Joseph Bednarz
Structural Option
Faculty Advisor: Dr. Boothby

October 31, 2005

Structural Technical Report #2:
Feasibility Study of Alternate Floor Systems

Executive Summary

This technical assignment involves the investigation of alternate floor framing systems for the River Tower at Christina Landing. Currently, the typical floor system for the residential portion of the River Tower is a post-tensioned floor plate concrete slab. This report will determine whether another type of system can be utilized, with the consideration of fire protection, overall floor depth, system dead weight, and assembly cost as determining factors. The overall purpose of this report is to determine whether these alternate floor systems could be utilized in an overall redesign of the structure.

The River Tower, standing at 25 stories in this design configuration, has since been redesigned for value engineering. In the actual redesign, the structural engineer considered a composite steel/braced frame system, a girder-slab proprietary system, and a filigree proprietary system. With this in mind, I have considered two forms of steel framed systems, both non-composite and composite, in this preliminary report. Girder-slab systems were researched, but only a suitable hollow core slab was found, not a composite system. As a proprietary system, a filigree system proved more difficult to research, and has not been considered in this preliminary report. Instead, I have investigated the use of one-way concrete joists as another alternate floor system. Finally, I have examined the use of a two-way flat plate reinforced concrete slab, without post-tensioning. Without the pre-stressing of the original configuration, drop panels were needed in this alternate reinforced concrete slab system at each column location.

The steel framing systems each significantly provide a lighter overall building weight, but sacrifice floor-to-floor height by several inches per floor. This would ordinarily be a deciding factor, had the River Tower design team not already acquired a code provision for building height from the city of Wilmington, DE. Other factors not considered in the scope of this preliminary report are column sizing and connections. The current architectural layout does not offer many viable options for column layouts, so the original grid lines were kept in order to fully compare each alternative system. Ultimately, the non-composite steel framing and non-prestressed two-way flat plate did not offer significantly different results than their counterparts, the composite steel framing and post-tensioned flat plate slab. The one-way concrete joist system proved too expensive and too deep to warrant further research. The composite steel framing system and hollow-core slab system will be scrutinized in more detail for upcoming technical assignments.

Introduction

This technical assignment presents preliminary research findings for the redesign of a typical floor system for the River Tower at Christina Landing condominium tower. The floor plan, shown below, for Levels 10 through 23 served as the basis for the following research designs. Specifically, an interior bay with consistent dimensions through most floors was used for comparative purposes. This bay, highlighted in the diagram above, lies between column lines 3 and 4 in the West-East direction, and column lines B and C in the North-South direction respectively. The slabs span between columns spaced at 28'-6" in the West-East direction and 23'-0" in the other direction on typical floors. The worst-case live load for a typical floor was determined to be 70 psf in a previous technical assignment, and was determined through a ratio between public and private spaces. The average superimposed dead load of a typical floor was taken as 12 psf to account for ceiling, mechanical and collateral loading. From the structural drawings, this building warrants a 2 hour fire-rating due to its largely residential use.
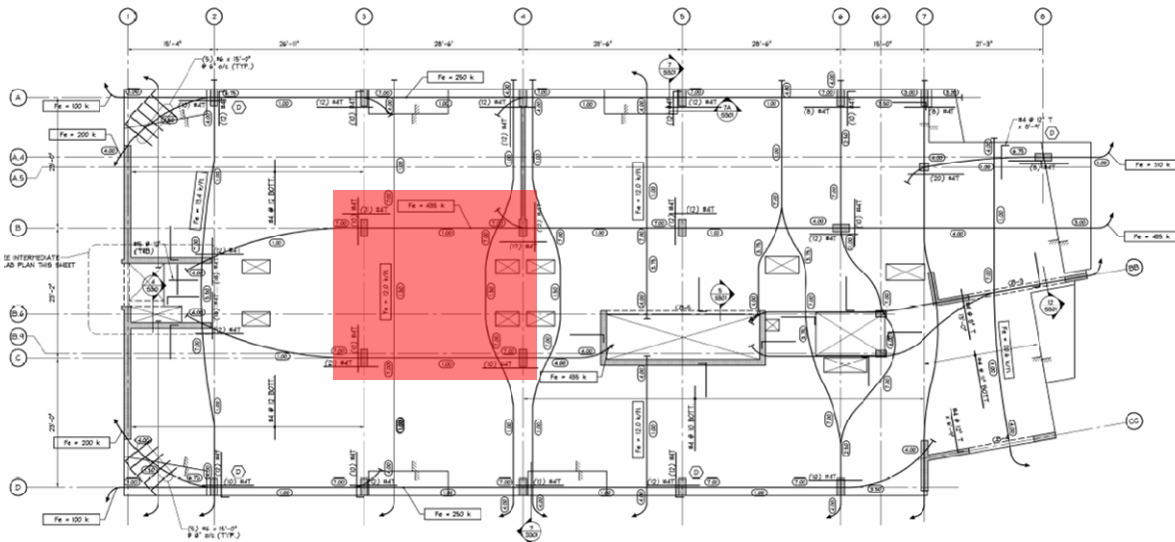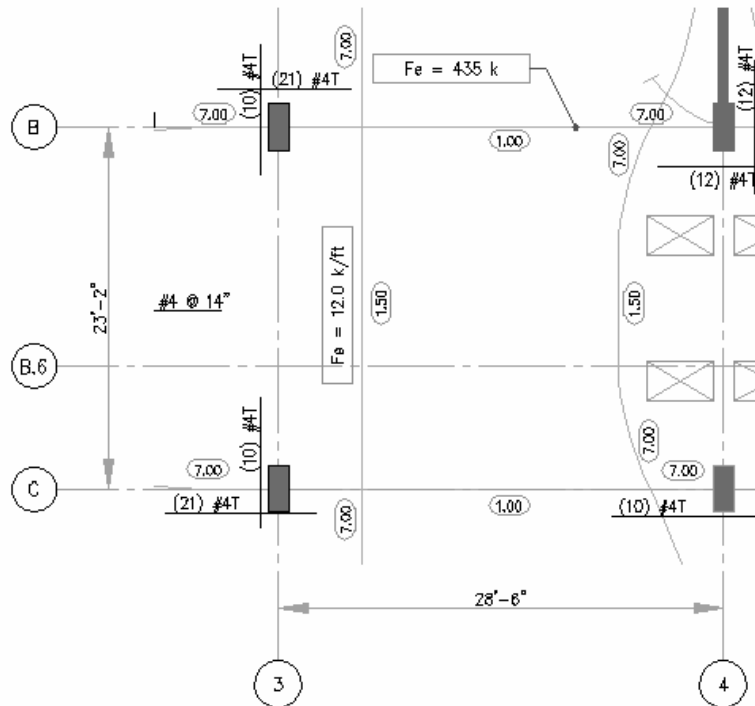

Typical Floor of River Tower Condominium: *Provided by O'Donnell & Naccarato, Structural Engineers*

Interior bay used for research highlighted in red and enlarged on next page

The following report weighs the benefits and disadvantages of several types of floor systems, including the original flat plate post-tensioned concrete slab. Alternate floor systems included in this analysis are non-composite and composite steel deck/concrete slab systems, a composite steel joist/deck/concrete slab system, and a one-way concrete joist system. Potential factors in determining feasibility include fire protection, system dead weight, and floor-to-floor height. The following pages list the benefits and disadvantages of each system, and a comparative chart lists the conclusions towards their feasibility in River Tower. Alternate column layouts were considered for this assignment, but due to the architectural dependency on the current grid lines, this layout was not changed from the original design.

