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Structural
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Office Building, Washington, DC*
Technical Assignment 2
10/31/05

*Building specifics omitted at owners request

Executive Summary

The purpose of this technical assignment is to compare alternate floor systems to the originally designed floor system. The first part is a review of the existing floor system as was investigated in detail for technical assignment 1. A reasonable loading is determined using IBC 2003 live loads, and ACI dead load guidelines. This loading was used to later in the report for design of the alternate floor systems.

Four alternate floor systems were considered. The original design was also considered without the effects of post-tensioning. The other systems were a one-way skip-joist, precast double tees, two-way waffle slab construction, and a non-composite metal deck system. Each system was roughly sized using a representative bay. Critical features of each system were checked and compared to other systems and the original to determine the feasibility of each alternative.

The factors used to check the framing systems were overall structure depth, effect to lateral system, strength, architectural impact, fire-rating, cost, material usage, LEED design, and constructability. Overall it appeared that the modified two-way slab with drop panels was the best choice, because the post-tensioning was not necessary in ultimate strength checks. The waffle slab was another good choice, as was the precast tees except for their excessive depth.

Introduction

The designed structural system of the office building in downtown Washington, DC consists of a few different components. The area in which this report will focus is the occupied tenant floors. These floors are characterized by flat post-tensioned slabs with drop panels around columns. The slabs are cast in place normal weight concrete. Four alternate systems will be evaluated and compared to the original system. Everyone knows DC is a concrete town, so an emphasis will be made on other concrete systems. The alternate systems:

Two-way flat slab with drop panels and no post-tension – An investigative design to compare the effect of post-tensioning on the two-way slab system using identical layouts will be performed.

One-way pan joist slab with additional columns – Additional columns will be added to force the span into a one-way condition.

Pre-cast Pre-stressed concrete tee's – A lightweight pre-cast concrete product that can be delivered to site and will help increase construction rate. The tee sections will be topped with a 2" layer of concrete to provide a clean appearance.

Two-way waffle slab – This two-way system will make up for the use of post-tension cables with an increased area of concrete.

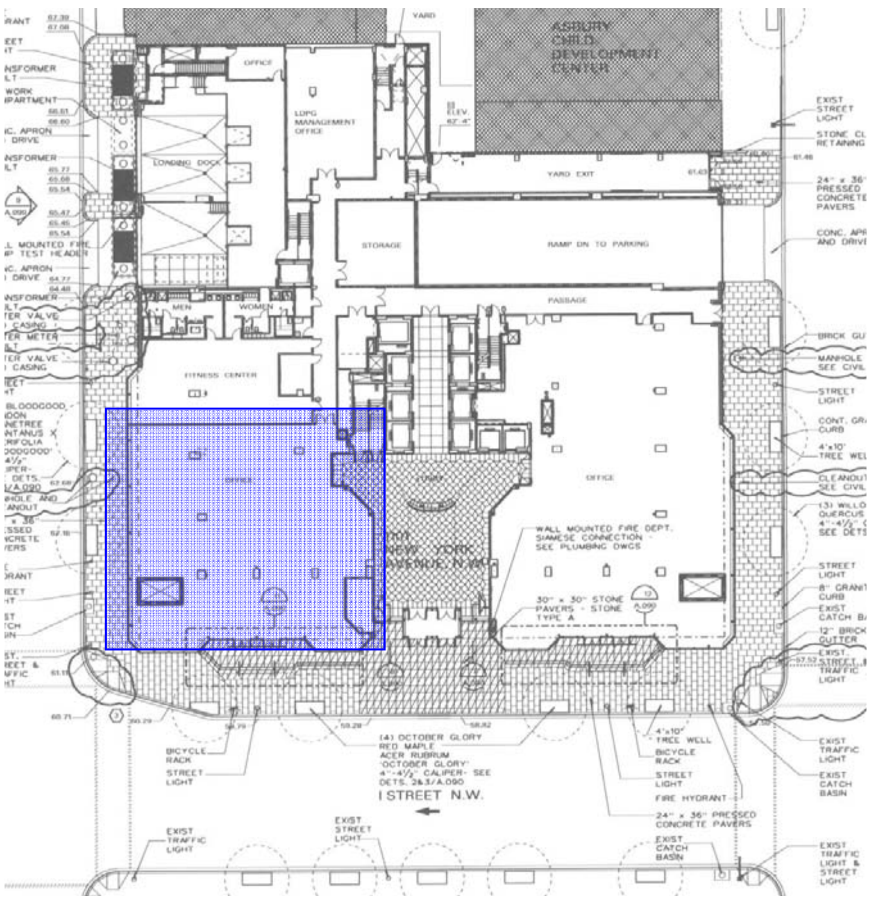
Cast in place slab on metal deck with steel beams. – Metal decking will be installed and topped with a substantial concrete slab. This utilizes the strength of steel and the economy of concrete.

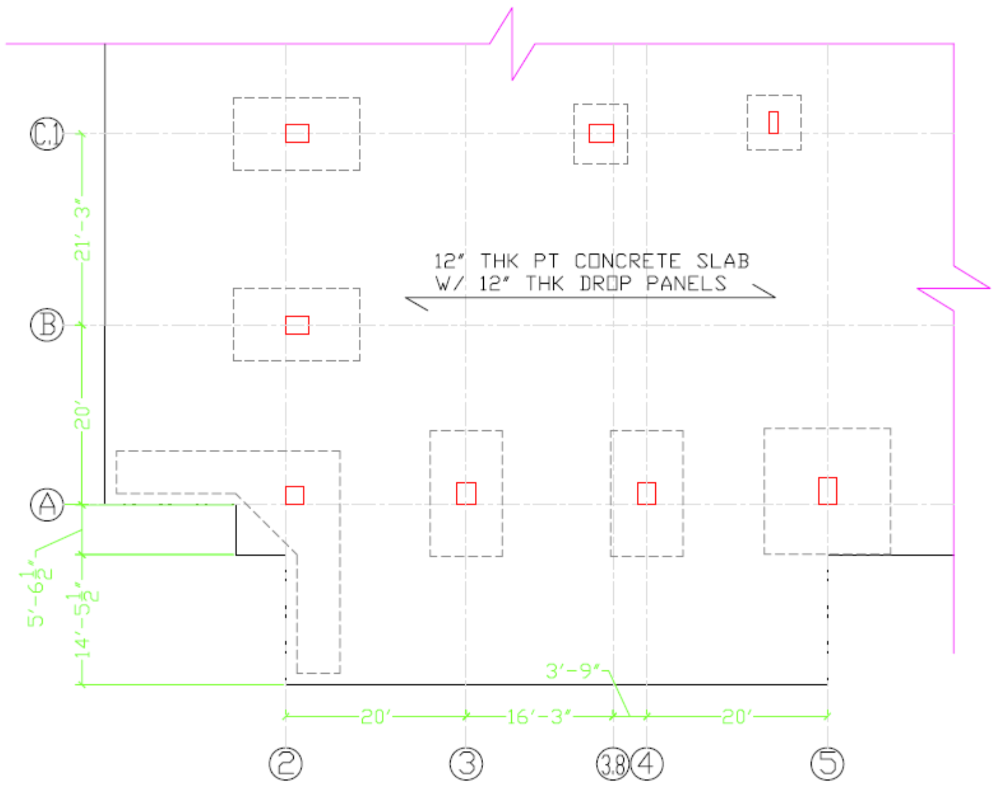
These systems will be detailed and typical sized determined. Then the pros and cons of each, both structural and non-structural, will be evaluated. Finally there will be an opportunity to decide whether or not these systems are feasible alternatives. Some of the points of structural comparison will be overall system depth, affect on lateral system design, stress and service load deflection. Non-structural considerations will be; affects to architecture, fire-rating, cost, material efficiency, LEED impact, constructability and durability.

Current design and loading

As stated before, the current design is a cast-in-place flat slab. The slab incorporates post-tensioning throughout and drop panels at columns with some thickened slab in other areas. There are critical columns around the exterior of the building where there is a 20’ cantilever and spans approaching 30’. This is the area that I will assume to be a typical and therefore representative situation. Figure 1 and 2 detail layout of the current PT slab system.

Figure 1 – key plan with area of interest





SW CORNER FLOORS 6-12 (TYP.)
NTS

Live load:

This area is a typical tenant occupied office. IBC 2003 calls for live load = 60 psf in offices. In addition, corridors are to be designed to 80 psf. The design team allowed corridors to be located anywhere for maximum tenant configuration. This requires that a minimum of 80 psf live load be used everywhere. There is also a 20 psf allowance for partitions to be installed. This comes to a total of 80 psf + 20 psf = 100 psf of live load distributed over the entire office floor area.

Dead load:

ASCE 7-02 is used to determine dead load allowances. Whenever possible the actual materials are used to determine dead load, instead of relying on figures for typical office construction.

Suspended plaster ceiling = 10psf

Concrete finish floor = included in structure weight

Light gauge steel partitions = 4psf

Floor tile or carpet = 1 psf

MEP = 4psf

Total superimposed dead load is estimated at 25 psf

Superimposed service load = 100 psf + 25 psf = 125 psf

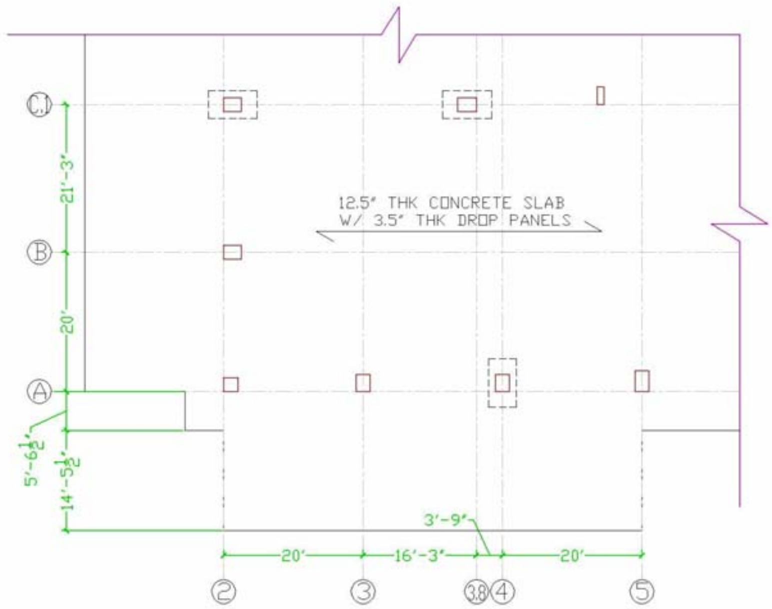
Superimposed factored load for CRSI = 1.4(25)+1.7(100) = 205 psf

These live and superimposed dead loads will be used in the sizing of alternate floor systems. These numbers are not necessarily the ones used by the engineers for the existing design, as some assumptions were made. The factored load is the load combination necessary to use the tables in CRSI Design Handbook 2002.

Alternate Systems

Two-Way Flat Slab with Drop Panels Non-tensioned

To determine the effect of post-tensioning, the same two-way system used in the original design was calculated without the benefit of post-tensioning. Drops were designed in accordance with ACI 318. Slab design was checked by hand and using a similar bay size in CRSI Design Handbook 2002. The calculations yielded a 12.5" slab with 3.5" drops (near minimum code allowed values). The design of the slab and drops for the representative bay is shown below.



