APPENDIX B

Structural Slab Design

Design calculations and tables are derived from Concrete Reinforcing Steel Institute Design Handbook, 2002.

Slab Design

Typical Bay Size: 30' x 30'
Average Column Size: 24" x 24"

Live Load: 100 PSF
Dead Load:

Ceiling…………………………………………………………………….. 10 PSF
Sarnatherm XPS Insulation………………………………… 0.69 PSF
Sarnafelt NWP-HD Separation Layer………………….... 0.13 PSF
Sarnafil G476-15 Waterproofing Membrane……….... 0.33 PSF
Drainage Panel 900………………………………………….... 0.23 PSF
Saturated Growth Media and Plants……………….…… 48 PSF
59.38 PSF ≈ 60 PSF

Strength Design

w_u = 1.4 Dead Load x 1.7 Live Load
w_u = 1.4 (60 PSF) x 1.7 (100 PSF)
w_u = 254 PSF

Clear span between the column and interior beam is conservatively estimated to be 13'-6". Clear span between columns is 28'-0". Therefore the clear span between column line and interior beam is likely even smaller than 13'-6" given that the beam design will likely yield a beam width of greater than 1'-0". Assuming a larger clear span value is a conservative estimate for the slab thickness design.

The minimum allowable slab thickness is $\ell/28$ = 15'/28 = 6.4". Therefore, a minimum slab thickness of 6.5" will be used.

Based on the Solid One-Way Slab tables in Chapter 7 of the CRSI Handbook, the minimum amount of reinforcement that can be used in a 6.5" slab based on a factored load of 254 PSF is $\rho \approx 0.0050$. End span and interior span tables located on pages 7-12 and 7-17, respectively, are used. End span loading is most critical in determining slab thickness because of the increased shear in these regions.

End Spans: See Table 1.

w_u = 312 PSF capacity > 254 PSF

Top Bars, #5 @ 11"
Bottom Bars, #5 @ 12"
Top Bars at Free End, #4 @ 12"
Temperature Bars, #4 @ 17"

Interior Spans: See Table 2.

w_u = 355 PSF capacity > 254 PSF

Top Bars, #5 @ 11”
Bottom Bars, #4 @ 10”
Temperature Bars, #4 @ 17”

Serviceability Check

1. Deflection - Maximum deflection occurs in the end span.

Service Load = $\left(\frac{1}{1.7}\right) w_u = \left(\frac{1}{1.7}\right)(232 \text{ PSF}) = 136.5 \text{ PSF}$

Live Load Deflection = $\left(\frac{L}{\text{Service}}\right)\left(\frac{l_n \times 12 \ ^{in}/_{ft}}{360}\right) < \frac{l}{360}$

$= \left(\frac{100 \text{ PSF}}{136.5 \text{ PSF}}\right)\left(\frac{13.5' \times 12 \ ^{in}/_{ft}}{360}\right) < \frac{15'}{360}$

= 0.33” < 0.50” OK!

2. Crack Control – Based on ACI 10.6.4, for ¾” concrete cover, bar spacing is limited to 12”. Bar spacing in design is satisfactory.

Beam Design

Live Load: 100 PSF
Dead Load:

Ceiling	10 PSF
6-1/2” Concrete Slab	81 PSF
Sarnatherm XPS Insulation	0.69 PSF
Sarnafelt NWP-HD Separation Layer	0.13 PSF
Sarnafil G476-15 Waterproofing Membrane	0.33 PSF
Drainage Panel 900	0.23 PSF
Saturated Growth Media and Plants	48 PSF
	140.38 PSF ≈ 141 PSF

Strength Design

w_u = 1.4 Dead Load x 1.7 Live Load
w_u = 1.4 (141 PSF) x 1.7 (100 PSF)
w_u = 368 PSF

Estimate end and interior span beam stem to be b=18”, h=22”. It was later determined that the interior spans could be designed with a beam width of 16” and larger reinforcing steel but for consistency in formwork and constructability, the interior span beams were left with a depth of 22” and a width of 18”

Beam Stem Estimate: $[18" \times (22"\text{-}6.5")]\left(\frac{150 \text{ PCF}}{144 \ in^2/ft^2}\right)(1.4) =$ 407 PLF

Area Factored Load: 368 PSF x 15’ = 5,520 PLF
Total Factored Load, w_u: 5,927 PLF

Determine load capacity of beams. See Tables 3 and 4 for end span and interior span load capacities.

End Spans: See Table 3.
w_u = 6.1 k/ft capacity > 5.9 k/ft

Bottom Bars, (2) #14 [ℓ_n + 12"]
(1) #14 [0.875 ℓ_n]
Top Bars, (3) #14
Open Stirrups: Max Spacing at Exterior End, 195G: (19)#5: 1@2", 18@9"
Open Stirrups: Max Spacing at Interior End, 164G: (16)#4: 1@2", 15@9"

Interior Spans: See Table 4.
w_u = 6.1 k/ft capacity > 5.9 k/ft

Bottom Bars, (2) #10 [ℓ_n + 12"]
(1) #10 [0.875 ℓ_n]
Top Bars, (3) #14
Open Stirrups: Max Spacing at Each End, 164G: (16)#4: 1@2", 15@9"

Girder Design

Convert to uniform loads.

