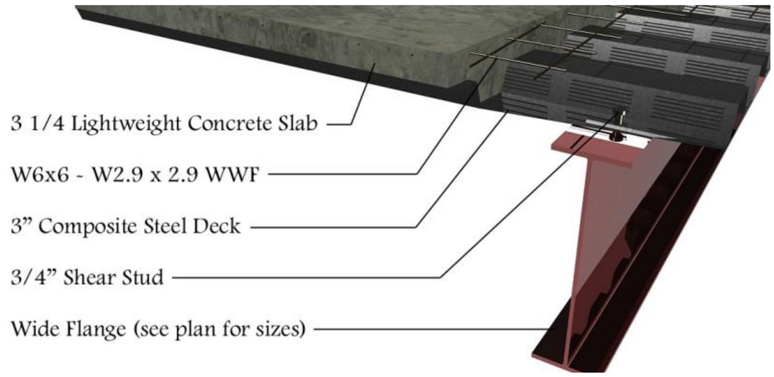
Loading Conditions

The loading conditions to be used in the design of each system are as follows:
(In accordance with IBC 2000)

Live Loads		Dead Loads	
Office	100 psf	Mechanical	5 psf
Corridor	100 psf	Misc.	5 psf
Lobby	100 psf	Floor Weight	See Appendix

For my calculations I will be using a live load of 100 psf and an initial 10 psf dead load. Since this is an open plan office building, an allowable load of 20 psf for moveable partitions is included in the office live load.

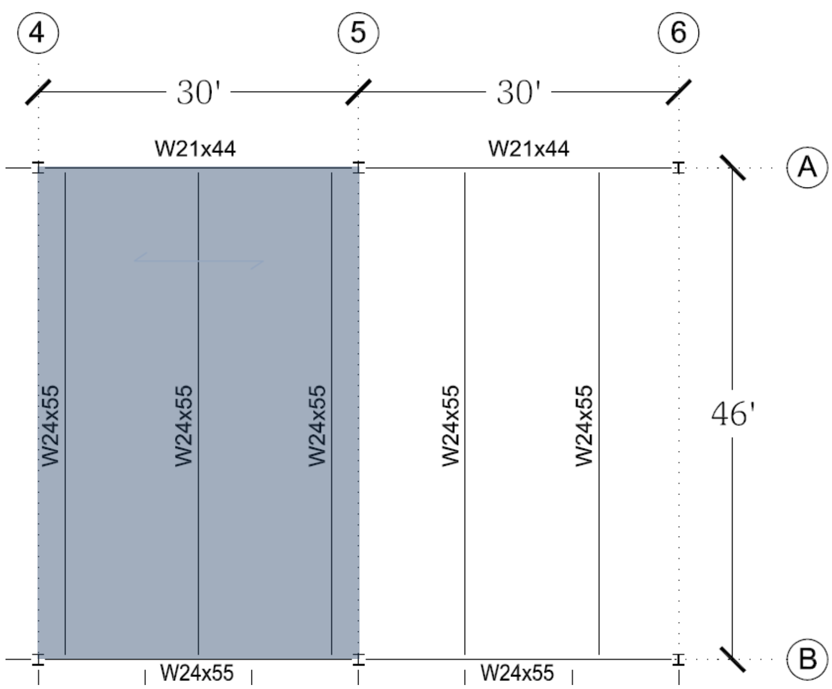
Existing Floor System



Floor Section

The existing floor system is a 6 ¼" composite beam and deck, supported by a steel frame. The slab is 3 ¼" of lightweight concrete (115 pcf) with a 28-day strength of 4000 psi. Below the slab is a 3" 18 gauge composite deck. Shear reinforcing is provided by ¾" headed shear studs. The typical beam size is W24x55 spaced at 12'-6" o.c. The beams frame into a W21x44 exterior girder and a W24x55 interior girder. Although the beams are not spaced evenly with the column lines, I will be using a bay size of 46' x 30' throughout the report.

A big advantage to this system is the use of lightweight concrete. Steel structures are known for their quick erection and are less expensive compared to other systems. Fabrication is performed in the factory, thus reducing the time for on-site preparation. However, there is a possibility of down time due to the members not being delivered to the site in a timely manner. As with all steel structures, the major downfall to this system is the need for fireproofing. Since all structural members require fireproofing, extra time and money is required for installation. This is a very suitable system for this building type and occupancy.