TWO-WAY FLAT SLAB W/ DROPS
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The design aids dictate the use of a 12" slab with 11" drops around columns. See appendix for reinforcing specifications. This system appears to be adequate for the loads considered. It is much lighter than the existing system but lacks much of the over-design strength. Seeing that it is very similar to the existing PT flat slab with drops, other aspects such as constructability, vibration, lateral resisting, and fire resistance will remain unaffected. See design aids for shear reinforcing specifications.

One-Way Skip-Joist

Adding columns in key spans will enable the bays to be designed as one-way systems. The area below is all open office space, so there is no architectural interference per se, just more unsightly columns. The example bay ends up being 41.25' by 19', a ratio of about 2.2:1, just out of two-way range. A common structural system to use in a one-way condition is a concrete pan skip-joist with concrete girders.

Load on joist/slab: 125 psf

Load on girder:

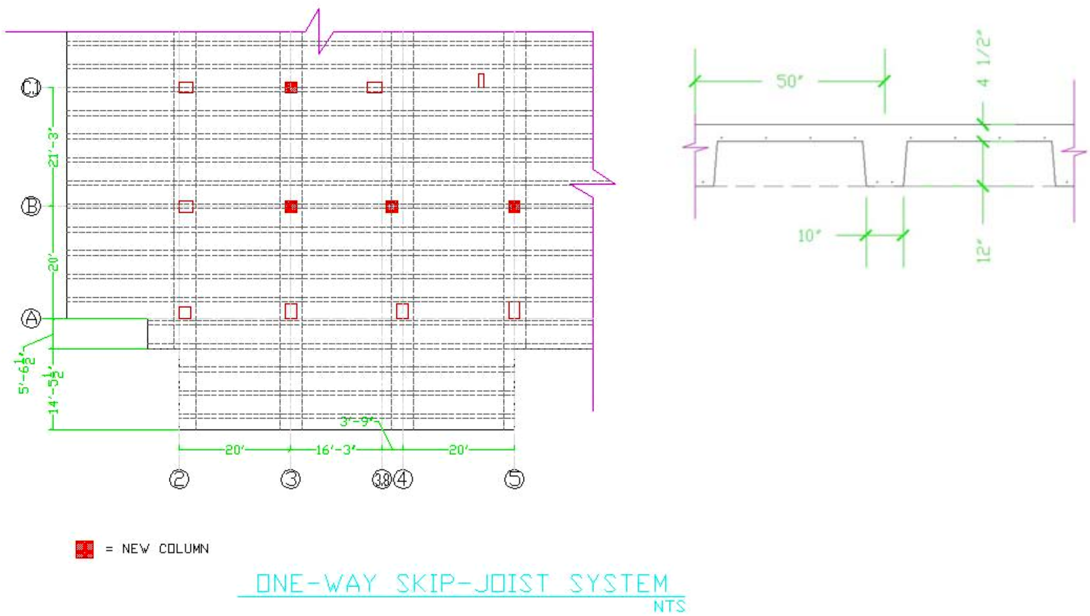
CRSI table 8.3 12+10+40=372 psf

DL (372 psf x 20’) + (25 psf x 20’) = 7.9 klf

LL (100 psf x 20’) = 2.0 klf

1.4(2.0) + 1.7(7.9) = 16.23 klf

The one-way joist system selected was a 40” pan joist with 10” ribs at 50” on center. The depth of the ribs and slab are 12” + 4.5” = 16.5” These joists frame into a 16.5 inch deep by 48 inch wide girder. The joist section and framing plan are shown below.



The overall structure depth for this system is only 16.5 inches. Very thick pans are needed to carry the factored loads on the structure, and in turn create a lot of additional structure weight. The thick pan ribs then create the need for very wide girders. The structure weight ends up being more than the existing system. This is not directly comparable because additional columns were added to create a one-way system, so there may not be foundation issues. The one-way joist system is very strong and stiff, so vibration will not be an issue. It is very easily constructed from metal pan forms, and economical because of the girder is the same depth as the slab and rib depth. The 4.5” thick slab guarantees an adequate fire rating. The design aids dictate the shear reinforcing.

Pre-cast Concrete Pre-stressed Tee's

Precast structural tee's are a possible alternate system. They share the pre-stress solution used in the actual design but are cast off-site.

Span = 42'

Total Load (LL + SDL) =125 psf

φM_n = 330,750 ft-lb = 28 in-k

USE 32-8.6 PT section

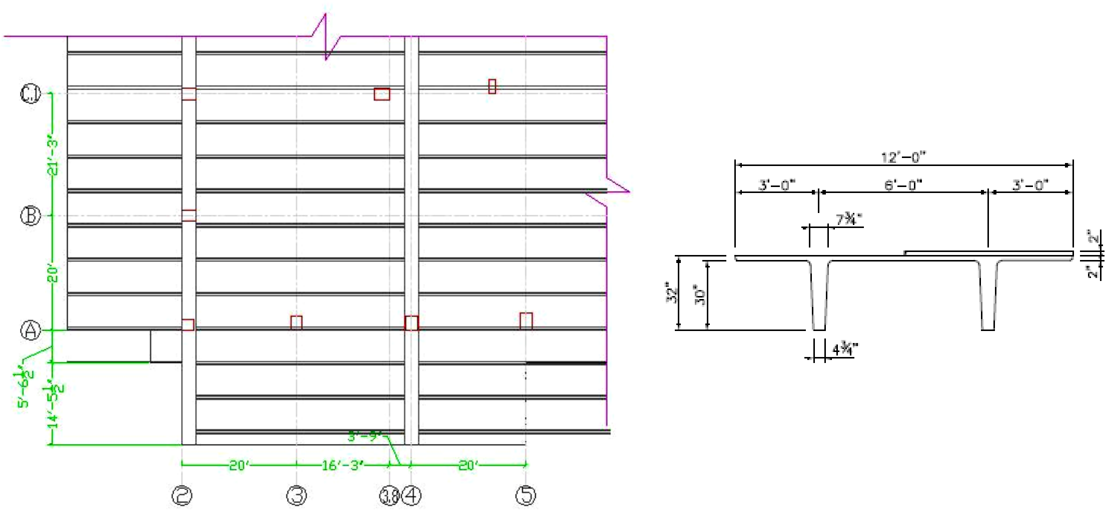
Self Wt = (150 pcf)x(6.6 sqft) = 990 lb/ft (12' section)

Self Wt = 82.5 psf

Precast Inverted Tee Girder

Service load = (125 psf + 82.5 psf)(20') = 4150 plf

USE 28IT44 (20 strand) girder



PRECAST DOUBLE TEES
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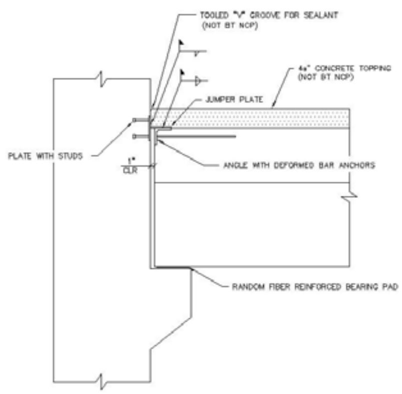
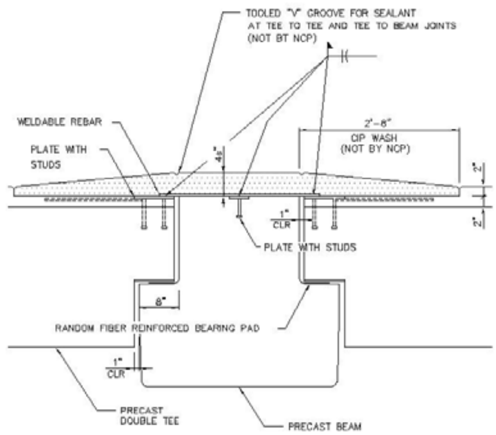
Precast double tees were chosen over hollow core planks because of their increased span capabilities. The double tees frame into inverted T girders along column lines. The girders in turn frame into columns or bearing walls (below grade). Examples of these connections are shown below.

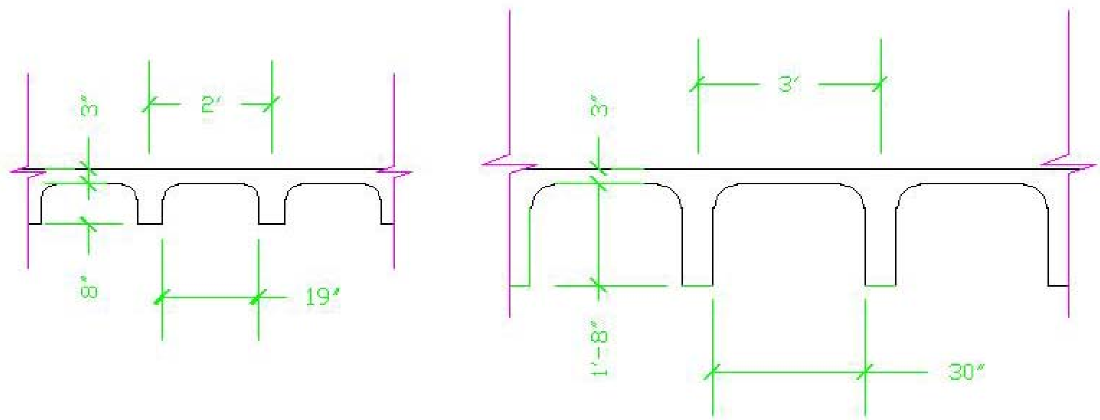




The precast double tees seems like a very good solution, but it has one major drawback. Given the depth of the ribs and the thickness of the seat ledge of the inverted tee, the overall structure floor depth becomes and issue. The seat ledge is 16”, the double tee has an over all depth of 32”, and when a 2” CIP topping is added, the total depth comes to 50”. That is over twice the depth of the existing system. This almost immediately rules out this alternative as a viable option. That is unfortunate because it can be erected quickly, it is lightweight, and it meets fire rating requirements. The precast beams and tees include all necessary tendons, flexure and shear reinforcing.