Concentrated load at center = 5.93 kips/ft (30 ft) = 177.9 kips

Estimate stem to be b=20", h=28".

$$[20" \times (28"\text{-}6.5")]\left(\frac{150 \text{ PCF}}{144 \text{ in}^2/\text{ft}^2}\right)(1.4) = \quad 627 \text{ PLF}$$

Concentrated load factored moment, $M = \dfrac{(177.9 \text{ k} \times 28')}{8} = 622.65 \text{ ft-kips}$

Equivalent uniform load, $w = \dfrac{11M}{l_n^2} = \dfrac{11(622.65' \text{ kips})}{(28')^2} = 8.74 \text{ kips/ft}$

Total factored uniform load (for $-M_u$), $w_u = 8.74 \, \text{kips}/\text{ft} + 0.63 \, \text{kips}/\text{ft} = 9.37 \, \text{kips}/\text{ft}$

Factored positive moment, $+M_u = 622.5 \text{ ft-kips} + \dfrac{0.63 \text{ PLF } (28')^2}{16} = 653.4 \text{ ft-kips}$

Equivalent uniform load (for $+M_u$), $w_u = \dfrac{16(622.65' \text{ kips})}{(28')^2} + 0.63 \, \text{kips}/\text{ft} = 13.3 \, \text{kips}/\text{ft}$

Determine load capacity of girders. See Tables 5 and 6 for end span and interior span load capacities.

End Spans: See Table 5.
w_u = 9.8 k/ft capacity > 9.37 k/ft

Bottom Bars, (3) #11 [ℓ_n + 12″]
(2) #11 [0.875 ℓ_n]
Top Bars, (4) #12
Open Stirrups: Max Spacing at Exterior End, 175FfI: (17)#5: 1@2″, 6@8″, 10@11″
Open Stirrups: Max Spacing at Interior End, 155FeI: (15)#5: 1@2″, 5@8″, 9@11″

Interior Spans: See Table 6.
w_u = 10.9 k/ft capacity > 9.37 k/ft

Bottom Bars, (2) #14 [ℓ_n + 12″]
(1) #14 [0.875 ℓ_n]
Top Bars, (4) #14
Open Stirrups: Max Spacing at Each End, 155FeI: (15)#5: 1@2″, 5@8″, 9@11″

Check Torsion.
Torsional moment capacity (with open stirrups) = 15 ft-kips.

Estimate T_u for the girder with live load on one side only.
w_u (live load) = 0.17 KLF (15′) = 2.55 kips/ft
T_u = 1/11 x (2.55 kips/ft)$(30'-1.67')^2$ = 186.1 ft-kips

T_u in girder = (60/1820)(186.1 ft-kips) = 6.13 ft-kips < 15
Closed stirrups and additional longitudinal bars are not required.

Check Shear.

Max V = (177.9 kips/2)+(0.63 KLF x 14′) = 97.8 kips
Equivalent w_u for shear = 97.8 kips / 14′ = 7.0 kips/ft
Initial stirrup spacing is ok.

Bottom Bar Check.

Equivalent w_u = 13.3 kips/ft
+M_u = 653.4 ft-kips

For a 20″ x 28″ girder with a clear span of 28′-0″ and (5)#11 bars, +M_u = 696 ft-kips. OK!

Initial Stirrup Adjustment.
Adjust for equivalent w_u of 7.0 kips/ft over the full span. Based on Table 5, use stirrup spacing 155I, (15)#5′s: 1@2″, 14@11″ at each end.