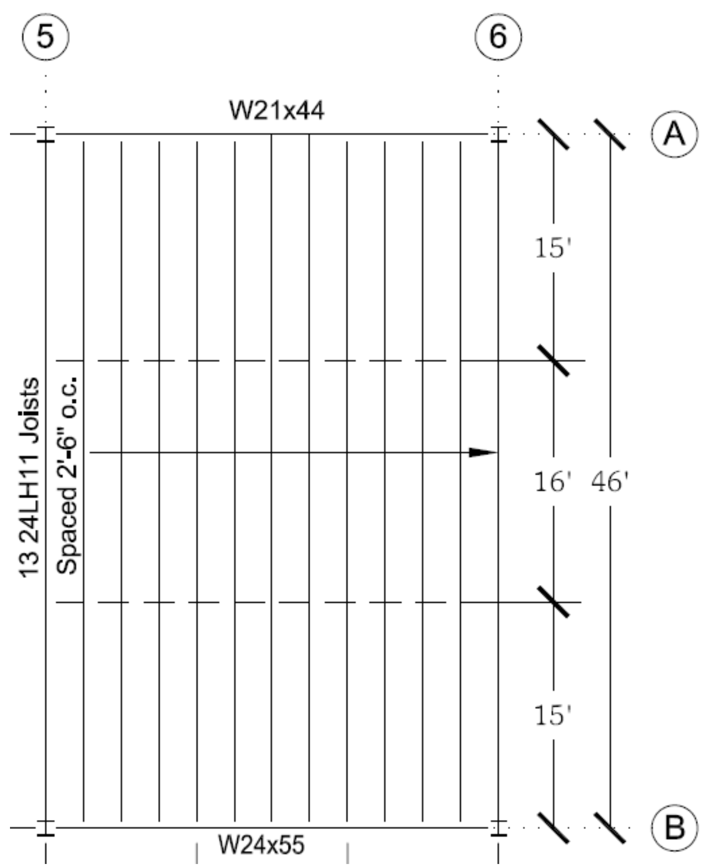


Enlarged Bay Plan

Alt. 1 – Open Web Steel Joists

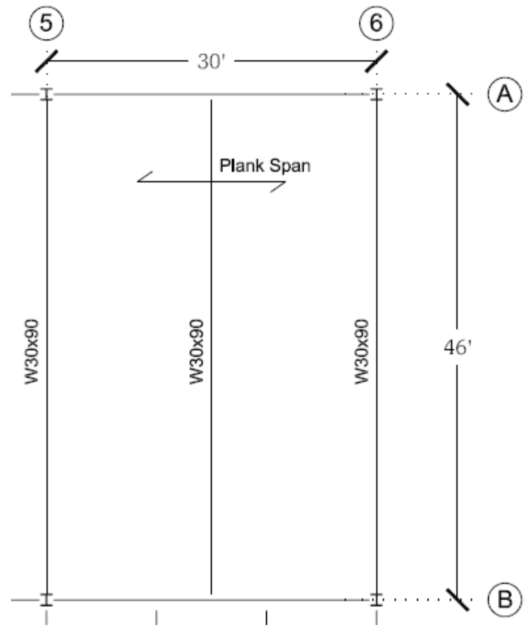
For this system I will remain with a steel frame but replace beams with LH-series steel joists. Joists and slabs are designed using the Steel Joist Institute design tables (see Appendix B). The forty-six foot span will require a spacing of 2'-6" and a slab thickness of 2 ½". Two rows of bridging are also needed. The concrete used in this system will also be lightweight concrete, but with a compressive strength of 3,000 psi. In order to achieve a deflection of $\frac{l}{360}$ with a live load of 250 psf, I chose to use a 24LH11 LH-series joist.

There are not many advantages to this system when compared to the composite slab and beam. The overall floor thickness is only a few inches less than the current system. This could help in some cases, but for the building location a height restriction was not an issue. One advantage, however, is the efficient use of steel. Steel joists weigh less than the W-beams, 55 plf for a wide flange and 25 plf for a steel joist. These systems have an easy constructability with little on-site preparation. Considering the long spans and the tendency for joists to cause floor vibrations this system would not be the best choice.