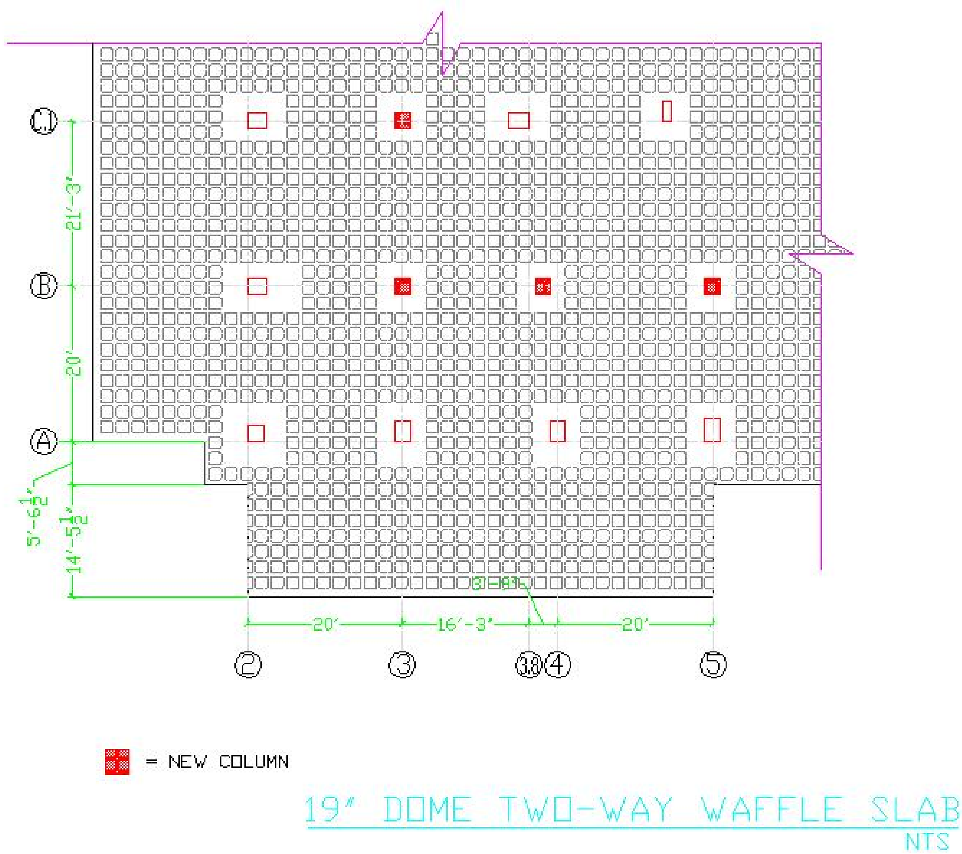
Two-way Waffle Slab

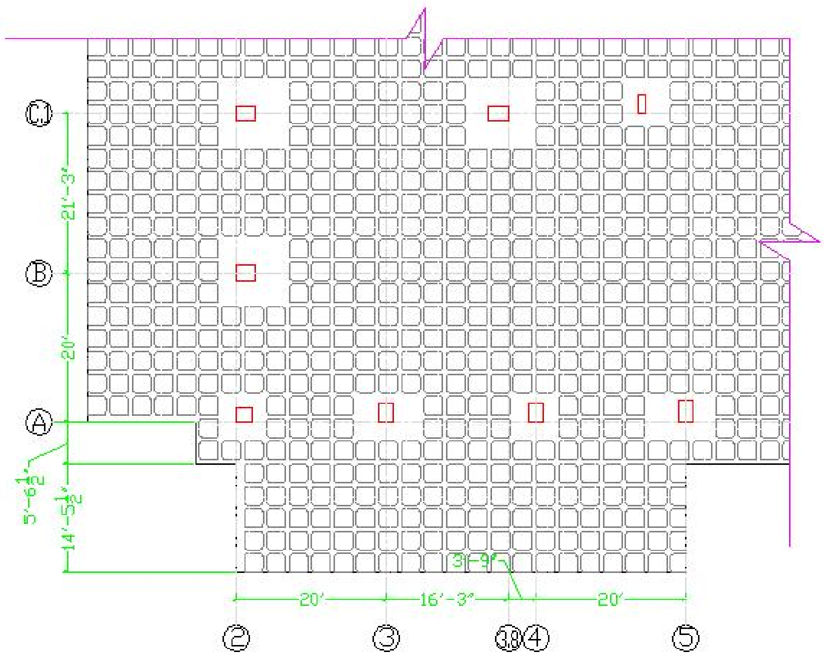
Waffle slabs work best in perfectly square bays. Some bays in this building are squares, and most others are very close, so this seems like a reasonable system to use. CRSI Design Handbook 2002 gives design tables for 19” domes and deeper 30” domes. The 19” domes were considered for a case with 20’ by 20’ bays, this was already determined to be architecturally feasible, but not very desirable. The waffle slab is essentially a slab with joists spanning both directions spaced at either 2' for the 19" domes or 3' for the 30"



domes. Sections of each are shown below.

This pattern is continued throughout the slab until columns are encountered. Around the columns, the adjacent domes are filled solid with concrete to prevent column punching shear. The examples of 19" and 30" dome waffle slab framing are shown below.





30" DOME TWO-WAY WAFFLE SLAB
NTS

The structure weight is increased somewhat through the use of the waffle slab. Overall depth is greatly reduced through the use of waffle slab construction. The 19" dome setup has a depth of only 9". The 30" dome is somewhat deeper at 23", but does not require the addition of columns into the floor plan. See the design aids for slab and rib reinforcing. Waffle slabs are not difficult to construct but do cost extra for the dome forms. They are fairly useless as far as allowing mechanical systems to run through them because there is no linear cavity. The minimum thickness is 3" of concrete so the fire rating will be slightly less than that of the other concrete systems.

Slab on Steel Deck with Steel Beams

Everyone knows that Washington DC is a concrete city. Concrete is almost exclusively used in all construction projects. Regardless a steel system will be investigated. A common method of steel construction utilizes concrete slab on metal decking. The deck is then supported by joists and girders, or directly by girders. In this case additional joists were necessary to meet unshored clear span requirements of the deck. The deck span was reduced to 10'. A superimposed live load of 100 psf was used to determine the adequate deck. The controlling factor actually ended up being the maximum unshored clear span capable of the deck in a multi-span condition. A 2.0 SB deck was chosen with 5" max, 3" min thickness normal weight concrete slab. This decking is supported by joists at 10' which frame into girders over 20' spans.

Joist design, assume fully braced by decking

Factored load = 2.5 klf

M max = 125 ft-k φMn = 139 ft-k

V max = 25 k φVn = 34 k

USE W14x26 for joists

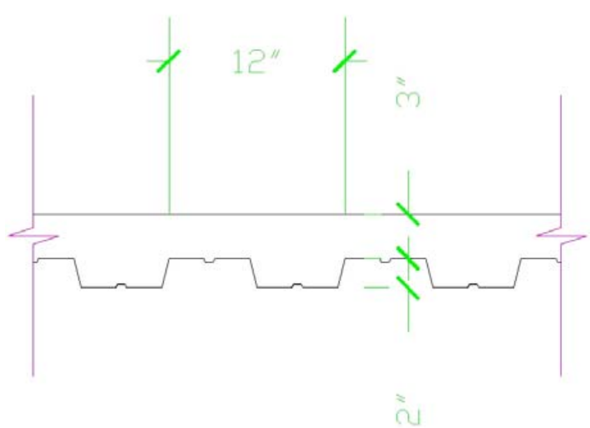
Self wt (20' x 26 lb/ft) = .52 k / 2 = .26 k

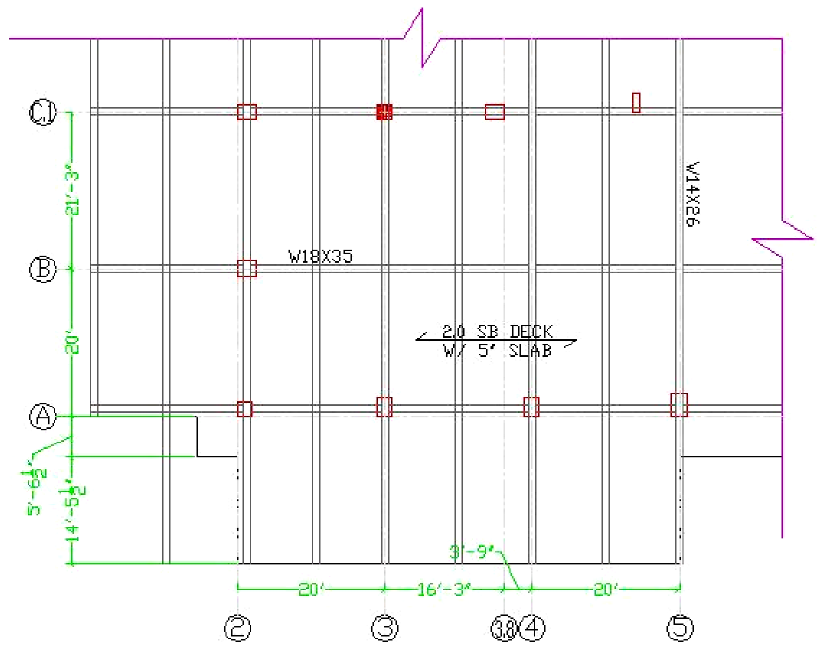
Girder design, Lb = 10'

M max = 170 ft-k φMn = 189 ft-k

V max = 17 k φVn = 23 k

USE W18x35 for girders





SLAB ON STEEL DECK
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The total structure depth at each floor for the metal deck with beams and girders comes to 5" + 13.9" + 17.7" = 36.6". This is roughly 12"-13" deeper than the existing system. The main problem is material availability. Steel is rare in Washington DC construction and therefore there are not many suppliers. Cost will also increase for this same reason. The concrete provides a floor to floor fire rating, and any exposed steel will have to be treated with fire proofing. This system is also relatively heavy because of all the intermediate framing required to hold the deck and slab. Design aids specify the use of WWF for the concrete slab.

Conclusions

Of the systems considered, the existing system, and variants thereof, displayed the most potential. Apparently the flat slab with drop panels will work just as well without the addition of post tensioning. The drops were a bit shallower which will save some structure weight, and there is no need for the specialty post-tensioning work. This will save considerably on construction costs. A one-way system was devised with the addition of columns into the office space. This was done for the purpose of incorporating a one-way design for comparison, but is not very practical for the actual application. The prestressed precast double tee beams seemed like a good solution. The only drawback was that they ended up requiring a huge floor depth. The waffle slab was also a good idea but very heavy. The total waffle depth actually ended up being slightly less than with the existing system. One steel system was looked into as well. Non-composite metal deck with a 5" concrete slab was placed on steel joists and girders. The system ended up being fairly deep and heavy. Also the fact that it is steel makes it an unlikely alternative. Some quick points of comparison are outlined in the following table.

= as good as existing system + better than existing - worse than existing

	PT flat-slab with drops (existing)	Flat slab with drops	One-way Skip-joist	Precast PT tees	Waffle slab	NC steel deck
Depth	=	+	+	-	+	-
Lateral	=	=	=	=	=	-
Strength	=	-	=	=	=	+
Arch.	=	=	-	=	=	-
Fire-rating	=	=	=	=	=	-
Cost	=	+	-	+	+	-
Material	=	+	-	=	=	+
LEED	=	+	-	+	+	-
Constr.	=	+	+	+	+	-

Overall, the existing system of flat-slab with drop panels, but without the post-tensioning seems like the best alternative. Also the waffle slab makes a decent alternative. The precast tees would be a good alternative as well if there was a way to reduce the depth of the system.

