OFFICE BUILDING

Ontario, CA

Structural Technical Report 2

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Proposed Alternate Floor Systems

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Structural Option

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Executive Summary

This technical report examines the existing floor system on the Office Building and provides an in-depth analysis of 4 additional alternative floor systems. A detailed description of advantages and disadvantages that coincide with is system is provided and then compared with the original composite floor system.

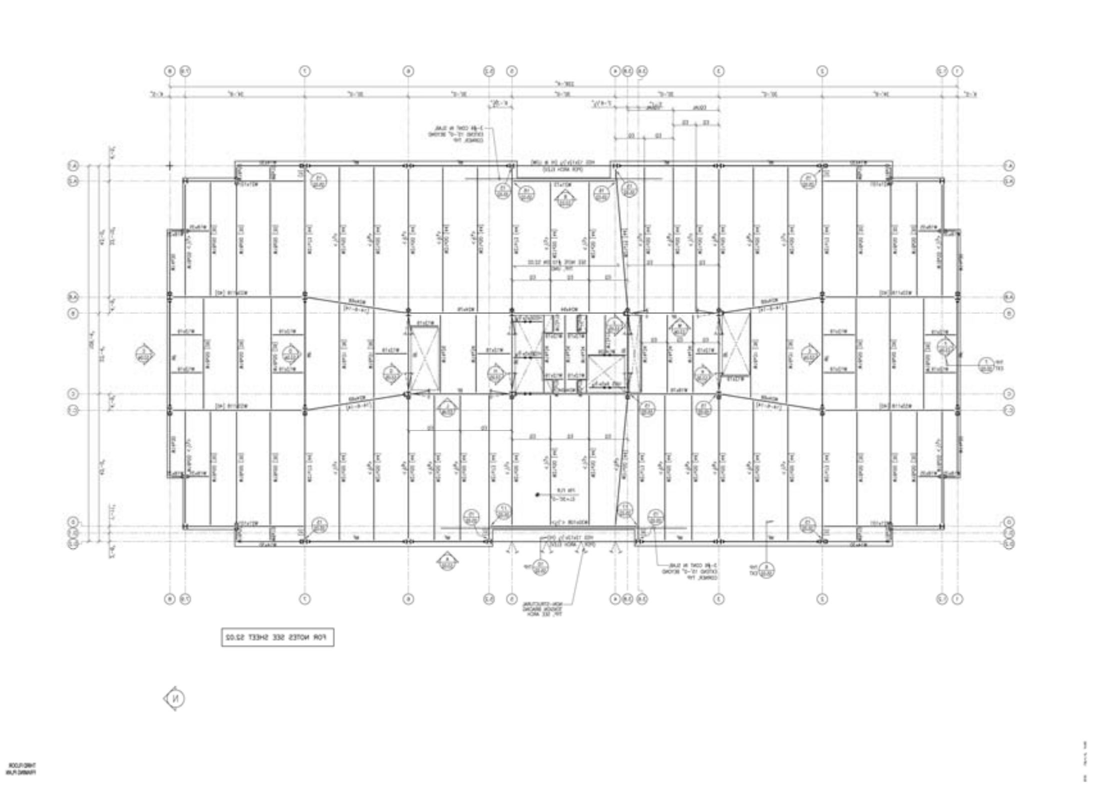
The four alternative floor systems examined in this report are a hollow-core precast plank system, a one-way joist system, a non-composite deck and a two-way flat slab with drop panels. All tables and charts referenced for the alternative designs are included in the appendix.

After analyzing all four alternative systems and comparing them with the original floor system, it was concluded that the most sufficient system was the one-way joist system.

Existing Floor System

This building consists of six floors, all of which are above grade. The same floor system is used on each floor, which is a composite lightweight concrete on steel deck system, with typical bays running 38'x 30'.

Each floor area is approximately 28,000 square feet. The second floor through the sixth floor have nearly identical floor plans, as well as beam, and girder sizes and applied loads. This allows for uniform floor systems throughout the building.



The existing composite floor system consists of 3.25" of lightweight concrete fill with # 3 reinforcing bars spaced at 18" O.C. each way and is supported by a 3" VERCO W3 Formlock 20 gauge metal deck.