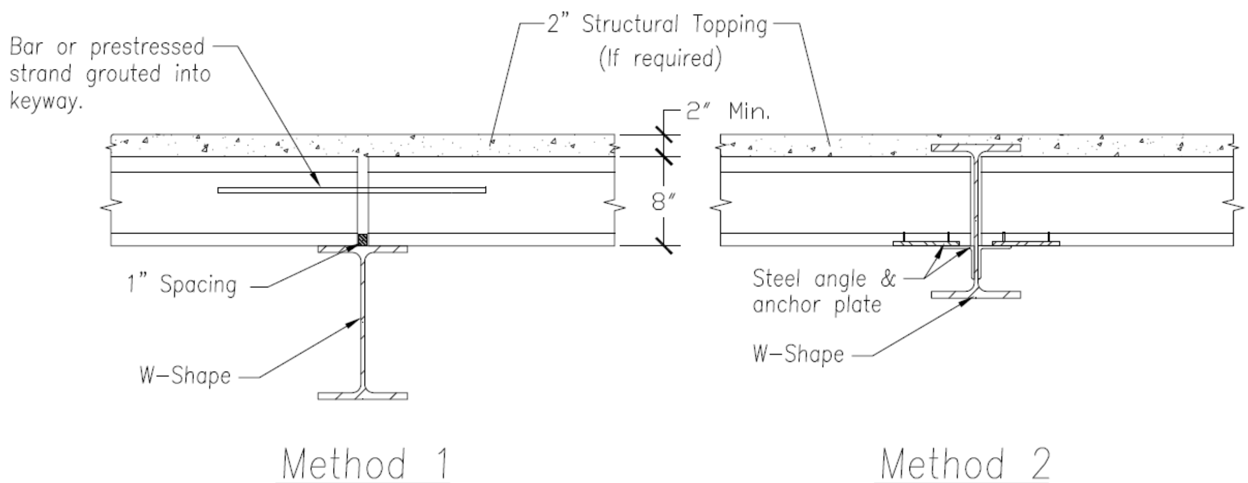
Joist Framing Plan

Alt. 2 – Hollow Core Plank

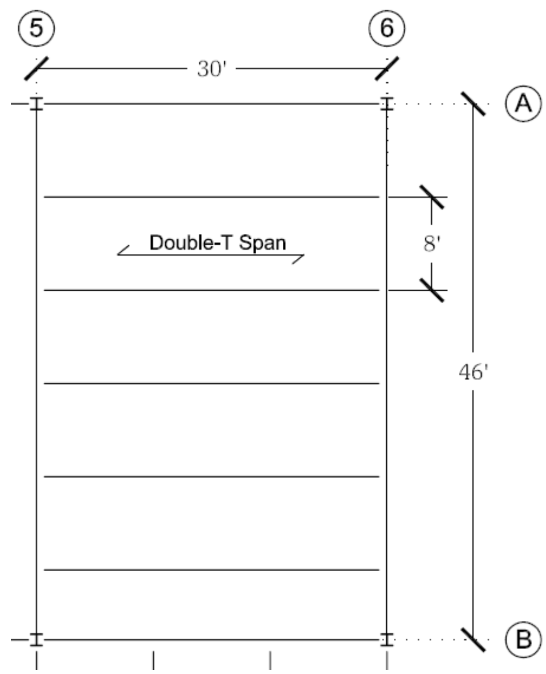


For my second alternative, I used a precast hollow core system. Design aides were obtained from the Spancrete Industries product catalog. With a live load of 110 psf, an 8" hollow core plank system can be used. The planks are 48" wide with a span of 15'. There are two assembly options for this system, which are illustrated below. Method one will be quicker and will require less work. Method two will allow for a more efficient use of space. Another advantage to this method is that it allows for more bracing of the beam, giving it increased lateral support. Several variations exist for each method. A 2" optional layer of structural concrete is offered for each assembly.