Design Aids

CRSI Design Handbook 2002

LRFD Manual of Steel Construction

PCI Design Handbook

Wheeling Deck Product Catalog

Nitterhouse Concrete Products Guide

Two-way flat slab with drop panels

f'_c = 4,000 psi
Grade 60 Bars

FLAT SLAB SYSTEM
SQUARE EDGE PANEL With Drop Panels
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		(3) Square Column		REINFORCING BARS (E. W.)						MOMENTS		
						Column Strip (1)			Middle Strip		Total Steel (psf)	Edge (−) (ft-k)	Bot. (+) (ft-k)	Int. (−) (ft-k)
		Depth (in.)	Width (ft)	Size (in.)	γ_f	Top Ext. +	Bottom	Top Int.	Bottom	Top Int.				
30	100	7.00	10.00	12	0.808	14-#5 3	12-#7	16-#6	15-#5	13-#5	3.10	257.4	514.8	693.0
30	200	9.00	10.00	16	0.707	14-#5 3	15-#7	18-#6	10-#7	11-#6	3.65	329.4	658.8	886.8
30	300	9.00	10.00	19	0.763	15-#5 5	12-#9	22-#6	12-#7	19-#5	4.62	401.5	803.1	1081.0
30	400	11.00	10.00	21	0.661	16-#5 3	17-#8	14-#8	11-#8	12-#7	5.27	473.2	946.3	1273.9
30	500	11.00	12.00	24	0.766	19-#5 6	13-#10	16-#8	13-#8	11-#8	6.20	545.2	1090.4	1467.9
31	100	9.00	10.33	12	0.729	14-#5 2	13-#7	16-#6	16-#5	14-#5	3.12	285.7	571.4	769.2
31	200	9.00	10.33	16	0.766	14-#5 5	13-#8	15-#7	11-#7	13-#6	3.96	364.7	729.3	981.8
31	300	11.00	10.33	19	0.683	15-#5 4	13-#9	16-#7	18-#6	15-#6	4.76	444.4	888.7	1196.4
31	400	11.00	10.33	22	0.749	18-#5 6	19-#8	15-#8	16-#7	18-#6	5.68	522.9	1045.8	1407.8
31	500	11.00	12.40	27	0.755	15-#6 4	18-#9	14-#9	12-#9	12-#8	6.78	599.3	1198.5	1613.4
32	100	9.00	10.67	12	0.794	15-#5 5	11-#8	17-#6	13-#6	15-#5	3.33	314.9	629.9	847.9
32	200	11.00	10.67	16	0.640	15-#5 2	12-#9	15-#7	13-#7	19-#5	4.27	403.4	806.8	1086.1
32	300	11.00	10.67	19	0.757	17-#5 6	18-#8	18-#7	12-#8	13-#7	5.16	490.7	981.3	1321.0
32	400	11.00	12.80	25	0.729	20-#5 5	14-#10	16-#8	11-#9	12-#8	6.21	575.3	1150.7	1549.0
32	500	11.00	12.80	30	0.718	16-#6 4	16-#10	15-#9	13-#9	13-#8	7.14	651.1	1302.2	1752.9
33	100	11.00	11.00	12	0.678	15-#5 1	16-#7	17-#6	14-#6	12-#6	3.44	347.3	694.7	935.1
33	200	11.00	11.00	16	0.743	15-#5 5	13-#9	16-#7	18-#6	15-#6	4.45	443.7	887.5	1194.7
33	300	11.00	11.00	21	0.747	19-#5 5	13-#10	15-#8	22-#6	11-#8	5.55	537.1	1074.2	1446.0
33	400	11.00	13.20	28	0.721	22-#5 6	15-#10	18-#8	12-#9	16-#7	6.55	628.5	1257.0	1692.2
33	500	11.00	13.20	33	0.680	17-#6 3	17-#10	16-#9	11-#10	14-#8	7.47	705.8	1411.6	1900.3
34	100	11.00	11.33	12	0.752	16-#5 4	14-#8	19-#6	12-#7	13-#6	3.74	380.6	761.2	1024.7
34	200	11.00	11.33	17	0.767	17-#5 6	14-#9	18-#7	12-#8	13-#7	4.83	485.4	970.8	1306.8
34	300	11.00	11.33	24	0.699	20-#5 4	17-#9	17-#8	14-#8	12-#8	5.88	584.8	1169.6	1574.5
34	400	11.00	13.60	30	0.700	17-#6 3	17-#10	19-#8	13-#9	14-#8	7.00	681.2	1362.3	1833.9
35	100	11.00	11.67	12	0.795	16-#5 6	12-#9	16-#7	13-#7	14-#6	3.95	415.9	831.9	1119.8
35	200	11.00	11.67	19	0.752	18-#5 6	19-#8	16-#8	16-#7	18-#6	4.98	528.2	1056.4	1422.1
35	300	11.00	11.67	26	0.715	22-#5 6	15-#10	18-#8	12-#9	22-#6	6.24	636.9	1273.8	1714.8
35	400	11.00	14.00	33	0.706	18-#6 5	18-#10	17-#9	14-#9	12-#9	7.34	734.7	1469.4	1978.1
36	100	11.00	12.00	14	0.767	16-#5 6	13-#9	22-#6	14-#7	12-#7	4.17	451.1	902.3	1214.6
36	200	11.00	12.00	21	0.760	20-#5 7	17-#9	16-#8	14-#8	12-#8	5.45	573.5	1147.0	1544.0
36	300	11.00	12.00	29	0.704	17-#6 5	17-#10	16-#9	13-#9	14-#8	6.66	686.8	1373.6	1849.1
36	400	11.00	14.40	36	0.660	27-#5 5	19-#10	18-#9	19-#8	13-#9	7.67	793.0	1586.1	2135.1

SQUARE INTERIOR PANEL
With Drop Panel(2)
No Beams

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

SPAN (ft)	Factored Superimposed Load (psf)	(3) Square Column Size (in.)	REINFORCING BARS (E. W.)					Concrete (cu. ft / sq. ft)
			Column Strip		Middle Strip		Total Steel (psf)	
			Top	Bottom	Top	Bottom		
30	100	12	15-#6	15-#5	13-#5	13-#5	2.82	1.065
30	200	19	23-#5	19-#5	15-#5	13-#5	3.16	1.083
30	300	22	15-#7	17-#6	10-#7	15-#5	4.02	1.083
30	400	25	16-#7	11-#8	11-#7	18-#5	4.59	1.102
30	500	27	14-#8	13-#8	10-#8	11-#7	5.31	1.147
31	100	12	20-#5	12-#6	13-#5	13-#5	2.78	1.083
31	200	19	26-#5	11-#7	16-#5	14-#5	3.41	1.083
31	300	23	15-#7	18-#6	14-#6	12-#6	4.10	1.102
31	400	25	14-#8	16-#7	13-#7	14-#6	4.98	1.102
31	500	27	16-#8	12-#9	11-#8	13-#7	5.93	1.147
32	100	12	16-#6	18-#5	14-#5	14-#5	2.90	1.083
32	200	19	26-#5	17-#6	13-#6	15-#5	3.57	1.102
32	300	23	22-#6	15-#7	12-#7	13-#6	4.43	1.102
32	400	26	15-#8	11-#9	11-#8	12-#7	5.37	1.147
32	500	30	17-#8	13-#9	12-#8	18-#6	6.12	1.147
33	100	12	16-#6	14-#6	11-#6	14-#5	2.97	1.102
33	200	19	15-#7	18-#6	14-#6	12-#6	3.82	1.102
33	300	23	18-#7	22-#6	13-#7	11-#7	4.71	1.102
33	400	26	17-#8	12-#9	12-#8	13-#7	5.74	1.147
33	500	33	15-#9	11-#1	13-#8	11-#8	6.52	1.147
34	100	12	18-#6	22-#5	12-#6	15-#5	3.16	1.102
34	200	19	22-#6	15-#7	12-#7	13-#6	4.13	1.102
34	300	23	16-#8	14-#8	14-#7	12-#7	5.15	1.102
34	400	29	18-#8	14-#9	22-#6	14-#7	6.07	1.147
35	100	12	19-#6	17-#6	13-#6	16-#5	3.32	1.102
35	200	19	18-#7	22-#6	13-#7	20-#5	4.31	1.102
35	300	23	17-#8	20-#7	12-#8	13-#7	5.43	1.102
35	400	32	16-#9	18-#8	14-#8	12-#8	6.42	1.147
36	100	12	16-#7	14-#7	20-#5	17-#5	3.58	1.102
36	200	19	37-#5	14-#8	14-#7	12-#7	4.71	1.102
36	300	25	18-#8	17-#8	22-#6	14-#7	5.68	1.102
36	400	34	17-#9	13-#10	12-#9	22-#6	6.84	1.147

NOTES: (1) 50 percent of these bars may be place in the middle third of column strip. (2) Drop panels same size as for edge panels. (3) Same column size above and below slab.

CONCRETE REINFORCING STEEL INSTITUTE

10-31

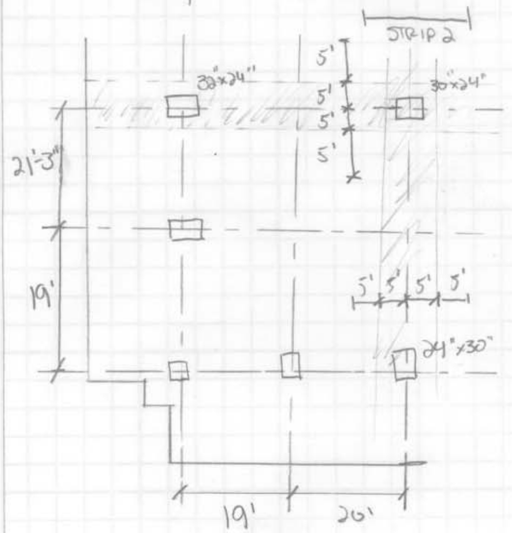
TABLE 11-4 PERIPHERAL SHEAR CONSTANTS AT COLUMNS

		Exterior Column			Interior Column		
Square Column $c_1 = c_2$ (in.)	Slab* (or Drop) (in.)	$C_{AB} = y_t$ (in.)	$A_c = b_o d$ (in.^{2})	J_c (in.^{4})	$C_{AB} = y_t$ (in.)	$A_c = b_o d$ (in.^{2})	J_c (in.^{4})
18	6	6.50	283	13208	11.25	405	34513
	8	6.73	435	22771	12.25	637	64847
	10	6.97	603	35355	13.25	901	108166
	12	7.20	787	51553	14.25	1197	167542
	14	7.44	987	72013	15.25	1525	246366
	16	7.68	1203	97435	16.25	1885	348351
	18	7.92	1435	128570	17.25	2277	477529
	20	8.16	1683	166221	18.25	2701	638251
	22	8.40	1947	211244	19.25	3157	835190
	24	8.64	2227	264546	20.25	3645	1073338
20	6	7.17	310	17399	12.25	441	44490
	8	7.40	474	29507	13.25	689	81854
	10	7.63	654	45117	14.25	969	134095
	12	7.87	850	64868	15.25	1281	204493
	14	8.10	1062	89452	16.25	1625	396647
	16	8.34	1290	119614	17.25	2001	414478
	18	8.58	1534	156149	18.25	2409	562225
	20	8.82	1794	199905	19.25	2849	744449
	22	9.06	2070	251781	20.25	3321	966030
	24	9.30	2362	312731	21.25	3825	1232168
22	6	7.84	337	22400	13.25	477	56231
	8	8.07	513	37470	14.25	741	101617
	10	8.30	705	56560	15.25	1037	163900
	12	8.53	913	80353	16.25	1365	246567
	14	8.76	1137	109586	17.25	1725	353427
	16	9.00	1377	145048	18.25	2117	488608
	18	9.24	1633	187578	19.25	2541	656557
	20	9.48	1905	238069	20.25	2997	862043
	22	9.72	2193	297466	21.25	3485	1110154
	24	9.96	2497	366765	22.25	4005	1406297
24	6	8.50	364	28284	14.25	513	69880
	8	8.73	552	46765	15.25	793	124344
	10	8.96	756	69820	16.25	1105	197852
	12	9.19	976	98176	17.25	1449	294101
	14	9.43	1212	132614	18.25	1825	417107
	16	9.66	1464	173967	19.25	2233	571206
	18	9.90	1732	223121	20.25	2673	761053
	20	10.14	2016	281011	21.25	3145	991625
	22	10.38	2316	348626	22.25	3649	1268217
	24	10.62	2632	427009	23.25	4185	1596446

*Slab, drop panel, or solid head (for waffle slabs) at the column.