SOLID ONE-WAY SLABS—END SPAN $f'_c = 3{,}000$ psi						Grade 60 Bars						Top Steel for $-M_u$ $\rho \approx 0.0050$
Thickness (in.)	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10
Top Bars	#4	#4	#4	#4	#5	#5	#5	#5	#5	#6	#6	#6	#6
Spacing (in.)	12	12	11	9	12	11	10	10	9	12	11	10	10
Bottom Bars	#4	#4	#4	#4	#4	#5	#5	#5	#5	#5	#6	#6	#6
Spacing (in.)	12	11	10	8	8	12	11	11	10	9	12	11	11
Top Bars Free End	#4	#4	#4	#4	#4	#4	#4	#4	#4	#4	#4	#4	#4
Spacing (in.)	12	12	12	12	12	12	12	12	12	12	12	12	12
T-S Bars	#3	#3	#3	#3	#4	#4	#4	#4	#4	#4	#4	#5	#5
Spacing (in.)	15	13	12	11	18	17	15	14	13	13	12	18	17
Areas of Steel (in.^{2}/ft) Top Interior	.200	.200	.218	.267	.310	.338	.372	.377	.413	.440	.480	.528	.528
Bottom	.200	.218	.240	.300	.300	.310	.338	.338	.372	.413	.440	.480	.480
Slab Wt. (psf)	50	56	63	69	75	81	88	94	100	106	113	119	125
CLEAR SPAN	FACTORED USABLE SUPERIMPOSED LOAD (psf)												
6′-0″	700	906											
6′-6″	586	761	967										
7′-0″	496	645	821										
7′-6″	423	552	704	988									
8′-0″	363	475	608	856	986								
8′-6″	314	412	528	747	861	976							
9′-0″	272	359	462	656	757	858							
9′-6″	237	314	405	579	669	759	916						
10′-0″	207	276	357	513	593	674	814	890					
10′-6″	158	191	248	364	481	591	722	790	957				
11′-0″	138	167	218	323	429	528	647	708	859	987			
11′-6″	120	146	192	287	383	473	582	636	774	890			
12′-0″	105	127	169	256	343	426	524	574	700	806	952		
12′-6″	91	111	149	228	308	383	473	518	634	731	865		
13′-0″	79	97	131	204	277	346	428	469	575	664	787	937	999
13′-6″	68	84	115	182	249	312	388	426	523	605	719	857	914
14′-0″	58	73	101	162	224	282	352	386	477	552	657	785	837
14′-6″	49	62	88	145	202	256	320	351	435	505	602	721	769
15′-0″	42	53	76	129	182	231	291	320	397	462	552	662	707
15′-6″		45	66	115	163	209	264	291	363	423	507	610	651
16′-0″			56	102	147	190	241	265	332	388	466	562	600
16′-6″			48	90	132	171	219	241	304	356	429	519	554
17′-0″			40	79	118	155	199	220	278	327	395	479	511
17′-6″				69	105	140	181	200	255	300	363	442	473
18′-0″				60	94	126	164	182	233	275	335	409	437
18′-6″				51	83	113	149	165	213	253	309	378	405
19′-0″				44	73	101	135	149	195	232	284	350	374
19′-6″					64	90	122	135	178	213	262	324	347
20′-0″					56	80	109	122	162	195	241	300	321

Table 1. End Span, Slab
CRSI, Page 7-12

SOLID ONE-WAY SLABS—INTERIOR SPAN $f'_c = 3{,}000$ psi						Grade 60 Bars						Top Steel for $-M_u$ $\rho \approx 0.0050$
Thickness (in.)	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10
Top Bars	#4	#4	#4	#4	#5	#5	#5	#5	#5	#6	#6	#6	#6
Spacing (in.)	12	11	10	9	12	11	10	10	9	12	11	10	10
Bottom Bars	#3	#3	#3	#4	#4	#4	#4	#4	#4	#5	#5	#5	#5
Spacing (in.)	10	9	7	12	11	10	10	9	8	12	11	10	10
T-S Bars	#3	#3	#3	#3	#4	#4	#4	#4	#4	#4	#4	#5	#5
Spacing (in.)	15	13	12	11	18	17	15	14	13	13	12	18	17
Areas of Steel (in.^{2}/ft) Top Interior	.200	.218	.240	.267	.310	.338	.372	.372	.413	.440	.480	.528	.528
Bottom	.132	.147	.189	.200	.218	.240	.240	.267	.300	.310	.338	.372	.372
Slab Wt. (psf)	50	56	63	69	75	81	88	94	100	106	113	119	125
CLEAR SPAN	FACTORED USABLE SUPERIMPOSED LOAD (psf)												
6′-0″	703	923											
6′-6″	589	775											
7′-0″	498	657	907										
7′-6″	425	562	778	988									
8′-0″	365	485	673	856									
8′-6″	315	420	586	747	935								
9′-0″	273	367	513	656	822								
9′-6″	238	321	452	579	727	894	980						
10′-0″	208	282	399	513	646	795	872						
10′-6″	181	243	317	410	539	661	779	882					
11′-0″	159	214	281	365	482	592	699	792	964				
11′-6″	139	189	249	326	432	532	629	713	870	994			
12′-0″	122	167	222	291	388	479	568	644	787	901			
12′-6″	107	148	197	261	349	433	514	583	715	819	967		
13′-0″	94	131	176	234	315	392	465	529	650	746	882		
13′-6″	82	116	157	210	285	355	423	481	593	681	806	959	
14′-0″	71	102	139	188	257	322	384	438	541	623	739	880	939
14′-6″	61	90	124	169	233	293	350	400	495	570	678	809	863
15′-0″	53	79	110	151	210	266	319	365	453	523	623	745	795
15′-6″	45	69	97	136	190	242	291	333	416	480	573	688	733
16′-0″		60	86	121	172	220	265	305	381	442	528	635	678
16′-6″		51	76	108	156	200	242	279	350	406	487	587	627
17′-0″		44	66	96	140	182	221	255	322	374	450	543	580
17′-6″			57	86	127	165	201	233	296	345	416	503	538
18′-0″			49	76	114	150	184	213	272	318	384	467	499
18′-6″			42	66	102	136	167	195	250	293	355	433	463
19′-0″				58	91	123	152	178	230	270	329	402	429
19′-6″				50	81	111	138	162	211	249	304	373	399
20′-0″				43	72	100	125	147	194	229	281	346	370