The hollow-core plank system is good for a fast paced project because of the precast concrete. Time need not be reserved for curing a concrete deck. Erection will be faster and valuable time and money will be saved. The beams will still need to be fireproofed; however, the concrete planks have a fire rating of two hours. One downfall to this system is its weight; a heavier floor will require larger beams. The concrete planks alone are almost twice the weight of a composite deck. Taking into account all nine stories, this will add a considerable amount of load to the foundation. Money saved on the flooring system may have to be spent on the foundation.

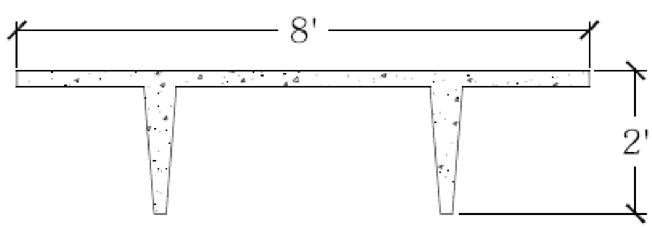


Alt. 3 – Pre-cast Double-T Plank



Another pre-cast concrete alternative is the Double-T plank. Spancrete design tables were used as a design aide (see Appendix B). To reduce the overall depth of the system, I chose to span the planks in the 30' direction. Considering the loading conditions and a 30' span a Spancrete 8DT24-N48H can be used. Each plank is 8'-0" wide by 24" deep with a 30' span. Since no structural topping is required the depth will remain at 24" and an average weight of 55 psf. This system is heavier than the current one, which will require design changes to the columns and foundation.

The double-T plank is also precast, so its advantages are similar to the hollow-core planks. One advantage with using this system when compared to the hollow-core plank is its weight. The plank itself is 6 psf and there is no need for a beam to break up the span. The double-T will not require fireproofing, as it already has a 2 hour rating. No curing time is needed for a concrete deck or the 2" structural concrete topping, which can reduce construction time. Since all components of this system are pre-fabricated, temperature and weather conditions will have less of an impact on the schedule. Any other system with cast-in-place concrete, designers and contractors will have to take into account appropriate temperatures for curing the concrete.



Double-T Section

Alt. 4 – Post-Tensioned Slab & Beam

While researching different concrete systems, I found a post-tensioned system to work best with a 46' span. This system is commonly used in parking structures, but is applicable towards office buildings requiring long spans. Beam sizes were rather large for the current bay arrangement without the use of post-tensioning. Post-tensioning will allow for a more efficient design when compared to the other systems, but with increased complexity. Using the CSI concrete beam tables, beam depth would be approximately 6" smaller than conventionally reinforced beams. It was found that the beam depth can be 24". The concrete will be lightweight with a compressive strength of 4,000 psi and steel yield strength of 60,000 psi. Post-tensioning will offset 90% of the slab dead weight, allowing for smaller beam sizes.

Although a more difficult system to construct, it definitely has its benefits. Beams will only be located on the column lines spanning the N-S direction. More clear space is available for the other disciplines. Having cast-in-place concrete becomes an issue when considering the construction time. Proper curing temperature must be considered in the winter months. Money would have to be spent to enclose and heat the structure during the cold weather.

Comparison of Systems

System	Existing System	Alt. 1 - Steel Joists	Alt. 2 - Hollow-core	Alt. 3 - Double-T	Alt. 4 - Post-Tensioning
Possible Impact on Foundation	n/a	None	Larger Foundation	Larger Foundation	None
Possible Impact on Schedule	n/a	No	Shorter	Shorter	Longer
Fireproofing	Required	Required (most difficult)	Required	Required	Not Required
System Depth	≈ 30”	≈ 27”	≈ 32”	≈ 24”	≈ 24”
Average Weight (Per squre foot)	40 psf	38 psf	64 psf	55 psf	48 psf
Viable Alternative	n/a	No	No	Yes	Yes

Appendix

Appendix A – Floor Weights

Existing System:

Floor Weight: $w_D = (115\ pcf)\frac{3.25"}{12} \approx 32\ psf\ + 3\ psf\ deck\ wt. =$ **35 psf**

Beam: **55 plf** @ 24" deep

Avg. Weight: $35\ psf + 2\left(\frac{46'(55\ plf)}{1380\ s.f.}\right) \approx \mathbf{40\ psf}$