(Continued nest page)

TWO-WAY FLAT SLAB WITH DROP PANELS



STRIP 1 - 39'

MINIMUM SLAB THICKNESS $= \ell_n/36 = (39' \times 12"/1' - 31")/36 = 12.14"$

USE 12.5" SLAB

MIN DROP DEPTH $= 1/4\, h = 1/4(12.5") = 3.125"$

USE 3.5" DROPS

DROP DIMENSIONS

$1/6\, \ell_n = 19'/6 = 3.16'$

$1/6\, \ell_n = (39 \times 12"/1' - 31")/12 = 36.42/6 = 6.07'$

USE 4' x 7' DROPS

LOADING

DEAD LOAD

$SW = (150\ lb/ft^3)(12.5" + (3.5 \times 1/3))/(12\ in/ft) = 170\ psf$

$SDL = 25\ psf$

$DL = 195\ psf$

LIVE LOAD = 100 psf

$W_u = 1.2(195) + 1.6(100) = 394\ lb/ft^2$

MIN S+T STEEL

$A_s = .0018 A_g = (12.5")(12 in/ft) .0018 = .27 in^2/ft$

SPACING (MIN) = 2h, 18 } LEAST 2(12.5) = 25" < 18

USE $S_{min} = 18"$

USE #5 @ 12" FOR S+T

STATIC MOMENT

$M_o = .394 \, k/in^2 \left(\frac{21.25 + 18.75}{2}\right)(36.42')^2 / 8$

$M_o = 1306.5$ ft-k

INTERIOR SUPPORT 65%	849.2 ftk	C.S. 75% 636.9 ftk	5'	127.38 ftk/ft
		M.S. 25% 212.3 ftk	5'	42.46 ftk/ft
MIDSPAN 35%	457.3 ftk	C.S. 60% 274.4 ftk	5'	54.88 ftk/ft
		M.S. 40% 182.9 ftk	5'	36.58 ftk/ft

#5 @ 12" $A_s = .31 in^2/ft$

$d_1 = 12.5" - .625" - .3125 - .75 = 10.81 \approx 10.75"$

$d_2 = 12.5 + 3.5 - .625 - .3125 - .75 = 14.25"$

$a = \frac{A_s f_y}{.85 f'_c b} = \frac{(.31)(60)}{.85(4)(12)} = .45$

ϕM_n (midspan) $= .9 A_s f_y (d - a/2) = .9(.31)(60)(10.75 - \frac{.45}{2})$

$\phi M_n = 176.19$ ftk/ft

ϕM_n (support) $= .9(.31)(60)(14.25 - \frac{.45}{2})$

$\phi M_n = 234.78$ ftk/ft

Use minimum reinforcing everywhere

12.5" slab w/ 3.5" drops

reinforced longitudinally w/

#5 @ 12"

STRIP 2 - 40.25'

12.5" SLAB, 3.5" DROP @ 4'x7'

$W_u = 394$ lb/ft^2

MIN S+T STEEL

$A_s = .0018 A_g = 12.5"(12 in/ft) .0018 = .27 in^2/ft$

$S_{min} = 18"$

USE #5 @ 12" FOR S+T

STATIC MOMENT

$M_o = .394 k/in^2 (20')(40.25' - 2')^2 / 8$

$M_o = 1441.1$ ft-k

INT. SUPPORT 65% = 936.7 ft-k	CS 75% = 702.5 ft-k	5'	140.5 ft-k/ft
	MS 25% = 234.2 ft-k	5'	58.5 ft-k/ft
MIDSPAN 35% = 504.4 ft-k	CS 60% = 302.6 ft-k	5'	60.5 ft-k/ft
	MS 40% = 201.8 ft-k	5'	40.3 ft-k/ft

#5 @ 12" $A_s = .31 in^2/ft$

$d_1 = 10.81 \approx 10.75"$

$d_2 = 14.25"$

$a = .45$

ϕM_n (midspan) = 176.19 ft-k/ft

ϕM_n (support) = 234.78 ft-k/ft

USE MIN REINFORCING

12.5" slab w/ 3.5" Drops

reinforced w/ #5 @ 12"

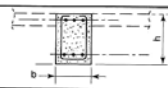
One-way skip joist

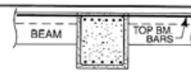
WIDE MODULE (1) ONE-WAY JOISTS MULTIPLE SPANS	40" Forms + 10" Ribs @ 50" c.-c. 12" Deep Rib + 4.5" Top Slab = 16.5" Total Depth FACTORED USABLE SUPERIMPOSED LOAD (PLF)										f'_c = 4,000 psi f_y = 60,000 psi
TOP BARS NO	# 4	# 4	# 4	# 5	# 6	End Span Defl. Coeff. (2)	# 4	# 5	# 5	# 6	# 7	Int. Span Defl. Coeff. (2)
AT	12.0	9.0	8.0	10.5	11.5		10.5	10.5	9.0	10.5	12.0	
BOTTOM BARS NO	2# 4	2# 5	2# 5	2# 5	2# 6		2# 4	2# 5	2# 5	2# 5	2# 6	
BARS NO	1# 4	1# 5	1# 6	2# 5	1# 7		1# 4	1# 5	1# 6	2# 5	1# 7	
STEEL (PSF)	.60	.89	1.04	1.23	1.50		.47	.47	.47	.47	.47	
CLEAR SPAN	END SPAN						INTERIOR SPAN					
24'-0" (3)	234	640	797	1021	1303	1.265	577	1167	1397	1722	2131	.779
STIR	#3- 25	#3- 75	#3- 86	#3- 98	#3-105		#3- 48	#3- 82	#3- 90	#3- 85	#3-107	
25'-0"	175	549	694	900	1160	1.490	491	1035	1246	1546	1924	.917
STIR	#3- 20	#3- 74	#3- 86	#3- 99	#3-111		#3- 45	#3- 83	#3- 91	#3- 93	#3-110	
26'-0"	122	468	602	793	1033	1.743	415	917	1113	1390	1739	1.073
STIR		#3- 72	#3- 85	#3- 99	#3-112		#3- 43	#3- 83	#3- 92	#3-100	#3-112	
27'-0"	75	396	521	697	920	2.027	347	813	994	1251	1575	1.247
STIR		#3- 71	#3- 85	#3-100	#3-114		#3- 40	#3- 83	#3- 93	#3-103	#3-115	
28'-0"	34	332	448	612	819	2.344	286	719	888	1127	1428	1.443
STIR		#3- 69	#3- 84	#3-100	#3-115		#3- 37	#3- 83	#3- 94	#3-105	#3-117	
29'-0"		274	382	535	728	2.698	231	635	792	1015	1296	1.660
STIR		#3- 67	#3- 83	#3-100	#3-116		#3- 33	#3- 83	#3- 94	#3-106	#3-105	
30'-0"		222	323	466	646	3.090	182	559	706	914	1177	1.901
STIR		#3- 64	#3- 81	#3-100	#3-117		#3- 29	#3- 83	#3- 94	#3-107	#3-112	
31'-0"		175	269	403	572	3.523	137	491	628	823	1069	2.168
STIR		#3- 61	#3- 80	#3-100	#3-118		#3- 25	#3- 82	#3- 95	#3-108	#3-120	
32'-0"		132	221	346	505	4.000	97	429	558	740	971	2.461
STIR		#3- 58	#3- 78	#3- 99	#3-119		#3- 20	#3- 81	#3- 94	#3-109	#3-122	
33'-0"		93	176	294	443	4.523	60	372	493	665	882	2.784
STIR		#3- 55	#3- 76	#3- 98	#3-119		#3- 15	#3- 80	#3- 94	#3-110	#3-124	
34'-0"		57	136	247	388	5.097		320	434	596	801	3.137
STIR		#3- 51	#3- 73	#3- 97	#3-119			#3- 79	#3- 94	#3-110	#3-125	
35'-0"			99	204	336	5.724		273	381	533	726	3.522
STIR			#3- 70	#3- 96	#3-119			#3- 77	#3- 93	#3-111	#3-127	
36'-0"			65	164	289	6.407		229	331	476	658	3.942
STIR			#3- 67	#3- 94	#3-119			#3- 75	#3- 92	#3-111	#-128	
PROPERTIES FOR DESIGN (CONCRETE .60 CF/SF)												
NEGATIVE MOMENT STEEL AREA (SQ. IN.)	.83	1.11	1.25	1.48	1.91		.95	1.48	1.72	2.10	2.50	
ACTUAL STEEL %	.503	.671	.755	.895	1.166		.575	.895	1.045	1.277	1.531	
EFF. DEPTH, IN.	14.75	14.75	14.75	14.69	14.63		14.75	14.69	14.69	14.63	14.56	
– ICR/IGR	.128	.161	.177	.199	.239		.142	.199	.223	.256	.287	
POSITIVE MOMENT STEEL AREA (SQ. IN.)	.60	.93	1.06	1.24	1.48		.60	.93	1.06	1.24	1.48	
ACTUAL STEEL %	.353	.549	.627	.732	.879		.353	.549	.627	.732	.879	
EFF. DEPTH, IN.	14.75	14.69	14.66	14.69	14.60		14.75	14.69	14.66	14.69	14.60	
+ICR/IGR	.116	.171	.192	.222	.257		.116	.171	.192	.222	.257	
SINGLE LEG STIRRUP AT 7 IN. CONSTANT SPACING-DISTANCE (IN.)												

(1) For gross section properties, see Table 8-3.
(2) Computation of deflection is not required above horizontal line (thickness ≥ $\ell_n/18.5$ for end spans, $\ell_n/21$ for interior spans).
(3) Single leg stirrup size space at X in. c.-c. Distance over which stirrups must extend from face of support at each end (in.).

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

JOIST-BAND BEAMS, INTERIOR SPANS





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

STEM h in.	STEM b in.	BARS[1] BOTTOM ℓ_n + 12 in.	BOTTOM 0.875 ℓ_n	Layers (2)	TOP	SPAN ℓ_n = 16 ft LOAD (4) k/ft	STIR. TIES (5)	ϕT_n ft-kips	A_ℓ sq. in.	STEEL WGT lb.	SPAN ℓ_n = 18 ft LOAD (4) k/ft	STIR. TIES (5)	ϕT_n ft-kips	A_ℓ sq. in.	STEEL WGT lb.	SPAN ℓ_n = 20 ft LOAD (4) k/ft	STIR. TIES (5)	ϕT_n ft-kips	A_ℓ sq. in.	STEEL WGT lb.	SPAN ℓ_n = 22 ft LOAD (4) k/ft	STIR. TIES (5)	ϕT_n ft-kips	A_ℓ sq. in.	STEEL WGT lb.	$+\phi M_n$ / $-\phi M_n$ (6) ft-kip	DEFL. (C) (7) × 10⁻⁶ in.
		2# 7	1# 7	1	4# 7	6.1	103E	10	-	248	4.8	103E	10	-	270	3.9	103E	10	-	292	3.2	103E	10	-	314	108	545
				1			193C	41	1.3	347		223C	40	1.3	395		243C	39	1.3	435		263C	39	1.3	474	142	
		2# 8	1# 8	1	4# 9	8.8	113E	10	-	341	6.9	123E	10	-	380	5.6	133E	10	-	420	4.6	133E	10	-	453	140	673
				1			144E	41	1.3	510		224C	40	1.3	682		244C	39	1.3	749		263C	39	1.3	593	224	
	24	2# 9	2# 9	1	4#11	13.9	154D	10	-	620	11.0	163D	10	-	582	8.9	173D	10	-	641	7.3	183D	10	-	700	224	578
				1			165D	41	1.3	877		185D	40	1.3	986		204D	39	1.3	874		224D	39	1.3	961	322	
		2# 9	2# 9	1	4#11	13.9	154D	10	-	620	11.0	163D	10	-	582	8.9	173D	10	-	641	7.3	183D	10	-	700	224	578
				1			165D	41	1.3	877		185D	40	1.3	986		204D	39	1.3	874		224D	39	1.3	961	322	
		2# 7	2# 7	1	5# 8	9.1	103E	18	-	337	7.2	103E	17	-	370	5.8	N/A	17	-	325	4.8	N/A	17	-	357	145	359
				1			323A	71	2.0	596		363A	69	2.0	670		403A	68	1.9	744		443A	67	1.9	818	231	
		2# 9	2# 9	1	5#10	14.6	133D	18	-	526	11.5	143D	17	-	586	9.3	153D	17	-	646	7.7	163D	17	-	706	233	454
				1			165D	70	2.0	958		184D	69	1.9	849		204D	68	1.9	942		443A	67	1.9	1045	351	
16.5	36	3# 9	2# 9	1	5#11	17.9	144D	18	-	747	14.1	154D	17	-	828	11.4	163D	17	-	793	9.5	173D	17	-	866	285	425
				1			165D	70	2.0	1070		185D	69	1.9	1202		205D	68	1.9	1334		225D	67	1.9	1467	417	
		3# 9	3# 9	1	5#14	21.0	154D	18	-	927	16.6	164D	17	-	1029	13.5	174D	17	-	1131	11.1	184D	17	-	1232	336	366
				1			325A	70	2.0	1766		185D	69	1.9	1388		205D	68	1.9	1541		225D	67	1.9	1694	551	
		3# 7	3# 7	1	6# 9	13.6	103E	26	-	482	10.7	113E	25	-	539	8.7	113E	25	-	588	7.2	N/A	24	-	541	217	304
				1			**	102	4.2	395		**	100	4.3	444		**	99	0.0	493		**	98	0.0	541	346	
		3# 8	3# 8	1	6#10	17.5	114E	26	-	692	13.8	123E	25	-	674	11.2	133E	25	-	745	9.3	133E	24	-	807	280	343
				1			194C	102	2.6	959		224C	100	2.6	1092		**	99	4.1	633		**	97	4.1	695	427	
	48	4# 9	3# 9	1	7#11	24.9	145D	25	-	1125	19.7	164D	25	-	1110	15.9	174D	25	-	1219	13.2	184D	24	-	1328	398	311
				1			325A	102	2.6	1969		185D	100	2.6	1528		205D	99	2.5	1696		265C	97	2.5	2016	579	
		4# 9	4# 9	1	6#14	28.0	155D	25	-	1286	22.2	165D	25	-	1421	18.0	174D	25	-	1386	14.8	184D	24	-	1512	448	285
				1			325A	102	2.6	2102		365A	100	2.6	2363		405A	99	2.5	2624		225D	97	2.5	2048	678	