## Existing System: Post-tensioned Flat Plate Concrete Slab

The typical River Tower condominium floors use an 8 inch, 5000 psi thick partially pre-stressed post-tensioned concrete flat plate system. An enlarged view of the interior span used for the preliminary research is shown above. The post-tensioning force in the long-span direction is listed at 12 kip/ft, while in the short-span direction this tensioning is 435 kips. In the banded post-tensioning direction (West-East), #4 tendons are placed every 12 inches, while in the uniform post-tensioned direction (N-S), #4 tendons are placed every 20 inches (omitted on diagram for clarity). At the columns, variable amounts (shown above) of #4 tendons are placed to help prevent punching shear in the flat slab and provide ultimate flexural strength for the slab. Through approximation of R.S. Means *Assemblies Cost Data*, this floor system costs $12.33 per square foot to construct. Please consult Appendix A for more detailed calculations.

System Summary:	Post-tensioned Floor Plate Slab
Advantages	- Post-tensioning saves need for more compressive reinforcement - Low vibration characteristics - Eight inch thickness provides adequate fire resistance - Banded tendon layout speeds construction time, saves on cost - Lack of drop panels reduces cost and floor thickness
Disadvantages	- Cast-in-place construction can lengthen erection process and increase installation costs - Susceptible to punching shear
Feasible for River Tower	(Existing Design System)

Alternate System #1: Hollow Core Slab System

8" × 4' Prestressed Concrete SpanDeck (U.L. Assembly #J952)
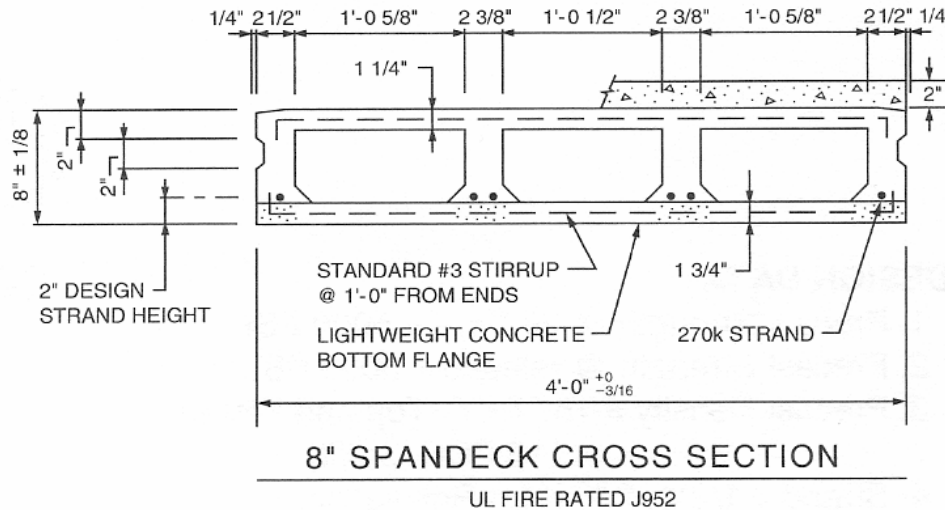

A hollow core slab system saves on material cost and system weight, since only the most necessary materials are used. These systems work similarly to pre-stressed floor slabs, but with voids to save on material cost. For this analysis, the hollow core slab was chosen based on a span of 24 feet, the short direction. Though the hollow core planks could hold the superimposed load without a concrete topping, a 2 inch cast-in-place concrete topping was factored into the design due to fire rating requirements of 2 hours for this condominium building. These planks need to rest on supports at the column lines: steel girders, concrete beams, or other bearing supports at the columns. These members were not analyzed as part of this preliminary report, but the overall depth of the bays would be controlled by the depth of the precast planks. Through approximation of R.S. Means *Assemblies Cost* Data, this floor system costs $10.14 per square foot to construct. Please consult Appendix B for more detailed information and calculations.

System Summary :	Hollow Core Slab System
Advantages	- Excellent Fire Resistance and Sound Attenuation - Precast offers quick and easy constructability, low maintenance - Similar column and column footing type can be used - Can be used as finished ceiling condition - Voids can be used for mechanical or electrical components - Provides basic lateral force-resistant diaphragm
Disadvantages	- Potentially limited competition for materials or labor - Possible constructability issues with contractors and erectors - Must rest on structural supports (not considered in this preliminary report)
Feasible for River Tower	YES

Alternate #2: **Composite System: Steel Beams, Girders, and Deck with 3" Concrete Slab**
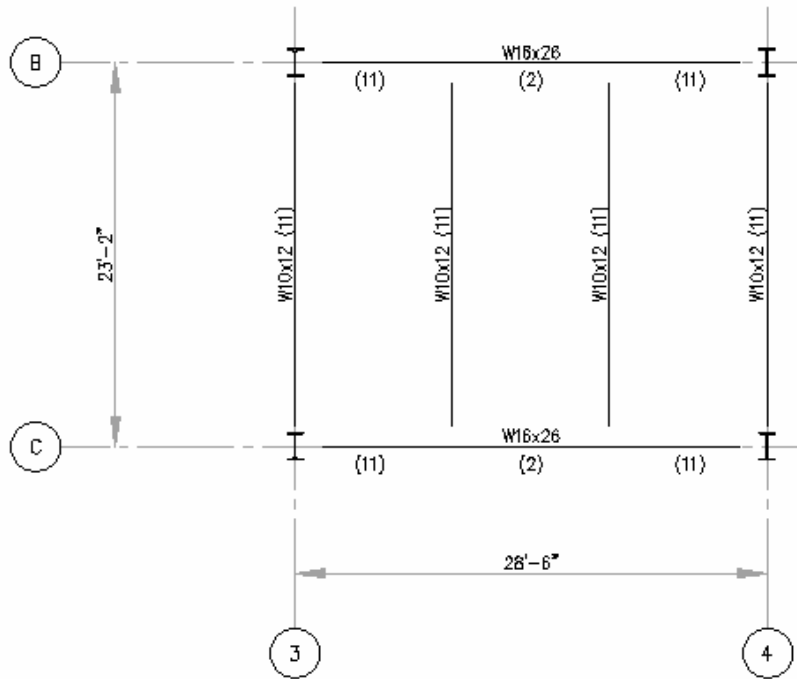
The beam and girder sizing were determined using RAM Structural Analysis software and had the following results. The largest depth in this configuration is the 15.7" depth of the W16×26 girder, but this occurs only in the 5.5" width of the flange. Primarily, the floor depth is controlled by the 10.2" deep W10×12 beams, which together with the 5" slab depth results in a difference of nearly seven inches from the existing floor system. The dead weight of this system, which includes the 3" concrete floor slab, 2" USD Lok-Floor metal decking, and structural steel components, is 44.8 psf. This system sacrifices floor depth and inherent fire protection, but has clear advantages in system weight and overall system cost, despite the expenses of steel procurement. Through approximation from R.S. Means *Assemblies Cost Data*, this system costs $19.37 per square foot to construct. Please consult Appendix C for more detailed information.