Table 2. Interior Span, Slab
CRSI, Page 7-17

f'_c = 4,000 psi
f_y = 60,000 psi

RECTANGULAR BEAMS, END SPANS

STEM h (in.)	STEM b (in.)	BARS(1) BOTTOM ℓ_n + 12 in.	BOTTOM 0.875 ℓ_n	Layers (2)	TOP	SPAN, ℓ_n = 28 ft LOAD (4) k/ft	STIR. TIES (5)	ϕT_n ft-kips	Aℓ sq. in.	STEEL WGT lb.	SPAN, ℓ_n = 30 ft LOAD (4) k/ft	STIR. TIES (5)	ϕT_n ft-kips	Aℓ sq. in.	STEEL WGT lb.	SPAN, ℓ_n = 32 ft LOAD (4) k/ft	STIR. TIES (5)	ϕT_n ft-kips	Aℓ sq. in.	STEEL WGT lb.	SPAN, ℓ_n = 34 ft LOAD (4) k/ft	STIR. TIES (5)	ϕT_n ft-kips	Aℓ sq. in.	STEEL WGT lb.	$+\phi M_n$ $-\phi M_n$ (6) ft-kip	DEFL (C) (7) $\times 10^{-9}$ in.
22	12	2# 8		1	2# 8	1.7	133G	5	-	303	1.4	133G	5	-	320	1.3	133G	5	-	336	1.1	123G	5	-	350	130	968
				1			243E	20	0.9	375		263E	20	0.9	402		283E	20	0.9	429		293E	20	0.9	451	130	
		2# 9		1	2#10	2.3	153G	5	-	416	2.0	163G	5	-	444	1.7	163G	5	-	467	1.5*	163G	5	-	491	161	905
				1			244E	20	0.9	603		264E	20	0.9	647		284E	20	0.9	691		294E	20	0.9	724	199	
		2#11		1	3#10	3.3	183G	5	-	620	2.9*	193G	5	-	660	2.6*	193G	5	-	697	2.3*	203G	5	-	737	238	716
				1			244E	20	0.9	796		264E	20	0.9	852		284E	20	0.9	909		294E	20	0.9	955	283	
		2#14		1	2#14	4.1*	194G	5	-	881	3.6*	204G	5	-	936	3.1*	214G	5	-	992	2.8*	214G	5	-	1040	320	615
				1			424B	20	0.9	1167		454B	20	0.9	1246		484B	20	0.9	1325		294E	20	0.9	1181	320	
	14	2# 9		1	3# 7	1.9	133G	7	-	360	1.7	133G	7	-	381	1.5	123G	6	-	398	1.3	123G	6	-	419	163	806
				1			243E	26	1.0	437		263E	26	1.0	468		283E	26	1.0	500		293E	26	1.0	526	149	
		2#10		1	3# 9	2.8	163G	7	-	503	2.5	163G	7	-	532	2.2*	173G	6	-	565	1.9*	173G	6	-	594	203	764
				1			244E	26	1.0	695		264E	26	1.0	745		284E	26	1.0	795		294E	26	1.0	835	236	
		2#10	1#10	1	3#11	4.1	184G	7	-	798	3.6*	194G	7	-	848	3.1*	203G	6	-	827	2.8*	203G	6	-	870	290	595
				1			245E	26	1.0	1081		265E	26	1.0	1159		284E	26	1.0	1045		294E	26	1.0	1099	344	
		2#14		1	4#10	4.6*	194G	7	-	913	4.0*	204G	7	-	971	3.5*	204G	6	-	1022	3.1*	214G	6	-	1080	330	553
				1			245E	26	1.0	1188		265E	26	1.0	1274		285E	26	1.0	1359		295E	26	1.0	1427	369	
	16	2# 9		1	3# 8	2.3	133G	8	-	398	2.0	133G	8	-	421	1.8	133G	8	-	444	1.6	133G	8	-	467	164	736
				1			214F	32	1.1	578		234F	32	1.1	623		244F	32	1.1	657		264F	32	1.1	702	194	
		2#11		1	3# 9	3.1	163G	8	-	563	2.7	163G	8	-	597	2.3	163G	8	-	630	2.1*	173G	8	-	667	246	677
				1			214F	32	1.1	731		234F	32	1.1	787		244F	32	1.1	831		264F	32	1.1	886	240	
		2#14		1	3#11	4.5*	184G	8	-	888	3.9*	194G	8	-	945	3.4*	194G	8	-	994	3.0*	203G	8	-	976	337	545
				1			215F	32	1.1	1130		235F	32	1.1	1215		245F	32	1.1	1282		265F	32	1.1	1368	351	
		2#10	2#10	1	3#14	5.3*	194G	8	-	1060	4.6*	194G	8	-	1119	4.1*	204G	8	-	1186	3.6*	214G	8	-	1253	378	462
				1			345C	32	1.1	1529		235F	32	1.1	1389		245F	32	1.1	1466		265F	32	1.1	1562	468	
	18	2# 8	1# 8	1	3# 8	2.5	133G	10	-	424	2.2	133G	10	-	449	1.9	133G	10	-	473	1.7	123G	10	-	494	195	645
				1			244E	39		646		264E	39	1.3	694		283E	39	1.2	582		293E	38	1.2	612	195	
		2# 9	1# 9	1	3#10	3.4	153G	10	-	589	3.0	163G	10	-	628	2.6	163G	10	-	662	2.3*	163G	10	-	697	242	603
				1			214F	39	1.3	769		264E	39	1.3	861		284E	39	1.2	918		294E	38	1.2	964	299	
		2#11	1#11	1	4#11	5.0	184G	10	-	992	4.4*	194G	10	-	1055	3.8*	194G	10	-	1110	3.4*	203G	10	-	1097	358	464
				1			215F	39	1.2	1244		235F	39	1.2	1336		245F	38	1.2	1411		265F	38	1.2	1503	455	
		2#14	1#14	1	3#14	6.1*	195G	10	-	1326	5.3*	205G	10	-	1409	4.7*	214G	10	-	1392	4.2*	214G	10	-	1463	481	410
				1			345C	39	1.2	1723		365C	39	1.2	1831		385C	38	1.2	1939		265F	38	1.2	1785	481	