(1) See "Recommended Bar Details", Fig. 12-1. For girders, use tabulated beam depth — 2 inches (b — 2").
(2) In "Layers" column, first line is number of layers for bottom bars, second line is for number of layers for top bars.
(3) For superimposed factored load capacity, deduct 1.4 x stem weight.
(4) Total capacities tabulated causing deflection in excess of $\ell_n/360$ are designated thus: * — $\ell_n/360$ < deflection < $\ell_n/240$
X — $\ell_n/240$ < deflection < $\ell_n/180$
Y — deflection > $\ell_n/180$

(5) For each beam design, first line is for open stirrups, secondline is for closed ties. See Fig. 12-4. At free ends, use stirrups tabulated for "Interior Spans". For b > 24 in., provide 4 legs (two stirrups) of size and spacing tabulated. For stirrup nomenclature, see page 12-13.

Other notation: N/A — STIRRUPS ARE NOT REQUIRED
** — MAXIMUM SPACING IS LESS THAN 3 INCHES. NOT RECOMMENDED
*** — SHEAR STRESS IS GREATER THAN $10\sqrt{f'_c}$
**** — TORSION STRESS EXCEEDS ALLOWABLE

(6) $+\phi M_n$ and $-\phi M_n$ are design moment strength capacities for rectangular section b × h.
(7) Midspan elastic deflection (in.) = C x (w/1.6) x ℓ_n^4, where w = tabulated load (k/ft.), ℓ_n in ft. "Average service load" is taken as w/1.6.

Two-way waffle slab

WAFFLE FLAT SLAB SYSTEM 30" X 30" Voids: 6" Ribs @ 36"

f'_c = 4,000 psi
Grade 60 Bars

Span c.-c. Columns $\ell_1 = \ell_2$ (ft)	SQUARE EDGE PANELS: Factored Super-imposed Load (psf)	(1) Steel (psf)	Square Edge Column $c_1 = c_2$ (in.)	γ_f	(2) Stirrups	Reinforcing Bars—Each Direction: Column Strip Top Edge No.-size +	Column Strip Bottom No. Ribs	Column Strip Bottom Bars per Rib	Column Strip Top Interior No.-size	Middle Strip Bottom No. Ribs	Middle Strip Bottom Long Bars	Middle Strip Bottom Short Bars	Middle Strip Top Interior No.-size	Moments −M Edge (ft-k)	+M Bot. (ft-k)	−M Int. (ft-k)	SQUARE INTERIOR PANELS: (1) Steel (psf)	Square Interior Column $c_1 = c_2$ (in.)	(2) Stirrups	Reinforcing Bars—Each Direction: Column Strip Bottom No. Ribs	Column Strip Bottom Bars per Rib	Column Strip Top Interior No.-size	Middle Strip Bottom No. Ribs	Middle Strip Bottom Long Bars	Middle Strip Bottom Short Bars	Middle Strip Top Interior No.-size
Total Depth = 23 in.	Rib Depth = 20 in.		Total Slab Depth = 3 in.														Total Depth = 23 in.			Rib Depth = 20 in.			Total Slab Depth = 3 in.			
30'- 0" D=12.500 RIB ON COLUMN LINE 1.048 CF/SF	50	2.27	15	0.641		22-#5+ 0	5	2-#5	22-#5	5	#5	#5	9-#5	200	399	537	2.25	15		5	2-#5	22-#5	5	#5	#5	9-#5
	100	2.27	15	0.641		22-#5+ 0	5	2-#5	22-#5	5	#5	#5	9-#5	240	480	646	2.25	15		5	2-#5	22-#5	5	#5	#5	9-#5
	150	2.34	15	0.641		22-#5+ 0	5	1-#5 and 1-#6	22-#5	5	#5	#5	9-#5	280	592	754	2.25	15		5	2-#5	22-#5	5	#5	#5	9-#5
	200	2.48	15	0.669		22-#5+ 0	5	1-#6 and 1-#7	22-#5	5	#5	#5	9-#5	320	732	863	2.25	15		5	2-#5	22-#5	5	#5	#5	9-#5
	300	3.02	15	0.735		22-#5+ 0	5	1-#7 and 1-#8	27-#5	5	#6	#6	9-#5	401	994	1080	2.60	15		5	2-#6	25-#5	5	#5	#5	9-#5
	400	3.79	15	0.817		22-#5+ 2	5	1-#8 and 1-#9	*23-#6	5	#7	#7	11-#5	482	1248	1297	3.26	15	†	5	2-#7	22-#6	5	#5	#6	10-#5
	500	4.33	15 *	0.642		22-#5+ 1	5	2-#9	27-#6	5	#7	#8	9-#6	562	1496	1514	3.81	15 *	†	5	1-#7 and 1-#8	25-#6	5	#6	#6	12-#5
33'- 0" D=12.500 RIB ON COLUMN LINE 1.02 CF/SF	50	2.37	16	0.640		25-#5+ 0	5	1-#5 and 1-#6	25-#5	6	#5	#5	10-#5	263	526	708	2.29	16		5	2-#5	25-#5	6	#5	#5	10-#5
	100	2.43	16	0.661		25-#5+ 0	5	2-#6	25-#5	6	#5	#5	10-#5	317	633	852	2.29	16		5	2-#5	25-#5	6	#5	#5	10-#5
	150	2.56	16	0.697		25-#5+ 0	5	1-#6 and 1-#7	25-#5	6	#5	#5	10-#5	370	774	997	2.40	16		5	1-#5 and 1-#6	25-#5	6	#5	#5	10-#5
	200	2.90	16	0.733		25-#5+ 0	5	1-#7 and 1-#8	29-#5	6	#5	#6	10-#5	424	961	1142	2.57	16		5	2-#6	27-#5	6	#5	#5	10-#5
	300	3.60	16 *	0.804		25-#5+ 0	5	1-#8 and 1-#9	26-#6	6	#6	#7	12-#5	532	1310	1432	3.10	16	†	5	2-#7	24-#6	6	#5	#5	11-#5
	400	4.46	16 *	0.641		25-#5+ 0	5	1-#9 and 1-#10	31-#6	6	#7	#7	10-#6	639	1647	1721	3.99	16 *	†	5	2-#8	29-#6	6	#6	#6	13-#5
36'- 0" D=12.500 RIB ON COLUMN LINE 0.998 CF/SF	50	2.42	18	0.637		27-#5+ 0	5	2-#6	27-#5	7	#5	#5	11-#5	337	674	908	2.29	18		5	2-#5	27-#5	7	#5	#5	11-#5
	100	2.54	18	0.676		27-#5+ 0	5	1-#6 and 1-#7	28-#5	7	#5	#5	11-#5	407	814	1095	2.39	18		5	1-#5 and 1-#6	27-#5	7	#5	#5	11-#5
	150	2.82	18	0.717		27-#5+ 0	5	1-#7 and 1-#8	33-#5	7	#5	#5	11-#5	476	966	1283	2.57	18	†	5	2-#6	30-#5	7	#5	#5	11-#5
	200	3.18	18	0.758		27-#5+ 0	5	2-#8	27-#6	7	#5	#6	12-#5	546	1210	1470	2.89	18	†	5	1-#6 and 1-#7	25-#6	7	#5	#5	11-#5
	300	4.21	18 *	0.868		27-#5+ 6	5	1-#9 and 1-#10	34-#6	7	#6	#7	11-#6	685	1660	1845	3.77	18 *	†	5	2-#8	31-#6	7	#5	#6	10-#6
39'- 0" D=15.500 RIB NOT ON COLUMN LINE 1.036 CF/SF	50	2.49	19	0.670		29-#5+ 0	6	1-#6 and 1-#7	30-#5	7	#5	#5	12-#5	437	874	1176	2.28	19		6	2-#5	29-#5	7	#5	#5	12-#5
	100	2.79	19	0.715		29-#5+ 0	6	2-#7	36-#5	7	#5	#6	12-#5	526	1051	1415	2.50	19		6	1-#5 and 1-#6	33-#5	7	#5	#5	12-#5
	150	3.11	19	0.789		29-#5+ 4	6	1-#7 and 1-#8	30-#6	7	#5	#6	14-#5	614	1230	1654	2.84	19		6	2-#6	28-#6	7	#5	#5	13-#5
	200	3.80	19 *	0.848		29-#5+ 8	6	1-#8 and 1-#9	34-#6	7	#6	#7	11-#6	703	1544	1893	3.42	19	†	6	2-#7	32-#6	7	#5	#6	15-#5
	300	4.91	19 *	0.637		30-#5+ 6	6	2-#10	44-#6	7	#7	#8	14-#6	880	2117	2371	4.31	19 *	†	6	2-#8	40-#6	7	#6	#6	13-#6
42'- 0" D=15.500 RIB NOT ON COLUMN LINE 1.015 CF/SF	50	2.72	21	0.680		31-#5+ 0	6	2-#7	37-#5	8	#5	#5	13-#5	539	1078	1452	2.55	21		6	2-#6	34-#5	8	#5	#5	13-#5
	100	3.20	21	0.748		31-#5+ 2	6	2-#8	32-#6	8	#5	#6	15-#5	650	1300	1750	2.91	21		6	1-#6 and 1-#7	29-#6	8	#5	#5	14-#5
	150	3.64	21 *	0.822		31-#5+ 7	6	1-#8 and 1-#9	37-#6	8	#6	#6	12-#6	760	1521	2047	3.31	21	†	6	2-#7	35-#6	8	#5	#5	16-#5
	200	4.26	21 *	0.880		31-#5+12	6	1-#9 and 1-#10	43-#6	8	#6	#7	14-#6	871	1844	2345	3.82	21 *	†	6	1-#7 and 1-#8	40-#6	8	#5	#6	13-#6

(Continued on next page)

NOTES See the notes on Page 11-19 regarding the * for column size and (1) for average reinforcing steel weight.
(2) A single dagger "†" indicates stirrups, equivalent to at least #5 bars spaced at 8 inches, are required in each joist rib from the face of the solid head to the first cross rib, i.e., a length of one module. A double dagger "††" indicates stirrups, equivalent to at least #5 bars spaced at 8 inches, are required in each joist rib from the face of the solid head to the second cross rib, i.e., a length of two modules. The size, configuration, and spacing of the stirrups are to be specified by the designer.