System Summary:	Composite Metal Deck/Concrete Slab System
Advantages	- Excellent stiffness – minimizes vibration issues - Structural shapes need fireproofing, slab/deck assembly do not - Lightens building weight considerably - Smaller column footings needed - Thinner/smaller column size minimizes architectural intrusion
Disadvantages	- Additional fireproofing necessary on structural supports (spray-on fiber or gypsum board) - Larger floor depth by almost seven inches - Change in lateral resistance system necessary - Ceiling finishing required underneath structural members
Feasible for River Tower	YES

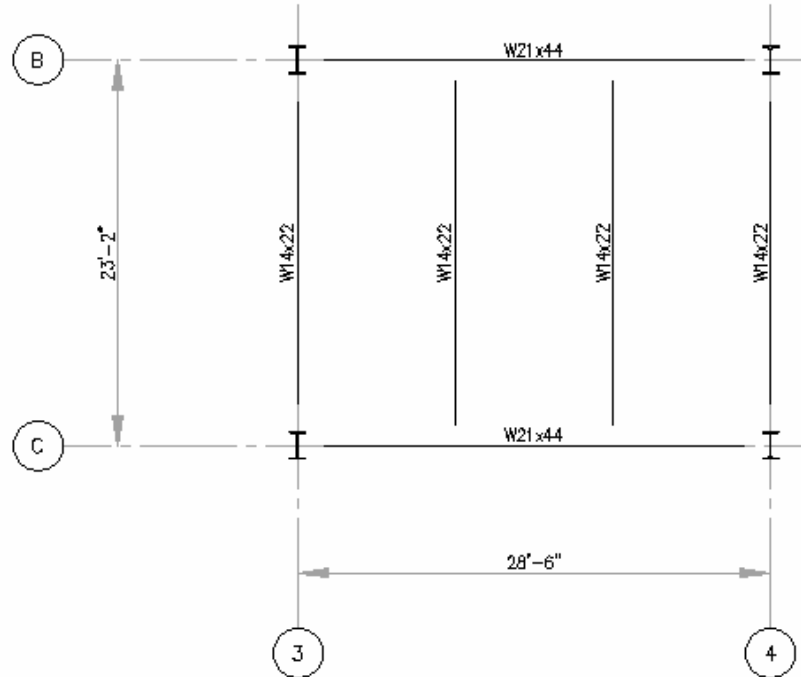**Alternate #3:** **Non-composite System: Steel Beams, Girders, and Deck on 3" Concrete Slab**


The beam and girder sizing were determined using RAM Structural Analysis software and had the following results. The largest depth in this configuration is the 20.7" depth of the W21×44 girder, but this occurs only in the 6.50" width of the flange. Primarily, the floor depth is controlled by the 13.7" deep W14×22 beams, which combined with a 5" slab depth results in a difference from the original floor system by almost eleven inches. The dead weight of this system, which includes the 3" concrete floor slab, 20 gage 2" USD Lok-Floor metal decking, and structural steel components, is 48.11 psf. Through approximation from R.S. Means *Assemblies Cost Data*, this system costs $14.30 per square foot to construct. Please consult Appendix D for more detailed information and calculations.

System Summary:	Non-Composite Metal Deck/Concrete Slab System
Advantages	- Structural shapes need fireproofing, slab/deck assembly do not - Lightens dead weight of structure - Smaller column footings needed - Thinner/smaller column size minimizes architectural intrusion
Disadvantages	- Additional fireproofing necessary on structural supports (spray-on fiber or gypsum board) - Less stiffness compared to composite steel/slab system - Larger floor depth by nearly eleven inches - Change in lateral resistance system necessary - Ceiling finishes required underneath structural members
Feasible for River Tower	NO

Alternate #4: **One-Way Concrete Joist Floor System**
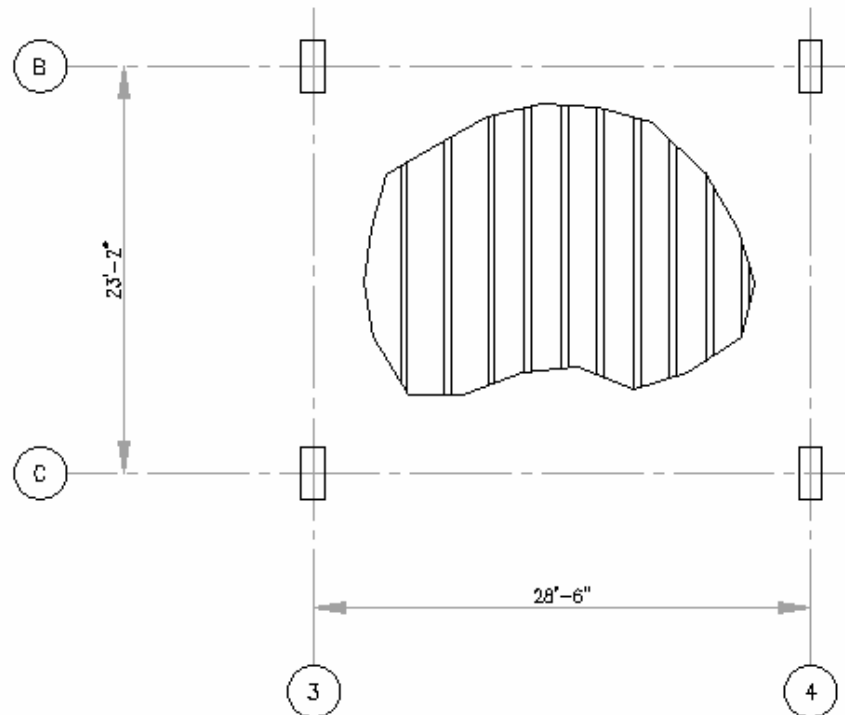
Standard square-end one-way concrete joists were designed using the CRSI Handbook. Because BOCA 1996 was referenced in the original floor design, the 1996 version of the CRSI Handbook edition was used to maintain design consistency. A 20" form system with 5" thick ribs spaced at 25" center-to-center was designed based on the typical loading configuration. This alternate system contains a 10" deep rib with a 3" top slab, making its total depth only 13 inches. To gauge a system with the minimum necessary depth, these joists were designed to span the short-span direction, taken at 24 feet to be conservative. The dead weight for this system is given as 67 psf from Table 8-1 of the CRSI Handbook. Through approximation from R.S. Means *Assemblies Cost Data*, this system costs $14.64 per square foot to construct. Please consult Appendix E for more detailed information and calculations.

System Summary:	One-Way Concrete Joist Floor System
Advantages	- Excellent stiffness criteria, meaning little deflection concern - Inherent fire protection - Voids between ribs can be used to place mechanical or electrical components - Original column and column footing type can be used - Original concrete shear walls can still be used
Disadvantages	- Expensive pour – cast-in-place concrete - Difficult construction – long spans and continuous pours - Needlessly deep floor depth compared to advantages of flat plate system properties
Feasible for River Tower	NO

Alternate #5: Two-Way Flat Plate Reinforced Concrete Slab
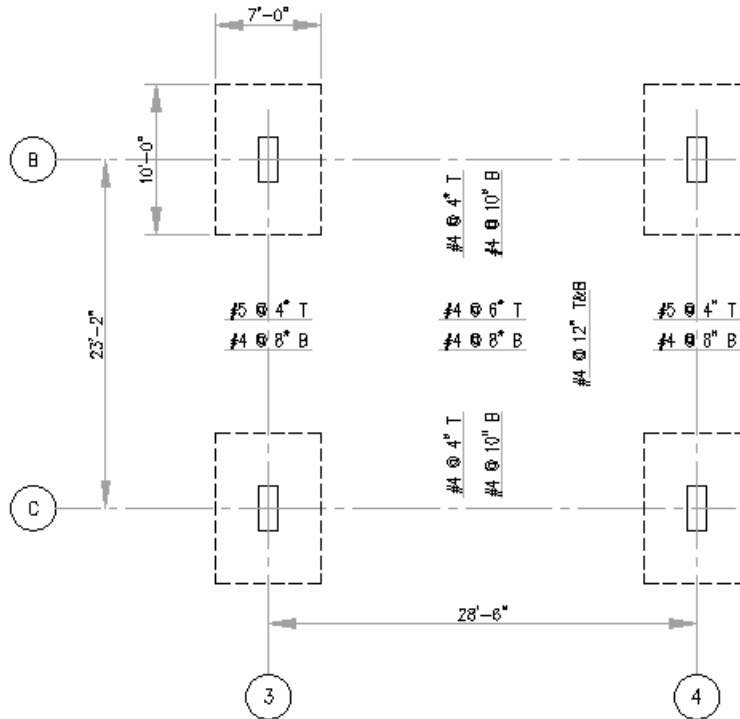
      For a two-way flat plate with reinforcing steel, a 9.25" thick, 5000 psi concrete slab was designed with 2.5" thick, 7 ft by 10 ft drop panels around the columns. For the short-span direction, #4 rebar is required at the following spacing: 12" at the top and bottom of the middle strip, 4" at the top of the column strip, and 10" at the bottom of the column strip. For the long-span direction, #4 rebar is used at 8" spacing for all bottom reinforcement. #4 bars are spaced at 6" for the top reinforcement of the middle strip, and #5 bars are used at 4" spacing for column strip top reinforcement. The system dead weight was determined to be 113.13 psf, neglecting the weight of the drop panels, which was judged to be negligible compared to the overall weight. The system cost was determined to be $14.07 through approximation of R.S. Means *Assemblies Cost Data*. Please consult Appendix F for more detailed information and calculations.