Table 3. End Span, Beams
CRSI, Page 12-31

f'_c = 4,000 psi
f_y = 60,000 psi

RECTANGULAR BEAMS, INTERIOR SPANS

STEM h (in.)	STEM b (in.)	BARS(1) BOTTOM ℓ_n + 12 in.	BOTTOM 0.875 ℓ_n	Layers (2)	TOP	SPAN, ℓ_n = 28 ft LOAD (4) k/ft	STIR. TIES (5)	ϕT_n ft-kips	Aℓ sq. in.	STEEL WGT lb.	SPAN, ℓ_n = 30 ft LOAD (4) k/ft	STIR. TIES (5)	ϕT_n ft-kips	Aℓ sq. in.	STEEL WGT lb.	SPAN, ℓ_n = 32 ft LOAD (4) k/ft	STIR. TIES (5)	ϕT_n ft-kips	Aℓ sq. in.	STEEL WGT lb.	SPAN, ℓ_n = 34 ft LOAD (4) k/ft	STIR. TIES (5)	ϕT_n ft-kips	Aℓ sq. in.	STEEL WGT lb.	$+\phi M_n$ $-\phi M_n$ (6) ft-kip	DEFL (C) (7) $\times 10^{-9}$ in.
22	12	2# 7		1	2# 9	2.1	123G	5	-	290	1.8	123G	5	-	307	1.6	123G	5	-	324	1.4	123G	5	-	342	100	516
				1			244E	21	0.9	488		263E	21	0.9	393		273E	20	0.9	415		283E	20	0.9	438	161	
		2# 8		1	2#10	2.7	143G	5	-	367	2.3	143G	5	-	389	2.0	143G	5	-	412	1.8	153G	5	-	437	130	551
				1			244E	21	0.9	558		264E	21	0.9	600		274E	20	0.9	632		284E	20	0.9	665	199	
		2#10		1	2#14	4.1	164G	5	-	651	3.6	173G	5	-	636	3.1	173G	5	-	673	2.8	183G	5	-	715	199	440
				1			244E	21	0.9	777		264E	21	0.9	835		274E	20	0.9	883		284E	20	0.9	931	320	
		2#11		1	2#14	4.5	164G	5	-	709	3.9	174G	5	-	758	3.4	184G	5	-	807	3.1	193G	5	-	789	238	418
				1			424B	21	0.9	1018		444B	21	0.9	1079		274E	20	0.9	950		284E	20	0.9	1001	320	
	14	2# 8		1	3# 8	2.7	133G	7	-	354	2.3	133G	7	-	375	2.1	133G	7	-	397	1.8	133G	7	-	418	131	476
				1			244E	27	1.0	558		264E	26	1.0	600		274E	26	1.0	632		293E	26	1.0	521	192	
		2# 9		1	3# 9	3.3	143G	7	-	441	2.9	153G	7	-	472	2.5	153G	7	-	499	2.3	153G	7	-	527	163	473
				1			244E	27	1.0	641		264E	26	1.0	689		274E	26	1.0	727		294E	26	1.0	775	236	
		2#11		1	3#11	4.8	164G	7	-	725	4.2	174G	7	-	775	3.7	174G	7	-	817	3.3	183G	7	-	802	243	386
				1			245E	27	1.0	1023		265E	26	1.0	1100		274E	26	1.0	976		294E	26	1.0	1039	344	
		2#10	1#10	1	4#10	5.2	164G	7	-	780	4.5	174G	7	-	835	4.0	184G	7	-	889	3.5	184G	7	-	935	290	351
				1			245E	27	1.0	1078		265E	26	1.0	1160		275E	26	1.0	1224		295E	26	1.0	1305	369	
	16	2# 8		1	3# 8	2.7	123G	8	-	352	2.4	123G	8	-	373	2.1	123G	8	-	394	1.8	123G	8	-	416	132	391
				1			214F	33	1.2	536		234F	33	1.1	579		244F	33	1.1	611		254F	32	1.1	644	194	
		2#10		1	3#10	4.2	153G	8	-	550	3.6	153G	8	-	584	3.2	163G	8	-	623	2.8	163G	8	-	657	205	402
				1			215F	33	1.1	870		234F	33	1.1	778		244F	32	1.1	824		254F	32	1.1	869	295	
		2#11		1	3#11	4.9	154G	8	-	721	4.3	164G	8	-	771	3.8	173G	8	-	758	3.3	173G	8	-	800	246	365
				1			215F	33	1.1	985		235F	33	1.1	1064		245F	32	1.1	1125		255F	32	1.1	1185	351	
		2#14		1	3#14	6.6	175G	8	-	1082	5.7	175G	8	-	1143	5.0	184G	8	-	1133	4.5	194G	8	-	1202	337	297
				1			345C	33	1.1	1487		365C	33	1.1	1584		245F	32	1.1	1428		255F	32	1.1	1508	468	
	18	2# 7	1# 7	1	3# 9	3.1	123G	10	-	401	2.7	123G	10	-	426	2.4	123G	10	-	450	2.1	123G	10	-	475	151	344
				1			244E	40	1.3	627		264E	39	1.3	675		284E	39	1.3	723		293E	39	1.3	594	242	
		2# 8	1# 8	1	3#10	4.0	143G	10	-	509	3.5	143G	10	-	541	3.1	143G	10	-	573	2.7	153G	10	-	609	195	367
				1			214F	40	1.3	693		234F	39	1.3	748		284E	39	1.3	837		294E	39	1.3	880	299	
		2#10	1#10	1	3#14	6.1	164G	10	-	895	5.3	174G	10	-	957	4.7	174G	10	-	1011	4.2	184G	10	-	1074	299	293
				1			215F	40	1.3	1163		235F	39	1.3	1254		245F	39	1.3	1327		265F	39	1.2	1419	481	
		2#11	1#11	1	3#14	6.8	165G	10	-	1051	5.9	174G	10	-	1042	5.2	184G	10	-	1110	4.6	194G	10	-	1178	358	279
				1			345C	40	1.3	1486		365C	39	1.3	1584		245F	39	1.2	1418		265F	39	1.2	1516	481	