Alternative Floor Systems

One - Way Joist System for Multiple Spans

The first proposed alternative floor system is a one-way joist system for multiple spans. This system works well for this building for a number of reasons. The first being that the existing typical bays have long spans and one – way joist systems work well for long spans. It is very similar to the current floor system which means minimal changes will need to be made. Another advantage to this system is the joist depth. Since the joists are deep, the slab thickness is minimized which in turn reduces the dead load.

One last advantage is that the pan forms can be re – used to reduce the cost of construction.

One disadvantage of this system is the time for construction for each floor. Although the pan forms may be re – used, the concrete must fully cure before the forms can be removed and used for the next floor. In addition, shoring must also be constructed to support the formwork until the concrete is fully cured.

With the aid of the CRSI tables, a sufficient design was found on page 8-28. The design specifies a joist span of 39' in the N-S direction with 20" deep joists and a 4.5" top slab. Each joist is reinforced with #8 bars at 12" O.C. at the top and one #7 and one #8 bar in the bottom.

STANDARD (1) ONE-WAY JOISTS MULTIPLE SPANS	30" Forms = 7" rib @ 37" c.-c. FACTORED USABLE SUPERIMPOSED LOAD (PSF)(2)	f'_c = 4,000 psi f_y = 60,000 psi

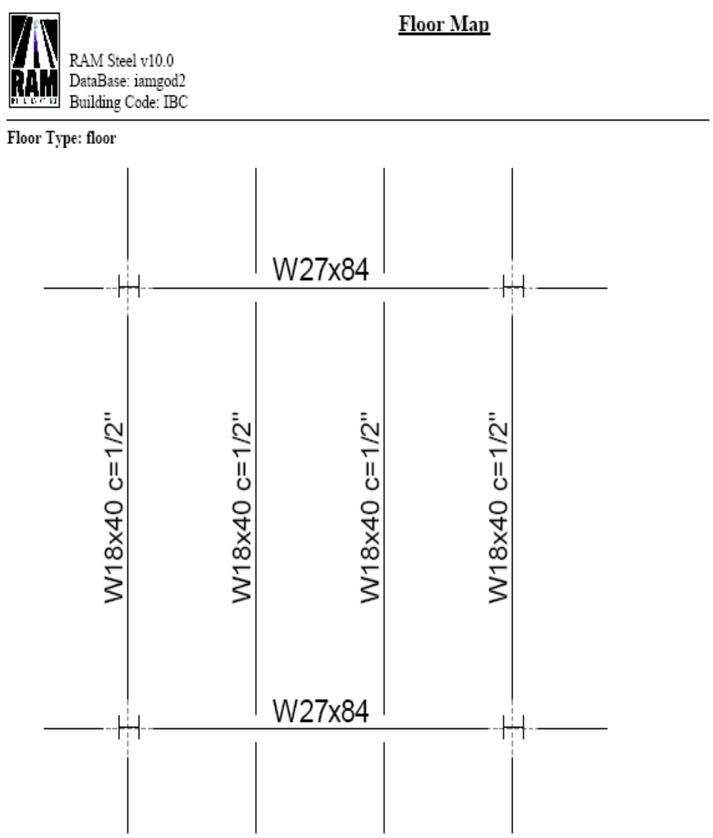
Depth	20" Deep Rib + 4.5" Top Slab = 24.5" Total Depth										
TOP BARS Size @	#5 11	#5 9.5	#6 11.5	#6 9.5	#7 11.5	End Span Defl. Coeff. (3)	#5 9.5	#6 11.5	#6 9.5	#7 11.5	#8 12	Int. Span Defl. Coeff. (3)
BOTTOM BARS # #	#6 #6	#6 #7	#7 #7	#7 #8	#8 #8		#5 #6	#6 #6	#6 #7	#7 #7	#7 #8	
Steel (psf)	1.20	1.40	1.63	1.89	2.16		1.36	1.64	1.93	2.23	2.65	
CLEAR SPAN	END SPAN						INTERIOR SPAN					
32'-0"	155 0	210 0	267 0	332 0	358 * 399	12.975	231 0	298 0	380 0	415 * 462	424 * 485 *	7.985
33'-0"	136 0	188 0	241 0	303 0	338 * 365	14.675	208 0	271 0	347 0	394 * 425	402 * 458 *	9.031
34'-0"	119 0	168 0	218 0	276 0	319 * 335	16.536	186 0	246 0	318 0	374 * 391	382 * 433 *	10.176
35'-0"	103 0	149 0	197 0	251 0	301 * 307	18.569	167 0	223 0	291 0	355 * 360	362 * 410 *	11.427
36'-0"	88 0	132 0	177 0	229 0	281 0	20.784	149 0	202 0	266 0	331 0	345 * 389 *	12.790
37'-0"	75 0	117 0	159 0	208 0	258 0	23.191	132 0	182 0	243 0	305 0	328 * 369 *	14.272
38'-0"	63 0	102 0	142 0	189 0	236 0	25.802	117 0	165 0	222 0	280 0	313 * 348	15.878
39'-0"	51 0	89 0	127 0	171 0	216 0	28.627	103 0	148 0	203 0	258 0	298 * 322	17.617
40'-0"	41 0	77 0	113 0	155 0	197 0	31.678	90 0	133 0	185 0	237 0	284 * 298	19.494
41'-0"		65 0	100 0	139 0	180 0	34.967	78 0	119 0	168 0	218 0	271 * 276	21.518
42'-0"		54 0	87 0	125 0	164 0	38.505	66 0	105 0	153 0	200 0	256 0	23.695
43'-0"		45 0	76 0	112 0	149 0	42.305	56 0	93 0	138 0	184 0	236 0	26.034
44'-0"			65 0	100 0	135 0	46.380	46 0	82 0	125 0	168 0	219 0	28.542
45'-0"			55 0	88 0	122 0	50.742		71 0	112 0	154 0	202 0	31.226