System Summary:	Two-Way Flat Plate Reinforced Concrete Slab
Advantages	- Low vibration characteristics - 9.25 inch thickness provides adequate fire resistance - Excellent stiffness = low deflection - Original column and column footing type would be similar - Original concrete shear walls can still be used
Disadvantages	- Susceptible to punching shear - Drop panels add additional floor thickness near supports - Difficult constructability – cast-in-place concrete
Feasible for River Tower	NO

Details of Cost Analysis

Through approximation from the 2005 R.S. Means *Assemblies Cost Data*, the existing and alternate systems were compared using 25 foot spans, and in some cases 25 ft by 30 ft bays, for comparative purposes. While this assemblies cost data is not totally applicable, such as in the case of concrete strength, this data provides a valuable preliminary estimate of the building cost concerns of these proposed systems. The values are compared in the following overall comparison chart.

Overall Comparison

Floor System	System Depth	Dead Weight	System Cost (per sq. ft.)	Further research?
Post-tensioned flat plate slab system	8"	98 psf	$12.33	**Existing**
Hollow Core Slab System	8" ± 1/8" precast + 2" topping	82.5 psf	$10.14	**YES**
Composite Steel Framing System	10.2" steel + 5" slab depth	44.8 psf	$19.37	**YES**
Non-Composite Steel Framing System	13.7" steel + 5" slab depth	48.11 psf	$14.30	**NO**
One-Way Concrete Joists	10" Deep Rib + 3" Top Slab	67 psf	$14.64	**NO**
Two-Way Flat Plate Slab with Drop Panels	9.25" + 2.5" at drop panels	113.31 psf	$14.07	**NO**

Conclusion

While each alternative system offered unique benefits to the overall building system, floor depth, dead weight, and building cost were deciding factors. The composite steel framing system provides both the lowest system weight and highest system cost. The non-composite steel framing system provides nearly the same system weight at a much lower cost, but at a greater floor depth. Budget would certainly control in most cases, but in this preliminary structural analysis, floor depth controlled overall. With this in mind, the non-composite system was judged to not warrant further analysis. The one-way composite joist system's poor overall cost and depth does not offset its benefits of dead weight to merit further research as well. The flat plate slab system with drop panels does not offer any significantly better results, particularly with self weight, than the original partially prestressed flat plate slab.

It is important to note that the potential change in floor system would affect the type of column footings used, but not the overall deep pile cap foundation system. Concrete columns would be supported with wooden column base connections, while steel columns would need steel base plates. The instabilities of the riverfront soil of the River Tower site would necessitate using deep piles regardless of floor system type. Lighter building weights would affect sizing of footings, however, and would potentially alleviate overturning capacities.

APPENDICES

A. Existing Floor System

B. Hollow Core Slab System Selection

C. Composite Steel Deck/Concrete Slab Floor System Selection

D. Non-composite Steel Deck/Concrete Slab Floor System Selection

E. One-Way Concrete Joist System Selection

F. Two-Way Flat Plate with Drop Panels Selection

G. R.S. Means Assemblies Cost Data

H. List of Resources

APPENDIX A:

Existing Floor System

System self-weight

W_{slab} = (8" slab)*(147 pcf)*(1ft/12") = 98 psf

Total Self-Weight of Typical Bay = 98 psf

Please consult Technical Assignments #1 and #3 for analysis of existing floor system.

APPENDIX B:

Hollow Core Slab System Selection

- <u>Superimposed Dead Load:</u>
    7 psf for ceiling/mechanical (presumed)
    5 psf for collateral (listed on drawings)

- <u>Worst Case Live Load (typical floor):</u> 70 psf

- **Total Superimposed Load (unfactored)** = 70 psf + 7 psf + 5 psf = **82 psf**
- Total Superimposed Load (factored) = 1.2(12 psf) + 1.4(70psf) = 114.8 psf

- *From Nitterhouse Concrete Products (see following data chart):*

    - Span = 23'-2" → 24' (spanning in this direction allows for a thinner hollow core slab)

    - Choose **8" × 4' Prestressed Concrete SpanDeck with 2" topping (U.L. J917)**
        - f'_c = 5000 psi at 28 days, 3000 psi at release
        - Precast density = 150 pcf (top and webs), 115 pcf (soffit)
        - Allowable Superimposed Load for 24' span = 112 psf (flexure) > 82 psf req'd
        - (4) ½" diameter, 270 ksi Low-Relaxation Strands at 2" height
        - Precast System Weight = 330 plf = 82.5 psf

Fire Rating from Underwriters' Laboratories
    - Restrained end: 2 in. concrete cover (1 in. gypsum board) required for 2 hour fire rating
    - Unrestrained end: 1 ½ hour rating with same cover requirements
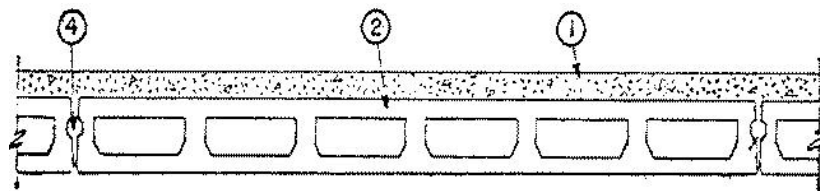
U.L. Assembly Diagram Key

1.) Floor Topping (concrete, gypsum, or floor mat material)
2.) Precast Plank
3.) Min. 1.5" End Bearing Detail
4.) Grout: 3500 psi
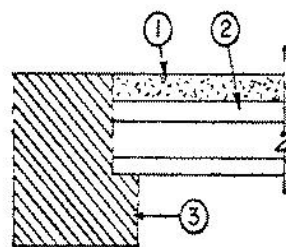
Restrained End Detail
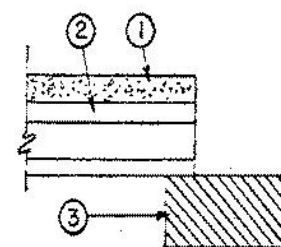
Unrestrained End Detail

Courtesy Nitterhouse Concrete Products, Inc.:
http://www.nitterhouse.com/DrawingSpecs/DrawingsSpecs.html

Prestressed Concrete
8" x 4' SpanDeck – U.L. – J952
(2" C.I.P. TOPPING)

PHYSICAL PROPERTIES
Composite

$A' = 295$ in.^{2}

$I' = 2624$ in.^{4}

$Y_{b'} = 5.61$ in.

$Y_{t'} = 2.39$ in. (To Top of SpanDeck)

$Y_{tt'} = 4.39$ in. (To Top of Topping)

$S'_b = 468$ in.^{3}

$S'_t = 1096$ in.^{3} (At Top of SpanDeck)

$S'_{tt} = 597$ in.^{3} (At Top of Topping)

Wt.$' = 330$ PLF

Wt.$' = 82.5$ PSF

DESIGN DATA
1. Precast Strength @ 28 days = 5000 PSI.
2. Precast Strength @ release = 3000 PSI.
3. Precast Density = 150 PCF (Top and Webs)
   = 115 PCF (Soffit)
4. Strand = 1/2"ø, 270K Lo-Relaxation.
5. Composite Strength = 3000 PSI.
6. Composite Density = 150 PCF.
7. Strand Height = 2.00 in.
8. Ultimate moment capacities (when fully developed) . . .
   4 – 1/2"ø, 270K = 88.3'K
   6 – 1/2"ø, 270K = 124.0'K
9. Maximum bottom tensile stress is $6\sqrt{f'c} = 424$ PSI.
10. All superimposed load is treated as live load in the strength analysis of flexure and shear.
11. Flexural strength capacity is based on stress/strain strand relationships.
12. Shear values are the maximum allowable before shear reinforcement is required.
13. Deflection limits were not considered when determining allowable loads in this table.
14. Load values to the left of the solid line are controlled by ultimate strength. Load values to the right are controlled by service stress.
15. All loads shown refer to allowable loads applied after topping has hardened.