Table 4. Interior Span, Beams
CRSI, Page 12-61

f'_c = 4,000 psi
f_y = 60,000 psi

RECTANGULAR BEAMS, END SPANS

TOTAL CAPACITY $U = 1.4D + 1.7L$ [3]

STEM h in.	STEM b in.	BARS[1] BOTTOM ℓ_n + 12 in.	BARS[1] BOTTOM 0.875 ℓ_n	Layers (2)	TOP	SPAN, ℓ_n = 24 ft LOAD (4) k/ft	STIR. TIES (5)	ϕT_n ft-kips	$A\ell$ sq. in.	STEEL WGT lb.	SPAN, ℓ_n = 26 ft LOAD (4) k/ft	STIR. TIES (5)	ϕT_n ft-kips	$A\ell$ sq. in.	STEEL WGT lb.	SPAN, ℓ_n = 28 ft LOAD (4) k/ft	STIR. TIES (5)	ϕT_n ft-kips	$A\ell$ sq. in.	STEEL WGT lb.	SPAN, ℓ_n = 30 ft LOAD (4) k/ft	STIR. TIES (5)	ϕT_n ft-kips	$A\ell$ sq. in.	STEEL WGT lb.	$+\phi M_n$ $-\phi M_n$ (6) ft-kip	DEFL (C) (7) $\times 10^{-9}$ in.
26	14	2#9		1	3#8	3.8	113I	9	-	348	3.2	123I	9	-	376	2.8	123I	8	-	399	2.4	123I	8	-	422	199	500
				1			184F	35	1.3	507		204F	34	1.2	553		214F	34	1.2	588		234F	33	1.2	633	234	
		2#11		1	3#9	5.0	134I	9	-	543	4.3	133I	9	-	523	3.7	143I	8	-	561	3.2	143I	8	-	594	299	459
				1			185F	35	1.2	772		205F	34	1.2	843		214F	34	1.2	741		234F	33	1.2	797	290	
		2#11	1#11	1	3#11	7.4	135I	9	-	823	6.3	145I	9	-	885	5.5	154I	8	-	873	4.8	164I	8	-	930	428	360
				1			295C	35	1.2	1193		205F	34	1.2	1074		215F	34	1.2	1141		235F	33	1.2	1228	428	
		2#11	1#11	1	4#11	8.2	135I	9	-	913	7.0	145I	9	-	981	6.0	165I	8	-	1063	5.2	165I	8	-	1119	428	352
				2			295C	35	1.2	1283		315C	34	1.2	1376		215F	34	1.2	1244		235F	33	1.2	1336	504	
	16	2#10		1	3#8	4.1	113I	11	-	395	3.5	113I	11	-	421	3.0	123I	10	-	452	2.6	123I	10	-	479	251	424
				1			165G	43	1.4	657		184G	42	1.4	587		214F	42	1.4	650		234F	42	1.4	700	236	
		2#11		1	3#10	5.8	134I	11	-	593	4.9	134I	11	-	629	4.2	143I	10	-	616	3.7	143I	10	-	652	302	406
				1			165G	43	1.4	793		185G	42	1.4	868		195G	42	1.4	924		205G	42	1.3	979	364	
		2#11	1#11	1	3#11	7.6	135I	11	-	827	6.5	145I	11	-	890	5.6	154I	10	-	876	4.8	164I	10	-	934	436	343
				1			245D	43	1.4	1116		265D	42	1.4	1204		195G	42	1.3	1117		205G	42	1.3	1186	436	