WAFFLE FLAT SLAB SYSTEM 19″ X 19″ Voids: 5″ Ribs @ 24″

f'_c = 4,000 psi
Grade 60 Bars

SQUARE EDGE PANELS

Total Depth = 11 in. Rib Depth = 8 in. Total Slab Depth = 3 in.

Span c.-c. Columns $\ell_1 = \ell_2$ (ft)	Factored Super-imposed Load (psf)	(1) Steel (psf)	Square Edge Column: $c_1 = c_2$ (in.)	Square Edge Column: γ_f	Square Edge Column: (2) Stirrups	Column Strip: Top Edge No.-size +	Column Strip: Bottom No. Ribs	Column Strip: Bottom Bars per Rib	Column Strip: Top Interior No.-size	Middle Strip: Bottom No. Ribs	Middle Strip: Bottom Long Bars	Middle Strip: Bottom Short Bars	Middle Strip: Top Interior No.-size	Moments: –M Edge (ft-k)	Moments: +M Bot. (ft-k)	Moments: –M Int. (ft-k)
14'- 0"	50	2.25	12	0.629		10-#5+ 0	4	2-#4	10-#5	3	#4	#4	4-#5	13	26	34
D= 6.417	100	2.25	12	0.636		10-#5+ 0	4	2-#4	10-#5	3	#4	#4	4-#5	17	35	45
RIB NOT ON	150	2.25	12	0.656		10-#5+ 0	4	2-#4	10-#5	3	#4	#4	4-#5	20	48	55
COLUMN LINE	200	2.25	12	0.677		10-#5+ 0	4	2-#4	10-#5	3	#4	#4	4-#5	24	60	65
0.599 CF/SF	300	2.25	12	0.717		10-#5+ 0	4	2-#4	10-#5	3	#4	#4	4-#5	32	84	86
	400	2.25	12	0.758		10-#5+ 0	4	2-#4	10-#5	3	#4	#4	4-#5	40	107	107
16'- 0"	50	2.30	12	0.694		12-#5+ 0	4	2-#4	12-#5	4	#4	#4	5-#5	19	38	52
D= 6.417	100	2.30	12	0.716		12-#5+ 0	4	2-#4	12-#5	4	#4	#4	5-#5	25	52	67
RIB NOT ON	150	2.30	12	0.739		12-#5+ 0	4	2-#4	12-#5	4	#4	#4	5-#5	31	72	83
COLUMN LINE	200	2.30	12	0.761		12-#5+ 0	4	2-#4	12-#5	4	#4	#4	5-#5	37	90	99
0.582 CF/SF	300	2.39	12	0.806		12-#5+ 0	4	1-#4 and 1-#5	12-#5	4	#4	#4	5-#5	48	126	130
	400	2.47	12	0.850		12-#5+ 0	4	2-#5	12-#5	4	#4	#4	5-#5	60	162	162
18'- 0"	50	2.25	12	0.734		13-#5+ 0	4	2-#4	13-#5	5	#4	#4	5-#5	28	55	74
D= 6.417	100	2.25	12	0.760		13-#5+ 0	4	2-#4	13-#5	5	#4	#4	5-#5	36	75	97
RIB NOT ON	150	2.25	12	0.787		13-#5+ 0	4	2-#4	13-#5	5	#4	#4	5-#5	44	103	120
COLUMN LINE	200	2.33	12	0.813		13-#5+ 0	4	1-#4 and 1-#5	13-#5	5	#4	#4	5-#5	53	130	143
0.571 CF/SF	300	2.58	12*	0.865		13-#5+ 0	4	1-#5 and 1-#6	13-#5	5	#4	#4	5-#5	70	182	188
	400	2.84	12*	0.630		13-#5+ 0	4	2-#6	14-#5	5	#4	#5	5-#5	87	233	234
20'- 0"	50	2.28	12	0.788		15-#5+ 0	5	2-#4	15-#5	5	#4	#4	6-#5	39	78	104
D= 8.417	100	2.28	12	0.816		15-#5+ 0	5	2-#4	15-#5	5	#4	#4	6-#5	50	105	136
RIB ON	150	2.36	12	0.844		15-#5+ 0	5	1-#4 and 1-#5	15-#5	5	#4	#4	6-#5	62	145	168
COLUMN LINE	200	2.45	12	0.872		15-#5+ 0	5	2-#5	15-#5	5	#4	#4	6-#5	74	182	199
0.590 CF/SF	300	2.80	12*	0.630		15-#5+ 0	5	2-#6	15-#5	5	#4	#5	6-#5	97	254	262
	400	3.48	14*	0.627		15-#5+ 0	5	1-#6 and 1-#7	14-#6	5	#5	#6	6-#5	120	323	323
22'- 0"	50	2.25	12	0.818		16-#5+ 0	5	2-#4	16-#5	6	#4	#4	7-#5	52	103	139
D= 8.417	100	2.25	12	0.850		16-#5+ 0	5	2-#4	16-#5	6	#4	#4	7-#5	68	140	182
RIB ON	150	2.40	12*	0.882		16-#5+ 0	5	2-#5	16-#5	6	#4	#4	7-#5	83	193	224
COLUMN LINE	200	2.56	12*	0.914		16-#5+ 0	5	1-#5 and 1-#6	16-#5	6	#4	#4	7-#5	99	243	267
0.579 CF/SF	300	3.26	14*	0.627		16-#5+ 0	5	1-#6 and 1-#7	15-#6	6	#5	#5	7-#5	130	337	349
	400	3.87	18*	0.623	3 S 4 1	16-#5+ 0	5	2-#7	18-#6	6	#5	#6	8-#5	156	392	419

SQUARE INTERIOR PANELS

Total Depth = 11 in. Rib Depth = 8 in. Total Slab Depth = 3 in.

Span c.-c. Columns $\ell_1 = \ell_2$ (ft)	Factored Super-imposed Load (psf)	(1) Steel (psf)	Square Interior Column: $c_1 = c_2$ (in.)	Square Interior Column: (2) Stirrups	Column Strip: Bottom No. Ribs	Column Strip: Bottom Bars per Rib	Column Strip: Top Interior No.-size	Middle Strip: Bottom No. Ribs	Middle Strip: Bottom Long Bars	Middle Strip: Bottom Short Bars	Middle Strip: Top Interior No.-size
14'- 0"	50	2.20	12		4	2-#4	10-#5	3	#4	#4	4-#5
D= 6.417	100	2.20	12		4	2-#4	10-#5	3	#4	#4	4-#5
RIB NOT ON	150	2.20	12		4	2-#4	10-#5	3	#4	#4	4-#5
COLUMN LINE	200	2.20	12		4	2-#4	10-#5	3	#4	#4	4-#5
0.599 CF/SF	300	2.20	12		4	2-#4	10-#5	3	#4	#4	4-#5
	400	2.20	12		4	2-#4	10-#5	3	#4	#4	4-#5
16'- 0"	50	2.26	12		4	2-#4	12-#5	4	#4	#4	5-#5
D= 6.417	100	2.26	12		4	2-#4	12-#5	4	#4	#4	5-#5
RIB NOT ON	150	2.26	12		4	2-#4	12-#5	4	#4	#4	5-#5
COLUMN LINE	200	2.26	12		4	2-#4	12-#5	4	#4	#4	5-#5
0.582 CF/SF	300	2.26	12		4	2-#4	12-#5	4	#4	#4	5-#5
	400	2.26	12	3 S 4 1	4	2-#4	12-#5	4	#4	#4	5-#5
18'- 0"	50	2.21	12		4	2-#4	13-#5	5	#4	#4	5-#5
D= 6.417	100	2.21	12		4	2-#4	13-#5	5	#4	#4	5-#5
RIB NOT ON	150	2.21	12		4	2-#4	13-#5	5	#4	#4	5-#5
COLUMN LINE	200	2.21	12		4	2-#4	13-#5	5	#4	#4	5-#5
0.571 CF/SF	300	2.36	12	3 S 4 1	4	1-#4 and 1-#5	13-#5	5	#4	#4	5-#5
	400	2.49	12*	3 S 4 1	4	2-#5	13-#5	5	#4	#4	5-#5
20'- 0"	50	2.25	12		5	2-#4	15-#5	5	#4	#4	6-#5
D= 8.417	100	2.25	12		5	2-#4	15-#5	5	#4	#4	6-#5
RIB ON	150	2.25	12		5	2-#4	15-#5	5	#4	#4	6-#5
COLUMN LINE	200	2.25	12		5	2-#4	15-#5	5	#4	#4	6-#5
0.590 CF/SF	300	2.39	12*	3 S 4 1	5	1-#4 and 1-#5	15-#5	5	#4	#4	6-#5
	400	2.99	12*	3 S 4 1	5	1-#5 and 1-#6	18-#5	5	#4	#5	6-#5
22'- 0"	50	2.23	12		5	2-#4	16-#5	6	#4	#4	7-#5
D= 8.417	100	2.23	12		5	2-#4	16-#5	6	#4	#4	7-#5
RIB ON	150	2.23	12		5	2-#4	16-#5	6	#4	#4	7-#5
COLUMN LINE	200	2.36	12*	3 S 4 1	5	1-#4 and 1-#5	16-#5	6	#4	#4	7-#5
0.579 CF/SF	300	2.81	12*	3 S 4 1	5	1-#5 and 1-#6	19-#5	6	#4	#4	7-#5
	400	3.47	16*	3 S 4 2	5	2-#6	17-#6	6	#4	#5	8-#5

(Continued on next page)

See the notes on Page 11-19.

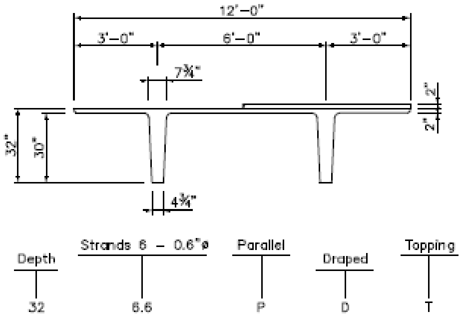
Precast PT Tee's

Prestressed Concrete
32"x12' Double Tee
(2" C.I.P. TOPPING)

PHYSICAL PROPERTIES

Precast

$A' = 951$ in.^{2} | $S_b' = 3198$ in.^{3}
$I' = 80{,}182$ in.^{4} | $S_t' = 11{,}570$ in.^{3} (at top of D.T.)
$Y_b = 25.07$ in. | $S_{tt}' = 8{,}979$ in.^{3} (at top of topping)
$Y_t' = 6.93$ in. (to top of D.T.) | Wt. = 991 PLF
$Y_{tt}' = 8.93$ in. (to top of topping) | Wt. = 83 PSF



DESIGN DATA
1. Precast strength @ RELEASE = 3000 PSI. (min.)
2. Precast strength @ 28 days = 6000 PSI.
3. Precast Density = 150 PCF
4. Strand = 0.6"ø 270k LO–relaxation.
5. Topping Strength = 3,000 PSI
6. Topping Density = 150 PCF
7. Maximum bottom tensile stress is $12\sqrt{f'c}$ =930 PSI.
8. All superimposed load is treated as live load in the flexural strength analysis.
9. Flexural capacity is based on stress/strain strand relationships.
10. Maximum moment capacity is critical at midspan for parallel strands and is critical near 0.4 span for draped strands.
11. All loads shown refer to allowable loads after the topping has hardened.