8" SPANDECK CROSS SECTION
UL FIRE RATED J952
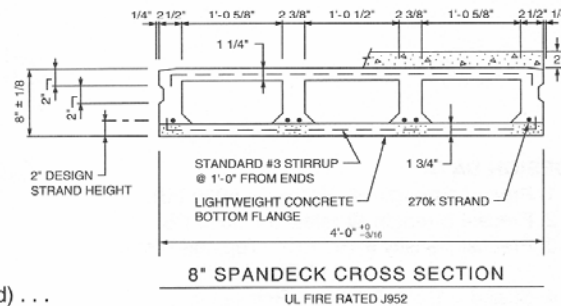
8" SPANDECK W/2" TOPPING			ALLOWABLE SUPERIMPOSED LOAD (PSF)																					
STRAND PATTERN			SPAN (FEET)																					
			10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Flexure	4 –	1/2"ø	750	675	611	546	462	394	338	291	252	218	191	167	146	128	112	98	85	74	63	51	41	31	
Shear	4 –	1/2"ø	527	469	421	382	348	317	294	272	252	235	219	197	176	157	140	129	122	110	98	88	78	70	
Flexure	6 –	1/2"ø	1098	900	898	794	676	580	502	437	382	336	296	262	233	207	185	165	147	132	116	101	87	74	63
Shear	6 –	1/2"ø	542	483	434	393	359	329	303	280	261	243	227	212	199	188	178	167	152	137	124	112	101	91	86

NITTERHOUSE
CONCRETE PRODUCTS

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.

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

REVISED 12/93

APPENDIX C:

Composite Steel Deck/Concrete Slab System Selection

RAM Structural System software was used to determine the steel beam and girder sizing, based on the selection of 2" Lok-Floor steel decking from the United Steel Deck catalog. A 20 gage 2" Lok-Floor decking has a maximum three-span unshored distance of 9.59', which just clears the 9.5' dimension of the three even-spaced beams in a typical bay. Three inches of lightweight concrete (f'c = 3000 psi) lie above this decking, giving a total slab depth of 5".

Self-Weights for a Typical 23'× 28.5' Composite Bay

20 gage 2" Lok-Floor Deck	= 1.80 psf
3" Concrete Slab	= 38.0 psf
(2) W18×35 = 2(35 plf)/(23 ft)	= 3.04 psf
(4) W12×14 = 4(14 plf)/(28.5 ft)	= 1.96 psf

Total Self-Weight of Typical Bay   = 44.8 psf

RAM Analysis Results for Composite System:
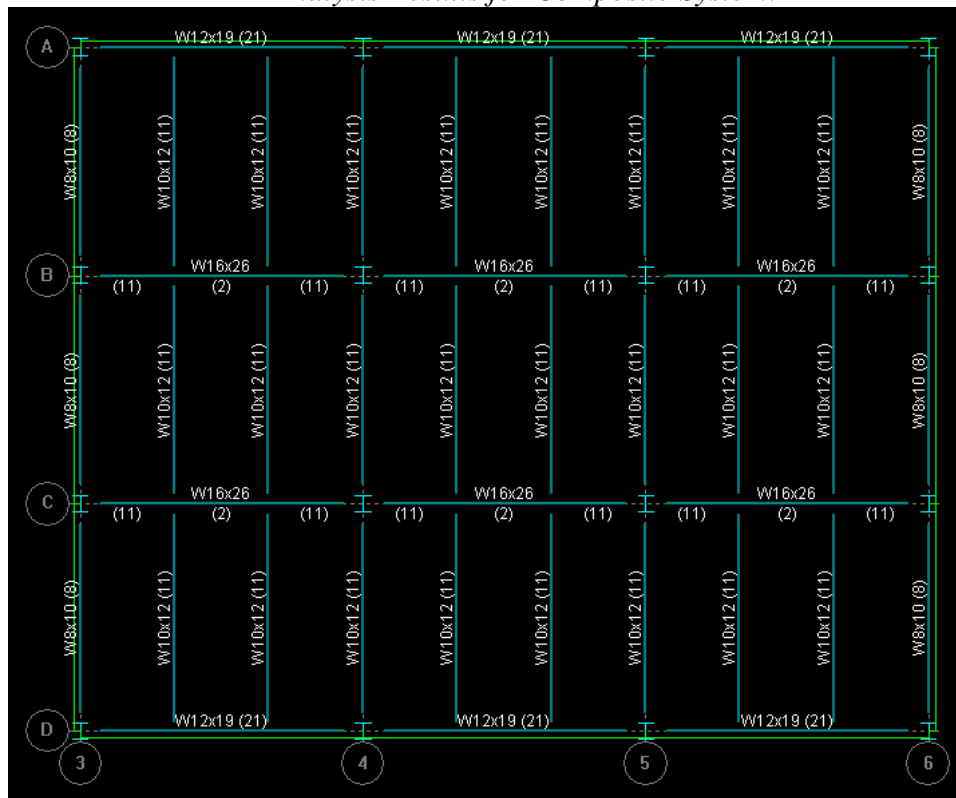
APPENDIX D:

Non-Composite Steel Deck/Concrete Slab System Selection

RAM Structural System software was used to determine the steel beam and girder sizing, based on the selection of 2" Lok-Floor steel decking from the United Steel Deck catalog. A 20 gage 2" Lok-Floor decking has a maximum three-span unshored distance of 9.59', which just clears the required 9.5' dimension (3 equal spans in 28.5' bay) of the three even-spaced beams in a typical bay. Three inches of lightweight (f'c = 3000 psi) concrete lie above this decking, giving a total slab depth of 5".

Self-Weights for a Typical 23'× 28.5' Non-composite Bay

20 gage 2" Lok-Floor Deck	= 1.8 psf
3" Concrete Slab	= 38 psf
(2) W18×60 = 2(60 plf)/(23 ft)	= 5.22 psf
(4) W14×22 = 4(22 plf)/(28.5 ft)	= 3.09 psf