Non-Composite System

The second proposed system is a concrete slab on metal decking supported by non-composite steel beams.

The fact that the beams are non-composite is the only difference between this floor system and the existing one. Since the beams are non-composite, the shear studs are eliminated which results in a faster construction time, and a reduction in labor costs.

The major disadvantage of this system is larger beam sizes. By removing the shear studs, the slab and steel beams no longer act together, therefore causing only the beam to counteract the moment. This larger beam size then takes away from the plenum space for mechanical equipment and electrical conduit., and the only way to make up for this lost space is to increase the floor-to-floor height.



This system was designed with the aid of RAM Steel, which designed for W18x40 beams And W27x84 girders as compared to W12x50 beams and W24x68 girders in the original composite system.

Two-Way Flat Slab With Drop Panels

The next system designed is a two-way flat slab with drop panels. This system works well for square bays. The addition of the drop panels prevents punching shear caused by the columns and allows for greater moment to be absorbed at the supports as compared to a two-way flat slab without drop panels. In addition, the slab thickness and column size may be reduced.

Much like the one-way joist system, an increase in construction time will result from the time it takes to construct the formwork and for the concrete to cure.

As before, the CRSI tables were referenced and an adequate design for a 30'x30' bay was found on page 10-26. The design specifies 10"x10" columns with a 12" thick slab. The column strips are reinforced with 15 #7 bars in the top and 17 #6 bars in the bottom while the middle strip is reinforced with 10 #7 bars in the top and 15 #5 bars at the bottom.

f'_c = 3,000 psi
Grade 60 Bars

FLAT SLAB SYSTEM — SQUARE EDGE PANEL With Drop Panels — No Beams | SQUARE INTERIOR PANEL With Drop Panels (2) — No Beams