Open-Web Steel Joist:

Floor Weight: $w_D = (115\ pcf)\frac{2.5"}{12} \approx 24\ psf + deck\ weight =$ **27 psf**

Joist Weight: **25 plf** @ 24" deep

Avg. Weight: $27\ psf + 13\left(\frac{46'(25\ plf)}{1380\ s.f.}\right) \approx \mathbf{38\ psf}$

Hollow Core Plank:

Plank Weight: **61 psf**

Beam: **90 plf**

Avg. Weight: $61\ psf + \left(\frac{46'(90\ plf)}{1380\ s.f.}\right) \approx \mathbf{64\ psf}$

Pre-cast Double-T:

8' x 24" Weight: **55 psf**

Beam: **84 plf**

Post-Tensioned Slab:

Floor Weight: $w_D = (115\ pcf)\frac{5"}{12} \approx \mathbf{48\ psf}$

w_{TL} = 100 psf(2.5’) + 38 psf(2.5’) = 345 plf w_{LL} = 250 plf

Joist Designation	Approx. Wt in Lbs. Per Linear Ft. (Joists only)	Depth in inches	SAFELOAD* in Lbs. Between	CLEAR SPAN IN FEET															
			28-32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
24LH03	11	24	11500	342 235	339 226	336 218	323 204	307 188	293 175	279 162	267 152	255 141	244 132	234 124	224 116	215 109	207 102	199 96	191 90
24LH04	12	24	14100	419 288	398 265	379 246	360 227	343 210	327 195	312 182	298 169	285 158	273 148	262 138	251 130	241 122	231 114	222 107	214 101
24LH05	13	24	15100	449 308	446 297	440 285	419 264	399 244	380 226	363 210	347 196	331 182	317 171	304 160	291 150	280 141	269 132	258 124	248 117
24LH06	16	24	20300	604 411	579 382	555 356	530 331	504 306	480 284	457 263	437 245	417 228	399 211	381 197	364 184	348 172	334 161	320 152	307 142
24LH07	17	24	22300	665 452	638 421	613 393	588 367	565 343	541 320	516 297	491 276	468 257	446 239	426 223	407 208	389 195	373 182	357 171	343 161
24LH08	18	24	23800	707 480	677 447	649 416	622 388	597 362	572 338	545 314	520 292	497 272	475 254	455 238	435 222	417 208	400 196	384 184	369 173
24LH09	21	24	28000	832 562	808 530	785 501	764 460	731 424	696 393	663 363	632 337	602 313	574 292	548 272	524 254	501 238	480 223	460 209	441 196
24LH10	23	24	29600	882 596	856 559	832 528	809 500	788 474	768 439	737 406	702 378	668 351	637 326	608 304	582 285	556 266	533 249	511 234	490 220
24LH11	25	24	31200	927 624	900 588	875 555	851 525	829 498	807 472	787 449	768 418	734 388	701 361	671 337	642 315	616 294	590 276	567 259	544 243