Total Self-Weight of Typical Bay = 48.11 psf

RAM Analysis Results of Non-Composite System:
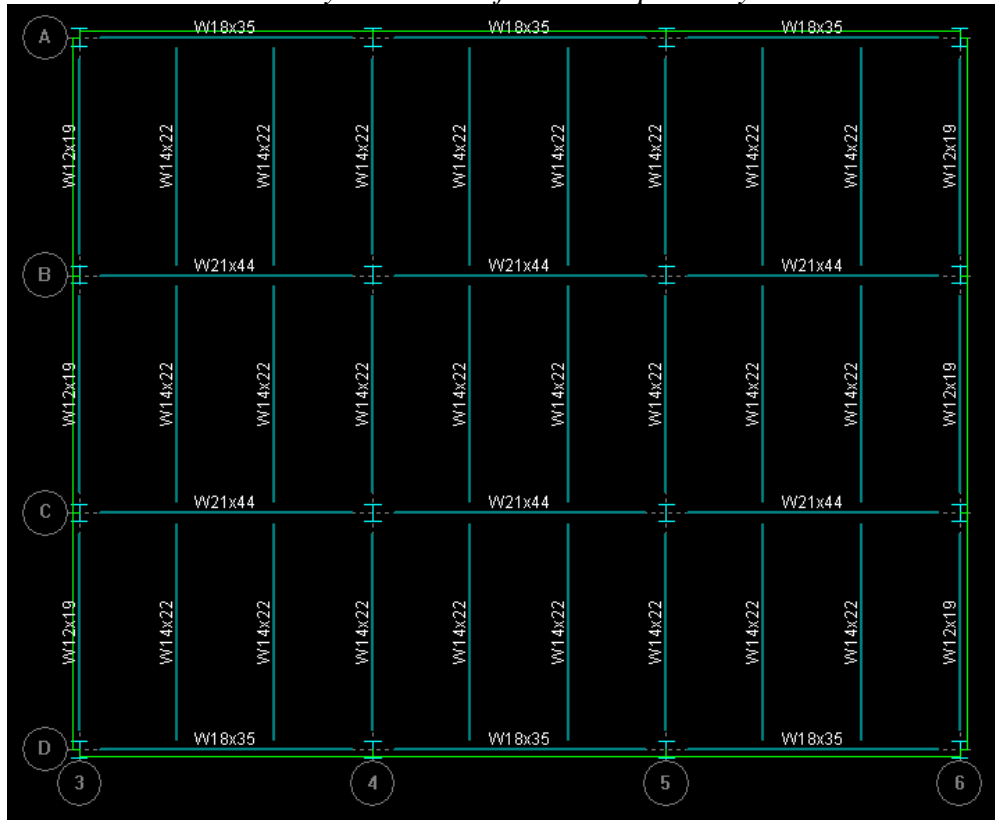
APPENDIX E:

One-Way Concrete Joist System Selection

LL =   70 psf (worst case for typical floor)
SDL = 2 psf (bridging)
      12 psf (ceiling/mechanical/collateral)

Factored w_u = 1.4(14 psf) + 1.7(70 psf) = 138.6 psf (to keep consistent with 1996 values)

Largest clear span = 28.5' – 2*[(16"/2)*(1ft/12in)] = 27.167' → Use 28' span (conservative)

Referencing 1996 CRSI Handbook (see scan of table on next page):

Multiple span one-way joists: 10" Deep Rib + 3" Top Slab = 13.0" Total Depth
    - End-span
            - Tabulated value: 164 psf > 138.6 psf   (OK)
            - Top Bars: #6 @ 11.5"
            - Bottom Bars: (1) #5 and (1) #6
            - Steel: 1.52 psf

    - Interior Span
            - Tabulated value: 164 psf > 138.6 psf   (OK)
            - Top Bars: #5 @ 9"
            - Bottom Bars: (1) #4 and (1) #5
            - Steel: 1.39 psf

Concrete Self-Weight = 67 psf (Table 8-1 of CRSI Handbook)

STANDARD ONE-WAY JOISTS MULTIPLE SPANS	20" Forms = 5" rib @ 25" c.-c. FACTORED USABLE SUPERIMPOSED LOAD (PSF)(2)								f'c = 4,000 psi fy = 60,000 psi		

Depth: 10" Deep Rib + 3.0" Top Slab = 13.0" Total Depth

	Size #					End Span Defl. Coeff. (3)					Int. Span Defl. Coeff. (3)
TOP BARS	#4 10.5	#4 8	#5 10	#6 11.5	#6 9.5		#4 10	#5 12	#5 9	#6 10	
BOTTOM BARS	#4 / #4	#4 / #5	#5 / #5	#5 / #6	#6 / #6		#3 / #4	#4 / #4	#4 / #5	#5 / #5	
Steel (psf)	.79	1.01	1.25	1.52	1.83		.82	1.08	1.39	1.78	

CLEAR SPAN	END SPAN						INTERIOR SPAN				
18'-0"	246 / 0	336 / 0	365* / 427	375* / 531	390* / 569*	.878	291 / 0	401 / 0	419* / 532	428* / 639*	.540
19'-0"	211 / 0	292 / 0	334* / 374	343* / 466	356* / 521*	1.090	251 / 0	350 / 0	386* / 468	394* / 586	.671
20'-0"	182 / 0	254 / 0	307* / 328	315* / 412	326* / 479*	1.338	217 / 0	307 / 0	358* / 413	364* / 520	.823
21'-0"	156 / 0	222 / 0	284* / 289	290* / 365	300* / 442	1.626	188 / 0	270 / 0	332* / 366	338* / 463	1.001
22'-0"	134 / 0	194 / 0	255 / 0	268* / 324	277* / 394	1.959	163 / 0	237 / 0	309* / 325	314* / 413	1.205
23'-0"	114 / 0	169 / 0	225 / 0	249* / 288	257* / 353	2.340	141 / 0	209 / 0	289* / 0	293* / 370	1.440
24'-0"	97 / 0	148 / 0	199 / 0	232* / 257	239* / 316	2.774	122 / 0	184 / 0	258 / 0	274* / 332	1.707
25'-0"	82 / 0	129 / 0	176 / 0	216* / 230	222* / 284	3.266	105 / 0	162 / 0	230 / 0	257* / 299	2.010
26'-0"	69 / 0	112 / 0	156 / 0	202* / 205	208* / 256	3.821	90 / 0	143 / 0	206 / 0	241* / 269	2.351
27'-0"	57 / 0	97 / 0	137 / 0	183 / 0	194* / 230	4.443	77 / 0	126 / 0	184 / 0	227* / 243	2.734
28'-0"	46 / 0	84 / 0	121 / 0	164 / 0	182* / 207	5.139	65 / 0	110 / 0	164 / 0	213* / 219	3.163
29'-0"		72 / 0	107 / 0	146 / 0	171* / 187	5.914	54 / 0	97 / 0	147 / 0	198 / 0	3.639
30'-0"		61 / 0	93 / 0	131 / 0	160* / 169	6.772	44 / 0	84 / 0	131 / 0	179 / 0	4.168
31'-0"		51 / 0	82 / 0	116 / 0	141** / 152	7.722		73 / 0	117 / 0	161 / 0	4.752

(1) Gross section properties, Table 8-1.
(2) First load is for standard square end joists; second load is for special tapered end joists.
(3) Computation of deflection is not required above horizontal line (thickness $\geq \ell_n/18.5$ for end spans, $\ell_n/21$ for interior spans).
(4) Exclusive of bridging joists and tapered ends.
*Controlled by capacity in shear.

PROPERTIES FOR DESIGN (CONCRETE .44 CF/SF) (4)

NEGATIVE BENDING										
STEEL AREA (SQ.IN.)	.48	.63	.77	.96	1.16		.50	.65	.86	1.10
STEEL % (UNIFORM)	.68	.89	1.11	1.38	1.67		.71	.92	1.23	1.59
(TAPERED)	.41	.53	.66	.83	1.00		.43	.55	.74	.95
EFF. DEPTH, IN.	11.75	11.75	11.69	11.63	11.63		11.75	11.69	11.69	11.63
-ICR/IGR	.182	.224	.259	.298	.340		.189	.227	.280	.328

POSITIVE BENDING										
STEEL AREA (SQ.IN.)	.40	.51	.62	.75	.88		.31	.40	.51	.62
STEEL %	.14	.17	.21	.26	.30		.11	.14	.17	.21
EFF. DEPTH, IN.	11.75	11.69	11.69	11.63	11.63		11.75	11.75	11.69	11.69
-ICR/IGR	.198	.244	.280	.330	.360		.157	.198	.244	.280

APPENDIX F:

Two-Way Flat Plate with Drop Panels System Selection

Please see the following pages for hand calculations, assumptions, and justifications.

System Summary

- 9.25" thick, 5000 psi concrete slab
- 7' × 10' drop panels at columns, 2.5" thick
- <u>Short-span Reinforcement</u>:
    - #4 @ 12" at top and bottom of middle strip
    - #4 @ 4" at top of column strip
    - #4 @ 10" at bottom of column strip
- <u>Long-span Reinforcement</u>:
    - #4 @ 8" for bottom reinforcement
    - #4 @ 6" for top of middle strip
    - #5 @ 4" for top of column strip

System Dead Weight

W_{slab} = (9.25" slab)*(147 pcf)*(1ft/12") = 113.31 psf
(The drop panels and reinforcing steel contribute weight to the design, but were omitted due to relatively small tributary area and overall value.)