Table of Safe Superimposed Loads (lbs. per sq. ft.)

Section	$\emptyset M_n$ (in. Kips)	Span in Feet																				
		46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86
32–6.6 PT	9,334	76	64	54	45	36																
32–8.6 PT	11,900	116	101	88	76	66	56	48	40	33												
32–10.6 PT	14,322	153	135	119	105	92	81	71	62	53	46	39	33									
32–12.6 PT	16,423	185	165	146	130	116	103	91	81	71	63	55	48	41	35	30						
32–14.6 DT	20,943	256	230	206	186	167	151	136	123	110	99	89	80	72	64	57	51	45	39	33		
32–16.6 DT	22,860							161	146	132	120	109	99	88	78	69	60	53	48	42	38	33
32–18.6 DT	24,486													105	94	84	75	66	58	51	44	39

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

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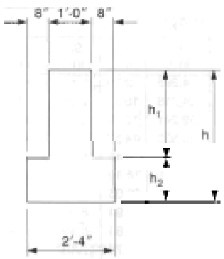
ND SM 6/94

INVERTED TEE BEAMS

Normal Weight Concrete



f'_c = 5,000 psi
f_{pu} = 270,000 psi
½ in. diameter
low-relaxation strand

Section Properties								
Designation	h in.	h_1/h_2 in.	A in^2	I in^4	y_b in.	S_b in^3	S_t in^3	wt plf
28IT20	20	12/8	368	11,688	7.91	1,478	967	383
28IT24	24	12/12	480	20,275	9.60	2,112	1,408	500
28IT28	28	16/12	528	32,076	11.09	2,892	1,897	550
28IT32	32	20/12	576	47,872	12.67	3,778	2,477	600
28IT36	36	24/12	624	68,101	14.31	4,759	3,140	650
28IT40	40	24/16	736	93,503	15.83	5,907	3,869	767
28IT44	44	28/16	784	124,437	17.43	7,139	4,683	817
28IT48	48	32/16	832	161,424	19.08	8,460	5,582	867
28IT52	52	36/16	880	204,884	20.76	9,869	6,558	917
28IT56	56	40/16	928	255,229	22.48	11,354	7,614	967
28IT60	60	44/16	976	312,866	24.23	12,912	8,747	1,017

1. Check local area for availability of other sizes.

2. Safe loads shown include 50% superimposed dead load and 50% live load. 800 psi top tension has been allowed, therefore additional top reinforcement is required.

3. Safe loads can be significantly increased by use of structural composite topping.

Key
6,929 — Safe superimposed service load, plf
0.3 — Estimated camber at erection, in.
0.1 — Estimated long-time camber, in.

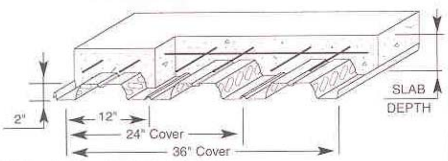
Table of safe superimposed service load (plf) and cambers

Designation	No. Strand	e	Span, ft																	
			16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50
28IT20	9	5.82	6929	5402	4310	3502	2887	2409	2029	1723	1473	1265	1091							
			0.3	0.3	0.4	0.4	0.5	0.6	0.6	0.7	0.7	0.8	0.8							
			0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	−0.1	−0.1							
28IT24	11	6.77	9714	7580	6054	4925	4086	3398	2868	2440	2090	1799	1556	1351	1175	1024				
			0.2	0.3	0.3	0.4	0.4	0.5	0.6	0.6	0.7	0.7	0.7	0.8	0.8	0.8				
			0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	−0.1	−0.2				
28IT28	13	8.44			8505	6951	5768	4848	4118	3529	3047	2648	2313	2030	1788	1579	1399	1242	1103	981
					0.3	0.4	0.5	0.5	0.6	0.7	0.7	0.8	0.9	0.9	1.0	1.0	1.1	1.1	1.1	1.1
					0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.0	−0.1
28IT32	15	9.17				9202	7646	6435	5474	4698	4064	3538	3097	2724	2406	2132	1894	1687	1505	1345
						0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.9	0.9	0.9	0.9
						0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	−0.1
28IT36	16	10.81						8485	7236	6227	5402	4718	4145	3660	3246	2890	2581	2311	2075	1866
								0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.9	0.9	0.9
								0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	−0.1
28IT40	19	11.28							8615	7415	6433	5620	4938	4361	3868	3444	3077	2756	2475	2226
									0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.8	0.9
									0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0
28IT44	20	12.89								9308	8092	7083	6239	5524	4913	4388	3932	3535	3186	2879
										0.4	0.5	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.8
										0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0
28IT48	22	14.16									9741	8539	7532	6680	5952	5326	4783	4310	3894	3528
											0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.8
											0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
28IT52	24	15.44											8935	7934	7080	6345	5707	5151	4664	4233
													0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.8
													0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
28IT56	26	16.74												9284	8294	7442	6703	6059	5493	4994
														0.5	0.6	0.6	0.7	0.7	0.8	0.8
														0.1	0.1	0.1	0.1	0.1	0.1	0.1
28IT60	28	18.04													9590	8613	7766	7027	6379	5807
															0.6	0.6	0.6	0.7	0.7	0.8
															0.1	0.2	0.2	0.2	0.2	0.2

Steel deck, joists, and girders

2.0 SB Normal Weight

Wheeling Composite Deck



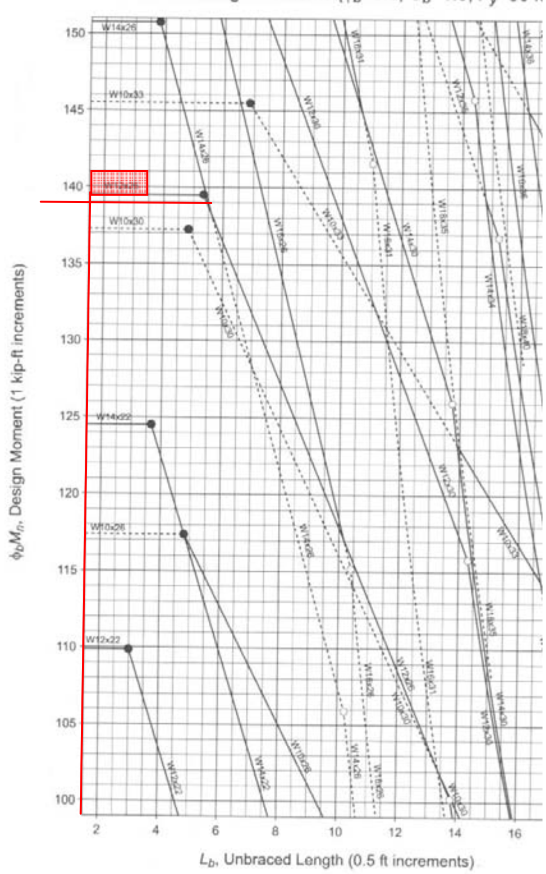
145 pcf Normal Weight Concrete

Section Properties (per ft. of width)

Gage	t in	Wd psf	Sp in³	Sn in³	Ip in⁴	In in⁴	As in²	Fy ksi
22	0.0295	2.0	0.257	0.258	0.317	0.309	0.472	50
20	0.0358	2.3	0.334	0.337	0.402	0.393	0.573	50
18	0.0474	3.0	0.507	0.517	0.557	0.552	0.759	40
16	0.0600	3.7	0.659	0.663	0.705	0.705	0.961	40

Total Slab Depth D / Wt. Conc. / Area Conc.	Gage	Maximum Unshored Clear Spans			Composite Properties		Superimposed Live Loads - psf: No Studs — Span - Feet and Inches											
		Single Span	Double Span	Triple Span	Iavg in⁴/ft	Sc in³/ft	7'-0"	7'-6"	8'-0"	8'-6"	9'-0"	9'-6"	10'-0"	10'-6"	11'-0"	11'-6"	12'-0"	12'-6"
	22	7'-1"	9'-1"	9'-4"	5.519	1.081	358	308	266	232	204	179	159	141	125	112	100	90
4-1/2"	20	8'-3"	10'-4"	10'-9"	5.917	1.288	400	372	323	283	248	220	195	174	155	139	125	113
42.3 psf	18	9'-3"	11'-5"	11'-10"	6.586	1.653	400	383	332	290	255	226	200	179	160	143	129	116
29.6 in²	16	10'-9"	12'-11"	13'-0"	7.219	2.02	400	383	332	290	255	226	200	179	160	143	129	116
	22	6'-9"	8'-7"	8'-11"	7.481	1.277	400	365	316	276	242	213	189	168	149	134	120	107
5"	20	7'-10"	9'-11"	10'-3"	8.006	1.522	400	400	383	335	295	261	232	207	185	166	149	135
48.3 psf	18	8'-9"	10'-11"	11'-3"	8.889	1.954	400	400	394	345	304	269	239	213	191	171	154	139
33.8 in²	16	10'-2"	12'-4"	12'-8"	9.733	2.394	400	400	394	345	304	269	239	213	191	171	154	139
	22	6'-5"	8'-3"	8'-7"	9.863	1.478	400	400	367	320	281	248	220	195	174	156	140	126
5-1/2"	20	7'-5"	9'-6"	9'-10"	10.536	1.763	400	400	400	390	343	304	270	241	216	194	175	158
54.4 psf	18	8'-4"	10'-5"	10'-9"	11.674	2.268	400	400	400	400	354	313	279	249	223	200	180	163
38.1 in²	16	9'-8"	11'-10"	12'-3"	12.769	2.784	400	400	400	400	354	313	279	249	223	200	180	163
	22	6'-2"	7'-11"	8'-2"	12.702	1.684	400	400	400	366	322	284	252	224	200	179	161	144
6"	20	7'-2"	9'-1"	9'-5"	13.548	2.010	400	400	400	400	393	348	309	276	247	222	200	181
60.4 psf	18	8'-0"	10'-0"	10'-4"	14.981	2.589	400	400	400	400	400	359	320	285	256	230	207	187
42.7 in²	16	9'-3"	11'-4"	11'-9"	16.369	3.184	400	400	400	400	400	359	320	285	256	230	207	187
	22	6'-0"	7'-7"	7'-11"	16.039	1.893	400	400	400	400	363	320	284	253	226	202	182	164
6-1/2"	20	7'-0"	8'-9"	9'-1"	17.081	2.262	400	400	400	400	400	393	349	312	280	252	227	205
66.5 psf	18	7'-10"	9'-8"	10'-0"	18.850	2.917	400	400	400	400	400	400	361	323	290	261	235	213
47.4 in²	16	9'-0"	10'-11"	11'-4"	20.575	3.594	400	400	400	400	400	400	361	323	290	261	235	213

Beam Design Moments (ϕ_b=0.9, C_b=1.0, F_y=50 k



Beam Design Moments (ϕ_b=0.9, C_b=1.0, F_y