Open Web Steel Joists

REINFORCED CONCRETE SLAB ALLOWABLE LOADS

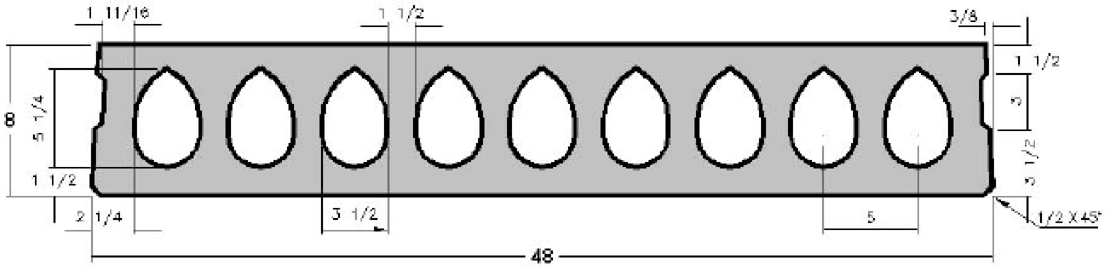
Total Slab Depth	Reinforcement		Superimposed Uniform Load (psf) — 3 Span Condition										
			Clear Span (ft.-in.)										
	W.W.F.	As	2- 0	2- 3	2- 6	2- 9	3- 0	3- 3	3- 6	3- 9	4- 0	4- 6	5- 0
2"	6X6-W1.4XW1.4	0.028*	194	153	124	103	86	74	63				
	6X6-W2.1XW2.1	0.042	285	225	183	151	127	108	93				
(t=1 1/2")	6X6-W2.9XW2.9	0.058	384	304	246	203	171	146	125				
2 1/2"	6X6-W1.4XW1.4	0.028*	268	212	172	142	119	102	88	76	67	53	
	6X6-W2.1XW2.1	0.042	396	313	254	210	176	150	129	113	99	78	
(t=2")	6X6-W2.9XW2.9	0.058	400	400	344	284	239	204	176	153	134	106	
3"	6X6-W1.4XW1.4	0.028*	342	271	219	181	152	130	112	97	86	68	
	6X6-W2.1XW2.1	0.042*	400	400	325	268	226	192	166	144	127	100	
(t=2 1/2")	6X6-W2.9XW2.9	0.058	400	400	400	366	307	262	226	197	173	137	
3 1/2"	6X6-W2.1XW2.1	0.042*	400	400	396	327	275	234	202	176	155		
	6X6-W2.9XW2.9	0.058*	400	400	400	400	375	320	276	240	211		
(t=3")	4X4-W2.9XW2.9	0.087	400	400	400	400	400	400	400	353	310		
4"	6X6-W2.1XW2.1	0.042*	400	400	400	384	322	275	237	206	181		
	6X6-W2.9XW2.9	0.058*	400	400	400	400	400	372	321	280	246		
(t=3 1/2")	4X4-W2.9XW2.9	0.087	400	400	400	400	400	400	400	400	358		
4 1/2"	6X6-W2.9XW2.9	0.058*	400	400	400	400	400	400	359	313	275		
	4X4-W2.9XW2.9	0.087	400	400	400	400	400	400	400	400	400		
(t=4")	4X4-W4.0XW4.0	0.120	400	400	400	400	400	400	400	400	400		
5"	6X6-W2.9XW2.9	0.058*	400	400	400	400	400	400	396	345	303		
	4X4-W2.9XW2.9	0.087*	400	400	400	400	400	400	400	400	400		
(t=4 1/2")	4X4-W4.0XW4.0	0.120	400	400	400	400	400	400	400	400	400		
			0.6C28		0.6C26		0.6C24			0.6C22			

NOTES:
1. * As does not meet A.C.I. criterion for temperature and shrinkage.
2. Recommended conform types are based upon S.D.I. criteria and normal weight concrete.
3. Superimposed loads are based upon three span conditions and A.C.I. moment coefficients.
4. Load values for single span and double spans are to be reduced.
5. Superimposed load values in bold type require that mesh be draped. See page 19.
6. Vulcraft's painted or galvanized form deck can be considered as permanent support in most building applications. See page 19. If uncoated form deck is used, deduct the weight of the slab from the allowable superimposed uniform loads.

Non-composite Slab

3.4 ULTRALIGHT LOAD TABLES
8" thick
.75" strand cover

SPANCRETE INDUSTRIES, INC.



No Structural Topping Dead Load Weight of Slab = 61 psf							
FIRE RATINGS (Hours)							
Code			Restrained		Unrestrained		
Rational Design			-		-		
SBC/UBC			2		-		
UL			2		3/4		
DILHR 51.045 Table 2			See 2.2		See 2.2		
Section Properties							
$A = 251\ in^2$ $I = 1817\ in^4$			Yt = 3.99 in Yb = 4.01 in		b = 15.4 in wt = 61 psf		
Mn ft-k/ft	11.05	14.97	19.73	26.65	31.37	32.84	35.89
Series	.75F-8506	.75F-8606	.75F-8706	.75F-8708	.75F-8710	.75F-8808	.75F-8712
Span in feet	Allowable Superimposed Load in Pounds per Square Foot						
13	257	366	499				
14	215	309	423				
15	181	263	362				
16	153	225	312	421			
17	130	193	271	367			
18	110	167	236	322			
19	94	145	207	284	350	359	
20	80	126	182	251	317	328	
21	68	109	160	223	284	298	
22	57	95	142	199	255	269	295
23	48	83	125	178	229	242	269
24	40	72	111	159	206	218	243
25		62	98	143	186	197	220