h = 12 in. = TOTAL SLAB DEPTH BETWEEN DROP PANELS

SPAN c.-c. $\ell_1 = \ell_2$ (ft)	Factored Superimposed Load (psf)	Square Drop Panel Depth (in.)	Square Drop Panel Width (ft)	Square Column ℓ_c = 12'-0" (3) Size (in.)	α_{ec}	Reinforcing Bars (E. W.) Column Strip (1) Top Ext.	Column Strip Bot.	Column Strip Top Int.	Middle Strip Bot.	Middle Strip Top Int.	Total Steel (psf)	Moments Edge (−) (ft-k)	Moments Bot. (+) (ft-k)	Moments Int. (−) (ft-k)	Interior: Factored Superimposed Load (psf)	Square Column ℓ_c = 12'-0" (3) Size (in.)	α_{ec}	Reinforcing Bars (E. W.) Col. Strip Top	Col. Strip Bot.	Mid. Strip Top	Mid. Strip Bot.	Total Steel (psf)	Concrete (cu. ft / sq. ft)
25	100	3	8.33	12	0.144	12-#5	10-#6	18-#5	11-#5	11-#5	2.76	45.8	333.6	413.6	100	12	0.072	16-#5	11-#5	11-#5	11-#5	2.66	1.027
25	200	3	8.33	15	0.298	12-#5	13-#6	12-#7	12-#5	11-#5	3.13	107.6	407.4	523.6	200	17	0.227	14-#6	11-#5	11-#5	11-#5	2.87	1.027
25	300	5	8.33	18	0.525	12-#5	11-#7	12-#7	13-#5	11-#5	3.41	195.8	466.8	626.0	300	21	0.427	15-#6	13-#5	11-#5	11-#5	3.10	1.046
25	400	7	8.33	20	0.705	12-#5	12-#7	13-#7	15-#5	13-#5	3.69	276.4	528.8	728.8	400	24	0.616	15-#6	15-#5	12-#5	11-#5	3.28	1.064
25	500	9	8.33	22	0.916	14-#5	11-#8	13-#7	9-#7	15-#5	4.29	368.2	591.0	831.8	500	25	0.674	12-#7	13-#6	10-#6	12-#5	3.79	1.083
25	600	9	10.00	23	0.976	12-#6	19-#7	12-#8	11-#7	9-#7	5.20	434.1	730.7	946.9	600	25	0.634	18-#6	9-#8	11-#6	15-#5	4.42	1.120
25	700	11	10.00	25	1.222	19-#5	20-#7	12-#8	10-#8	10-#7	5.84	539.3	829.6	1048.4	700	25	0.611	18-#6	11-#8	10-#7	10-#7	5.22	1.146
26	100	3	8.66	12	0.141	12-#5	16-#5	14-#6	11-#5	11-#5	2.75	51.1	376.7	466.9	100	12	0.070	17-#5	11-#5	11-#5	11-#5	2.60	1.027
26	200	5	8.66	15	0.288	12-#5	14-#6	12-#7	13-#5	11-#5	3.13	118.2	461.2	591.5	200	18	0.257	14-#6	12-#5	11-#5	11-#5	2.82	1.046
26	300	5	8.66	18	0.513	12-#5	12-#7	26-#5	15-#5	9-#6	3.63	218.2	529.3	708.5	300	21	0.417	13-#7	15-#5	12-#5	11-#5	3.31	1.046
26	400	7	8.66	20	0.689	13-#5	11-#8	14-#7	9-#7	15-#5	4.07	308.6	600.3	825.5	400	24	0.600	13-#7	17-#5	13-#5	12-#5	3.54	1.064
26	500	9	8.66	22	0.894	16-#5	12-#8	12-#8	10-#7	9-#7	4.53	410.1	665.4	939.4	500	26	0.733	13-#7	14-#6	15-#5	13-#5	3.94	1.083
26	600	11	10.39	24	1.047	18-#5	20-#7	12-#8	10-#8	10-#7	5.39	506.4	797.6	1064.4	600	26	0.672	18-#6	10-#8	10-#7	16-#5	4.60	1.146
26	700	11	10.39	25	1.191	15-#6	17-#8	22-#6	15-#7	15-#6	6.16	601.8	909.6	1184.6	700	26	0.672	12-#8	12-#8	14-#6	10-#7	5.40	1.146