		6#6	6#6	2	3#14	9.0	145FdI	11	-	1007	7.7	145I	11	-	1068	6.6	165I	10	-	1156	5.8	165I	10	-	1217	471	301
				1			245D	43	1.4	1282		265D	42	1.4	1382		285D	42	1.3	1481		305D	41	1.3	1581	590	
	18	2#8	1#8	1	3#9	4.5	113I	13	-	410	3.9	113I	13	-	437	3.3	113I	13	-	464	2.9	123I	13	-	496	238	377
				1			165G	52	1.5	682		184G	51	1.5	609		194G	51	1.5	649		264E	50	1.5	763	296	
		2#10	1#10	1	3#10	6.4	134I	13	-	638	5.5	134I	13	-	678	4.7	143I	13	-	667	4.1	143I	13	-	707	368	363
				1			165G	-52	1.5	846		185G	51	1.5	926		195G	51	1.5	986		205G	50	1.5	1046	368	
		2#11	1#11	1	3#14	8.4	135I	13	-	959	7.2	145I	13	-	1030	6.2	154I	13	-	1023	5.4	164I	13	-	1089	442	292
				1			245D	52	1.5	1260		265D	51	1.5	1358		285D	51	1.5	1455		305D	50	1.5	1553	602	
		2#11	2#11	1	3#14	10.5	155FeI	13	-	1101	8.9	165FdI	13	-	1182	7.7	165I	13	-	1249	6.7	165I	13	-	1315	568	268
				1			295C	52	1.5	1475		265D	51	1.5	1481		285D	51	1.5	1588		305D	50	1.5	1695	602	
	20	2#9	1#9	1	3#9	5.2	113I	15	-	463	4.4	113I	15	-	495	3.8	123I	15	-	531	3.3	123I	15	-	562	298	345
				1			155H	61	1.7	724		165H	61	1.7	777		175H	60	1.7	829		185H	59	1.6	881	298	
		2#10	1#10	1	3#11	7.1	134I	15	-	694	6.0	134I	15	-	738	5.2	143I	15	-	729	4.5	143I	15	-	773	371	328
				1			215E	61	1.7	1015		225E	61	1.7	1079		175H	60	1.6	1018		185H	59	1.6	1082	447	
		2#11	2#11	1	3#14	10.6	145FdI	15	-	1092	9.1	155FcI	15	-	1173	7.8	155I	15	-	1240	6.8	165I	15	-	1321	576	259
				1			295C	61	1.7	1495		265D	61	1.7	1499		285D	60	1.6	1607		265E	59	1.6	1632	612	
		3#11	2#11	1	4#14	13.3	295C	15	-	1573	11.3	175EhI	15	-	1486	9.8	175FII	15	-	1573	8.5	185FII	15	-	1673	696	219
				1			485A	61	1.7	2156		315C	61	1.7	1888		345C	60	1.6	2037		365C	59	1.6	2164	776	

Table 5. End Span, Girder
CRSI, Page 12-34

f'_c = 4,000 psi
f_y = 60,000 psi

RECTANGULAR BEAMS, INTERIOR SPANS

TOTAL CAPACITY $U = 1.4D + 1.7L$ [3]