Total Self-Weight of Typical Bay = <u>113.31 psf</u>

*(Shear reinforcement would also be required in this slab,
but was not designed in this preliminary analysis.)*

Flat Plate (2-Way) with Drop Panels

$\frac{23.167}{4} = 5.79'$ 16.9'   5.79'

23'2"   28'6"   16"x36" column

Min. thickness → ACI 9.5.3

Table 9.5(c)

$f_y = 60$ ksi, $f'_c = 5$ ksi

Interior panel → with drop panel

$t = \frac{\ell_n}{36} = \frac{(28.5'(12"/ft) - 16")}{36} = 9.056" →$ Use 9.25" slab
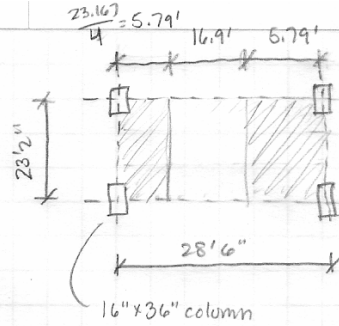
13.3.7.1 → Drop panel thickness $\geq \frac{1}{4} t_{slab} = \frac{1}{4}(9.25") = 2.31" \sim 2.5"$

Drop panel extends $\geq \frac{1}{6}$ (span length)

Long span: $\frac{1}{6}(28.5'(\frac{12in}{ft}) - 16") = 54.33" = 4.52'$

Short span: $\frac{1}{6}(23.167'(\frac{12in}{ft}) - 36") = 40.33" = 3.36'$

∴ Use 7' by 10' drop panel

13.3.7.3: Check distance from edge of drop panel to edge of column

$(\frac{10}{2})(\frac{12in}{ft}) - \frac{16"}{2} = 52in$

$\frac{1}{4}(52in) = 13in > 2.5"$ thickness ✓

Loading

Self weight $= (147 pcf)(9.25")(\frac{1ft}{12"}) = 113.31$ psf

(Drop panel area is much smaller than total bay, omit its self weight)

SDL = 12 psf (ceiling/mech./collateral)

LL = 70 psf (taken from ratio of public/private spaces)

Design $w_u = 1.2(113.31 + 12 psf) + 1.6(70 psf) = 262.372$ psf

Min. Reinforcement (unit strip method)

$A_s = 0.0018 A_g = 0.0018(9.25")(12in/ft) = 0.1998 in^2$

Max. spacing = $\begin{cases} 2t = 18.5" \\ 18" \end{cases}$ ∴ Use #4 @ 12" min. reinf top and bottom

Static Moment

Shortspan $M_0 = \frac{w_u \ell_2 \ell_n^2}{8} = \frac{(262.372psf)(28.5')(23.167' - 36"/12"/ft)^2}{8} = 380.12$ kip·ft

		Total Mu	Width	Moment/width
Interior support (M-) 65% M_0	C.S. 75%	185.31 kip·ft	11.58'	16.0 ft·kip/ft
	M.S. 25%	61.77 kip·ft	16.9'	3.66 ft·kip/ft
Midspan (M+) 35% M_0	C.S. 60%	79.83 kip·ft	11.58'	6.89 ft·kip/ft
	M.S. 40%	53.22 kip·ft	16.9'	3.15 kip·ft/ft

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Verify #4 @ 12" works

$A_{s\,\#4} = 0.2\ in^2/ft$

$d = 9.25" - 0.75"\ cover - 0.5"\ bar - \frac{0.5"}{2} = 7.75"$

$a = \frac{A_s\,f_y}{0.85\,f'_c\,b} = \frac{(0.2\,in^2)(60\,ksi)}{0.85(5\,ksi)(12\,in/ft)} = 0.235"$

$\phi M_n = \phi\,A_s\,f_y\,(d - a/2) = 0.9(0.2\tfrac{in^2}{ft})(60\,ksi)(7.75" - \frac{0.235"}{2})$

$\phi M_n = 82.43\ in\cdot kip/ft = 6.87\ ft\cdot kip/ft$ ∴ good for both top and bottom of middle strips ($> 3.66\ kip\cdot ft/ft$)

Try #4 @ 10" for bottom of C.S. (midspan)

$A_s = 0.2\,in^2/10"\left(\frac{12\,in}{ft}\right) = 0.24\,in^2/ft,\ d = 7.75"\ still$

$a = \frac{(0.24\tfrac{in^2}{ft})(60\,ksi)}{0.85(5\,ksi)(10\,in/ft)} = 0.381"$

$\phi M_n = (0.9)(0.24\tfrac{in^2}{ft})(60\,ksi)(7.75" - \frac{0.381"}{2}) = 97.96\ \tfrac{kip\cdot in}{ft} = 8.16\ \tfrac{kip\cdot ft}{ft}$

$8.16\ kip\cdot ft/ft > 6.89\ kip\cdot ft/ft$ ∴ Use for bottom of C.S. (midspan)

Try #4 @ 6" for top reinf. of C.S.

$A_s = 0.2\,in^2/(6")\left(12\,in/ft\right) = 0.4\ in^2/ft,\ d = 7.75"\ still$

$a = \frac{(0.4\,in^2/ft)(60\,ksi)}{0.85(5\,ksi)(6"/ft)} = 0.941"$

$\phi M_n = (0.9)(0.4\,in^2/ft)(60\,ksi)(7.75" - \frac{0.941"}{2}) = 157.24\ \tfrac{kip\cdot in}{ft} = 13.1\ \tfrac{kip\cdot ft}{ft}$

Decrease spacing → Try #4 @ 4"

$A_s = \frac{0.2\,in^2}{4"}\left(\frac{12\,in}{ft}\right) = 0.6\,in^2/ft,\ d = 7.75"$

$a = \frac{(0.6\,in^2/ft)(60\,ksi)}{0.85(5\,ksi)(4"/ft)} = 2.11"$

$\phi M_n = (0.9)(0.6\,in^2/ft)(60\,ksi)(7.75" - \frac{2.11"}{2}) = 216.92\ \tfrac{kip\cdot in}{ft} = 18.08\ \tfrac{kip\cdot ft}{ft}$

$18.07\ kip\cdot ft/ft > 16\ kip\cdot ft/ft$ ∴ OK for top reinf. of C.S.

<u>Longspan direction</u> $\ell_n = 28.5' - \frac{16"}{12"/ft} = 27.167'$

$\ell_2 = 23.167'$

$M_0 = \frac{w_u\,\ell_2\,\ell_n^2}{8} = \frac{(262.372\,psf)(23.167')(27.167')^2}{8} = 560.76\ kip\cdot ft$

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Long span
$M_0 = 560.76$ kip·ft
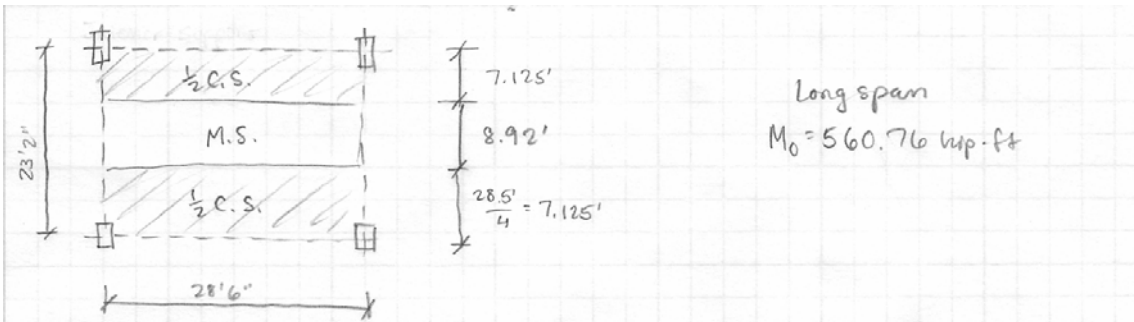
		Total Mu	Width	Moment/width
Int. Support (65% M₀)	C.S. (75%)	273.37 kip·ft	14.25'	19.18 kip·ft/ft
	M.S (25%)	91.124 kip·ft	8.92'	10.22 kip·ft/ft
Midspan (35% M₀)	C.S. (60%)	117.76 kip·ft	14.25'	8.26 kip·ft/ft
	M.S. (40%)	78.5 kip·ft	8.92'	8.8 kip·ft/ft