27	100	5	9.00	12	0.133	12-#5	18-#5	14-#6	12-#5	12-#5	2.83	54.5	426.0	526.7	100	12	0.066	12-#6	12-#5	12-#5	12-#5	2.65	1.046
27	200	5	9.00	15	0.283	12-#5	9-#8	13-#7	15-#5	12-#5	3.41	131.2	519.5	665.5	200	18	0.251	12-#7	14-#5	12-#5	12-#5	3.06	1.046
27	300	7	9.00	18	0.487	12-#5	11-#8	26-#5	9-#7	10-#6	3.87	236.8	598.5	797.6	300	22	0.453	12-#7	9-#7	9-#6	12-#5	3.38	1.064
27	400	9	9.00	20	0.656	13-#5	12-#8	27-#5	14-#6	9-#7	4.29	338.2	681.4	932.7	400	24	0.568	13-#7	14-#6	15-#5	9-#6	3.77	1.083
27	500	11	9.00	22	0.858	16-#5	19-#7	12-#8	9-#8	10-#7	4.98	452.8	755.1	1061.5	500	26	0.698	18-#6	12-#7	9-#7	15-#5	4.25	1.101
27	600	11	10.80	24	1.022	14-#6	16-#8	22-#6	10-#8	9-#8	5.60	562.1	860.9	1196.8	600	27	0.733	12-#8	11-#8	14-#6	18-#5	4.94	1.146
28	100	5	9.33	12	0.131	13-#5	11-#7	16-#6	10-#6	12-#5	3.04	60.3	476.7	589.2	100	12	0.065	14-#6	12-#5	12-#5	12-#5	2.67	1.046
28	200	5	9.33	15	0.278	13-#5	18-#6	16-#7	12-#6	13-#5	3.57	144.9	582.4	745.4	200	18	0.246	13-#7	15-#5	12-#5	12-#5	3.10	1.046
28	300	7	9.33	18	0.477	13-#5	12-#8	16-#7	10-#7	16-#5	4.05	261.8	672.3	894.3	300	22	0.442	26-#5	13-#6	10-#6	12-#5	3.44	1.064
28	400	9	9.33	20	0.642	15-#5	14-#8	16-#7	12-#7	10-#7	4.81	374.4	766.1	1046.5	400	24	0.554	15-#7	12-#7	12-#6	15-#5	4.22	1.083
28	500	11	11.20	23	0.870	18-#5	16-#8	22-#6	10-#8	15-#6	5.24	511.8	845.1	1189.8	500	27	0.714	15-#7	18-#6	14-#6	12-#6	4.54	1.146
29	100	7	9.66	12	0.123	13-#5	17-#6	15-#6	15-#5	13-#5	3.10	63.5	534.6	659.3	100	12	0.061	13-#6	13-#5	13-#5	13-#5	2.69	1.064
29	200	7	9.66	15	0.264	13-#5	15-#7	19-#6	10-#7	15-#5	3.76	155.7	653.8	834.3	200	18	0.234	13-#7	12-#6	13-#5	13-#5	3.24	1.064
29	300	9	9.66	19	0.542	13-#5	13-#8	15-#7	15-#6	10-#7	4.26	317.5	738.3	992.9	300	22	0.417	26-#5	11-#7	16-#5	10-#6	3.70	1.083
29	400	11	9.66	20	0.624	14-#5	16-#8	16-#7	10-#8	11-#7	5.04	411.4	859.9	1171.3	400	24	0.526	15-#7	10-#8	10-#7	16-#5	4.35	1.101
29	500	11	11.60	23	0.851	14-#6	23-#7	14-#8	11-#8	10-#8	5.72	565.1	947.2	1330.5	500	27	0.696	13-#8	12-#8	12-#7	10-#7	5.07	1.146
30	100	7	10.00	12	0.121	14-#5	11-#8	17-#6	12-#6	13-#5	3.33	69.8	593.6	731.8	100	12	0.060	15-#6	15-#5	13-#5	13-#5	2.81	1.064
30	200	7	10.00	15	0.260	14-#5	13-#8	16-#7	11-#7	12-#6	3.99	170.9	727.2	927.0	200	18	0.230	14-#7	19-#5	15-#5	13-#5	3.32	1.064
30	300	9	10.00	19	0.532	14-#5	20-#7	17-#7	10-#8	14-#6	4.70	348.6	822.7	1104.6	300	22	0.408	15-#7	17-#6	10-#7	15-#5	4.01	1.083
30	400	11	10.00	20	0.612	1-6#5	23-#7	14-#8	12-#8	13-#7	5.34	452.1	958.6	1303.5	400	24	0.514	16-#7	15-#7	11-#7	18-#5	4.61	1.101