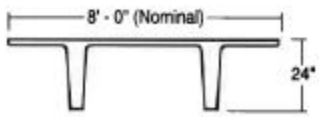
2 Inch Bonded Structural Topping Dead Load Weight of Slab with Topping = 86 psf							
FIRE RATINGS (Hours)							
Code			Restrained		Unrestrained		
Rational Design			-		-		
SBC/UBC			3		-		
UL			2		3/4		
DILHR 51.045 Table 2			See 2.2		See 2.2		
Section Properties							
$A = 336\ in^2$ $I = 3425\ in^4$			Yt = 4.63 in Yb = 5.27 in		B = 15.4 in wt = 86 psf		
Mn ft-k/ft	14.18	19.24	25.42	33.09	40.37	42.53	47.23
Series	.75F 8506 T	.75F-8606 T	.75F-8706 T	.75F-8708 T	.75F-8710 T	.75F-8808 T	.75F-8712 T
Span in feet	Allowable Superimposed Load in Pounds per Square Foot						
15	226	332	461				
16	190	283	396	471			
17	160	242	343	439			
18	135	209	298	410			
19	114	180	261	361	385		
20		156	228	318	363		
21		134	200	282	342		
22		116	176	251	322		
23		100	155	224	288	305	
24			137	200	259	277	290
25			121	178	233	249	276
26			106	160	210	225	258
27				143	190	204	233

Hollow Core Plank

1.4 Double tee load tables
8'-0" x 24" Double tee

SPANCRETE

Issued 10/94



No Structural Topping
Dead Load Weight of Tee = 55 psf

SECTION PROPERTIES

$A = 423 \text{ in.}^2$ $\quad Y_1 = 7.08$ in.
$I = 22{,}187 \text{ in.}^4$ $\quad Y_2 = 16.92$ in.

ϕM_n ft - k	266	391	511	627	737	843	944
SERIES	8DT24-N48H	8DT24-N68H	8DT24-N88H	8DT24-N108H	8DT24-N128H	8DT24-N148H	8DT24-N168H
Span in Feet	ALLOWABLE SUPERIMPOSED LOAD IN POUNDS PER SQUARE FOOT						
24	234						
26	193						
28	160	257					
30	133	218	300				
32	111	186	257				
34	93	159	221	261			
36	78	137	192	227			
38	65	118	166	198			
40	54	102	145	173			
42	45	88	126	152			
44	37	76	110	134			
46		66	96	118			
48		57	84	104	123		
50		48	73	91	109		
52		41	63	80	96		
54			55	70	85		
56			47	62	76		
58			40	54	67	75	
60				47	59	67	
62				40	52	59	
64					45	52	
66					39	46	
68						40	47
70						35	41
72							36

1" - 1 1/2" Camber   1 1/2" or More Camber

Appendix C – Rough Calculations

<u>JOIST CALCULATIONS</u>

Joist Load: 25 plf (46')(11 joists) = 12.65 kips $\frac{12650\ lb}{30'} = 421\ plf$

w_u = 1.2(421) + 1.2(38 psf)(46') + 1.6(100 psf)(46') = 9.96 klf

Beam Moment: $M_u = \frac{9.96\ (30^2)}{8} = 1{,}120'^k$ → W30x99 (ΦM_n = 1170'k / ΦV_n = 417k)

<u>PRE-CAST HOLLOW CORE</u>

Beam Moment: w_u = 1.2(61 psf)(15') + 1.6(100 psf)(15') = 3.5 klf

$M_u = \frac{3.5(46^2)}{8} = 925'^k$ → W30x90 (ΦM_n = 1060'k / ΦV_n = 374k)

<u>DOUBLE-T CALCULATIONS</u>

Beam Moment: w_u = 1.2(55 psf + 10 psf)(30') + 1.6(100 psf)(30') = 7.14 klf

$M_u = \frac{7.14(30^2)}{8} = 803'^k$ → W24x84 (ΦM_n = Mn840'k / ΦV_n = 306k)