STEM h in.	STEM b in.	BARS[1] BOTTOM ℓ_n + 12 in.	BARS[1] BOTTOM 0.875 ℓ_n	Layers (2)	TOP	SPAN, ℓ_n = 24 ft LOAD (4) k/ft	STIR. TIES (5)	ϕT_n ft-kips	$A\ell$ sq. in.	STEEL WGT lb.	SPAN, ℓ_n = 26 ft LOAD (4) k/ft	STIR. TIES (5)	ϕT_n ft-kips	$A\ell$ sq. in.	STEEL WGT lb.	SPAN, ℓ_n = 28 ft LOAD (4) k/ft	STIR. TIES (5)	ϕT_n ft-kips	$A\ell$ sq. in.	STEEL WGT lb.	SPAN, ℓ_n = 30 ft LOAD (4) k/ft	STIR. TIES (5)	ϕT_n ft-kips	$A\ell$ sq. in.	STEEL WGT lb.	$+\phi M_n$ $-\phi M_n$ (6) ft-kip	DEFL (C) (7) $\times 10^{-9}$ in.
26	14	2#9		1	3#9	5.5	113I	9	-	381	4.7	113I	9	-	408	4.1	123I	9	-	439	3.5	123I	9	-	467	199	287
				1			185F	35	1.3	671		204F	35	1.3	590		214F	34	1.2	628		234F	34	1.2	679	290	
		2#10		1	3#10	6.9	124I	9	-	522	5.8	124I	9	-	557	5.0	134I	9	-	599	4.4	133I	9	-	581	248	272
				1			185F	35	1.3	760		205F	35	1.3	832		215F	34	1.2	885		235F	34	1.2	957	359	
		2#10	1#10	1	4#10	8.8	125I	9	-	729	7.5	135I	9	-	789	6.5	144I	9	-	778	5.6	144I	9	-	825	359	226
				1			295C	35	1.3	1112		205F	35	1.2	990		215F	34	1.2	1055		235F	34	1.2	1140	460	
		2#14		1	3#14	11.0	264C	9	-	967	9.3	145FcI	9	-	998	8.1	145I	9	-	1059	7.0	155I	9	-	1134	411	200
				1			295C	35	1.3	1294		315C	35	1.2	1393		345C	34	1.2	1510		365C	34	1.2	1609	574	
	16	2#9		1	3#9	5.6	103I	11	-	378	4.8	113I	11	-	409	4.1	113I	11	-	437	3.6	123I	11	-	468	200	245
				1			165G	44	1.4	645		185G	43	1.4	711		195G	43	1.4	758		204G	42	1.4	653	294	
		2#11		1	3#11	8.3	125I	11	-	685	7.1	124I	11	-	666	6.1	134I	11	-	717	5.3	144I	11	-	769	302	232
				1			245D	44	1.4	988		265D	43	1.4	1069		195G	43	1.4	976		205G	42	1.4	1038	436	
		2#14		1	3#14	11.3	145FdI	11	-	942	9.6	135I	11	-	989	8.3	145I	11	-	1064	7.2	155I	11	-	1139	418	190
				1			245D	44	1.4	1217		265D	43	1.4	1317		285D	43	1.4	1417		305D	42	1.4	1517	590	
		2#14		1	5#11	11.6	145FeI	11	-	1000	9.9	145FdI	11	-	1066	8.5	145I	11	-	1132	7.4	155I	11	-	1212	418	191
				2			245D	44	1.4	1275		265D	43	1.4	1380		285D	43	1.4	1485		305D	42	1.4	1590	627	
	18	2#8	1#8	1	3#10	6.6	113I	13	-	438	5.6	113I	13	-	470	4.9	113I	13	-	502	4.2	123I	13	-	539	238	218
				1			165G	53	1.6	711		185G	53	1.6	783		195G	52	1.5	835		205G	51	1.5	887	368	
		2#9	1#9	1	3#11	8.2	114I	13	-	583	7.0	124I	13	-	632	6.1	134I	13	-	681	5.3	133I	13	-	666	296	216
				1			245D	53	1.6	970		185G	52	1.5	889		195G	52	1.5	949		205G	51	1.5	1009	442	
		2#11	1#11	1	3#14	11.5	135FdI	13	-	912	9.8	135I	13	-	971	8.5	145I	13	-	1045	7.4	145I	13	-	1105	442	179
				1			245D	53	1.6	1212		265D	52	1.5	1313		285D	52	1.5	1413		305D	51	1.5	1513	602	
		2#10	2#10	1	4#14	13.3	145FII	13	-	1057	11.3	155FeI	13	-	1142	9.7	155FdI	13	-	1213	8.5	155I	13	-	1284	477	157
				1			295C	53	1.6	1444		315C	52	1.5	1556		285D	52	1.5	1566		305D	51	1.5	1677	759	
	20	2#8	1#8	1	3#10	6.7	103I	16	-	435	5.7	113I	16	-	472	4.9	113I	15	-	504	4.3	113I	15	-	535	239	189
				1			155H	63	1.7	701		165H	62	1.7	754		175H	61	1.7	807		185H	61	1.7	859	371	
		2#10	1#10	1	3#11	8.5	114I	16	-	647	7.3	124I	15	-	701	6.3	124I	15	-	746	5.5	133I	15	-	743	371	190
				1			215E	63	1.7	986		225E	62	1.7	1051		175H	61	1.7	992		185H	61	1.7	1058	447	
		2#11	1#11	1	4#14	12.4	135FdI	16	-	1038	10.6	135I	15	-	1108	9.1	145I	15	-	1193	7.9	145I	15	-	1263	447	154
				1			295C	63	1.7	1456		265D	62	1.7	1463		285D	61	1.7	1575		265E	60	1.7	1603	776	
		2#14	1#14	1	4#14	14.8	265C	16	-	1385	12.6	155FII	15	-	1309	10.9	155FeI	15	-	1392	9.5	165FdI	15	-	1489	612	141
				1			485A	63	1.7	2011		315C	62	1.7	1739		345C	61	1.7	1885		305D	60	1.7	1884	776	

Table 6. Interior Span, Girder
CRSI, Page 12-64