(Continued)

Hollow-Core Precast Plank

Lastly, a hollow-core precast plank system was chosen as the final system to be analyzed. Numerous advantages of this system include quick assembly time once on site, no shoring is required and the entire thickness including the top slab is only 10". Since these planks are manufactured in a plant, high quality is assured. Longer spans and higher load capacities are possible because the steel strands are pre-stressed.

As with all systems, there are also some disadvantages of hollow-core precast planks. Depending on the company the planks are ordered from, the leed time may be very long which means orders must be placed well in advance to the start of construction or the project will be delayed. Skilled workmanship is required in the assembly of these planks to ensure quality, especially because the joints between panels may be complicated.

Using the 6th Edition of the PCI Handbook, a design was found on page 2-32. For a 38' span a sufficient design includes a 4" wide and 8" thick plank covered by a 2" top slab. The plank is reinforced with 5 straight #8 bars.

68-S	476	430	393	361	332	309	286	269	253	235	223	209	200	180	165	153	142	132	121	110	101	92	84	77	70	63	56	51	45	40
	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.7	0.7	0.6	0.5	0.4	0.2	0.1	–0.1	–0.3
	0.3	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.9	0.9	1.0	1.0	1.0	1.0	0.9	0.9	0.9	0.8	0.7	0.6	0.4	0.2	0.0	–0.2	–0.5	–0.8	–1.1	–1.5
78-S	488	442	402	370	341	318	295	275	259	241	229	215	203	195	180	168	157	144	135	126	118	110	101	92	84	77	70	64	58	52
	0.3	0.3	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.9	0.9	1.0	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.0	0.9	0.8	0.7	0.6	0.5	0.3
	0.4	0.5	0.5	0.6	0.7	0.8	0.8	0.9	1.0	1.0	1.1	1.2	1.2	1.2	1.3	1.3	1.3	1.3	1.3	1.2	1.2	1.1	1.0	0.8	0.7	0.5	0.3	0.0	–0.3	–0.7

4HC8 + 2

Table of safe superimposed service load (psf) and cambers (in.) — **2 in. Normal Weight Topping**

Strand Designation Code	Span, ft																											
	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
66-S	489	445	394	340	294	256	224	197	173	153	135	119	105	93	82	68	56	45	36	26								
	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.1	0.0	–0.0	–0.1	–0.2	–0.3								
	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.0	–0.1	–0.2	–0.3	–0.4	–0.6	–0.7	–0.9	–1.2	–1.4								
76-S	498	457	420	387	347	304	267	235	208	184	164	146	130	116	103	88	74	62	51	41	31							
	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.1	–0.0	–0.1	–0.2							
	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.1	0.0	–0.1	–0.2	–0.4	–0.5	–0.7	–0.9	–1.2	–1.4							
58-S	492	451	414	384	357	333	310	293	274	245	219	196	177	159	143	126	110	95	82	70	59	49	40	32				
	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.5	0.5	0.5	0.1	0.3	0.2	0.1	0.0	–0.1				
	0.3	0.3	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.4	0.3	0.3	0.3	0.2	0.1	–0.1	–0.2	–0.4	–0.6	–0.9	–1.2	–1.5	–1.8				
68-S		463	426	393	366	342	319	299	282	267	251	239	216	195	177	158	140	124	110	97	84	73	62	53	44	36	28	
		0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.7	0.7	0.6	0.5	0.4	0.2	0.1	–0.1	
		0.4	0.5	0.5	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.6	0.6	0.6	0.5	0.4	0.3	0.2	0.0	–0.2	–0.4	–0.6	–0.9	–1.2	–1.6	–2.0	–2.4	
78-S		472	435	402	375	348	325	305	288	273	257	245	232	220	207	186	167	149	133	119	106	94	83	73	64	55	46	38
		0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.9	0.9	1.0	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.0	0.9	0.9	0.7	0.6	0.5	0.3
		0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.8	0.9	0.9	0.9	0.9	0.8	0.8	0.7	0.7	0.6	0.4	0.3	0.1	–0.1	–0.3	–0.6	–0.9	–1.3	–1.7	–2.2

Strength is based on strain compatibility; bottom tension is limited to $7.5\sqrt{f'_c}$ *; see pages 2–7 through 2–10 for explanation.*

Comparison Chart

System	Depth	Weight	Cost		
	(in)	(psf)	Mat.	Inst.	Total
One-Way Joist	25.5	105	$7.10	$9.45	$16.55
Non-Composite	4.75	52	$11.45	$6.20	$17.65
Two-Way Flat Slab	12	150	$7.00	$8.25	$15.25
Hollow-Core Precast	10	68	$14.35	$4.93	$19.28
Composite	6.25	70	$8.80	$4.61	$13.41

Conclusion

After considering the advantages and disadvantages of each system, the best alternative floor system appears to be the one-way joist system. Although it is a bit more expensive than the two-way flat slab, the one-way joist system weighs considerably less, and this system is very similar to that of the existing composite system.

Appendix References

PCI Design Handbook - 6th Edition

CRSI Design Handbook 2002

Vulcraft website for composite slab information