From short span calculations, #4 @ 6" could apply (13.1 kip·ft/ft) but let's check #4 @ 8":

$$A_s = \frac{0.2 \text{ in}^2}{8"}\left(\frac{12 \text{in}}{ft}\right) = 0.3 \text{ in}^2/ft, \quad d = 7.75"$$

$$a = \frac{(0.3 \text{ in}^2/ft)(60 \text{ ksi})}{0.85(5 \text{ ksi})(8"/ft)} = 0.529"$$

$$\Phi M_n = (0.9)(0.3 \text{ in}^2/ft)(60 \text{ ksi})\left(7.75" - \frac{0.529"}{2}\right) = 121.27 \text{ kip·in}/ft = 10.11 \text{ kip·ft}/ft$$

∴ Use #4 @ 8" for bottom reinforcement
∴ Use #4 @ 6" for top reinf. for M.S.

Try #5 @ 10" for top (C.S.) reinf.

For #5 ⟶ $d = 9.25" - 0.75" - 5/8 - \frac{5/8"}{2} = 7.5625"$

$$A_s = 0.31 \text{ in}^2/10"\left(\frac{12 \text{in}}{ft}\right) = 0.372 \text{ in}^2/ft$$

$$a = \frac{(0.372 \text{ in}^2/ft)(60 \text{ ksi})}{0.85(5 \text{ ksi})(10"/ft)} = 0.525"$$

$$\Phi M_n = (0.9)(0.372 \text{ in}^2/ft)(60 \text{ ksi})\left(7.5625" - \frac{0.525"}{2}\right) = 146.64 \frac{\text{kip·in}}{ft} = 12.22 \text{ kip·ft/ft}$$

Try #5 @ 6"

$d = 7.5625'$, $A_s = \frac{0.31 \text{ in}^2}{6"}\left(\frac{12 \text{in}}{ft}\right) = 0.62 \text{ in}^2/ft$

$$a = \frac{(0.62)(60)}{0.85(5)(6")} = 1.46"$$

$$\Phi M_n = (0.9)(0.62 \text{ in}^2/ft)(60 \text{ ksi})\left(7.5625" - \frac{1.46"}{2}\right) = 228.75 \frac{\text{kip·in}}{ft} = 19.06 \frac{\text{kip·ft}}{ft}$$

Try #5 @ 4"

$d = 7.5625"$, $A_s = 0.31 \text{ in}^2/ft (12 \text{in}/ft)\left(\frac{1}{4}"\right) = 0.93 \text{ in}^2/ft$

$$a = \frac{(0.93)(60)}{0.85(5)(4)} = 3.28"$$

$$\Phi M_n = (0.9)(0.93 \text{ in}^2/ft)(60 \text{ ksi})\left(7.563" - \frac{3.28"}{2}\right) = 297.48 \frac{\text{kip·in}}{ft} = 24.79 \frac{\text{kip·ft}}{ft}$$

∴ OK for top reinf. of C.S.

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APPENDIX G:

R.S. Means Assemblies Cost Data (2005)

Existing System: *Two-Way Flat Plate Concrete Slab*

General: Flat Plates: Solid uniform depth concrete two-way slab without drops or interior beams. Primary design limit is shear at columns.

Design and Pricing Assumptions:
Concrete f'c to 4 KSI, placed by concrete pump.
Reinforcement, fy = 60 KSI.
Forms, four use.
Finish, steel trowel.
Curing, spray on membrane.
Based on 4 bay x 4 bay structure.

System Components	QUANTITY	UNIT	MAT.	INST.	TOTAL
SYSTEM B1010 223 2000 15'X15' BAY 40 PSF S. LOAD, 12" MIN. COL.					
Forms in place, flat plate to 15' high, 4 uses	.992	S.F.	1.42	4.41	5.83
Edge forms to 6" high on elevated slab, 4 uses	.065	L.F.	.01	.21	.22
Reinforcing in place, elevated slabs #4 to #7	1.706	Lb.	.78	.60	1.38
Concrete ready mix, regular weight, 3000 psi	.459	C.F.	1.51		1.51
Place and vibrate concrete, elevated slab less than 6", pump	.459	C.F.		.57	.57
Finish floor, monolithic steel trowel finish for finish floor	1.000	S.F.		.70	.70
Cure with sprayed membrane curing compound	.010	C.S.F.	.06	.07	.13
TOTAL			3.78	6.56	10.34

B1010 223 — Cast in Place Flat Plate

	BAY SIZE (FT.)	SUPERIMPOSED LOAD (P.S.F.)	MINIMUM COL. SIZE (IN.)	SLAB THICKNESS (IN.)	TOTAL LOAD (P.S.F.)	MAT.	INST.	TOTAL
2000	15 x 15	40	12	5-1/2	109	3.78	6.60	10.38
2200		75	14	5-1/2	144	3.81	6.60	10.41
2400	RB1010-010	125	20	5-1/2	194	3.95	6.65	10.60
2600		175	22	5-1/2	244	4.04	6.70	10.74
3000	15 x 20	40	14	7	127	4.35	6.65	11
3400		75	16	7-1/2	169	4.62	6.80	11.42
3600	RB1010-100	125	22	8-1/2	231	5.05	6.95	12
3800		175	24	8-1/2	281	5.10	6.95	12.05
4200	20 x 20	40	16	7	127	4.36	6.65	11.01
4400		75	20	7-1/2	175	4.67	6.80	11.47
4600		125	24	8-1/2	231	5.10	6.95	12.05
5000		175	24	8-1/2	281	5.10	7	12.10
5600	20 x 25	40	18	8-1/2	146	5.05	6.95	12
6000		75	20	9	188	5.20	7.05	12.25
6400		125	26	9-1/2	244	5.60	7.25	12.85
6600		175	30	10	300	5.85	7.35	13.20
7000	25 x 25	40	20	9	152	5.20	7.05	12.25
7400		75	24	9-1/2	194	5.50	7.20	12.70
7600		125	30	10	250	5.85	7.35	13.20
8000								

From linear interpolation: Total Cost/S.F. = $12.33

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<u>Alternate System #1:</u> *Hollow Core Concrete Slab*
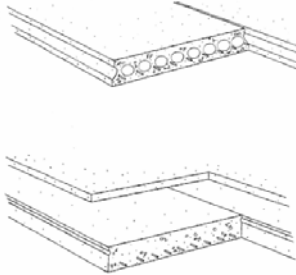
General: Units priced here are for plant produced prestressed members, transported to site and erected.

Normal weight concrete is most frequently used. Lightweight concrete may be used to reduce dead weight.

Structural topping is sometimes used on floors: insulating concrete or rigid insulation on roofs.

Camber and deflection may limit use by depth considerations.

Prices are based upon 10,000 S.F. to 20,000 S.F. projects, and 50 mile to 100 mile transport.

Concrete is f'c = 5 KSI and Steel is fy = 250 or 300 KSI

Note: Deduct from prices 20% for Southern states. Add to prices 10% for Western states.

Description of Table: Enter table at span and load. Most economical sections will generally consist of normal weight concrete without topping. If acceptable, note this price, depth and weight. For topping and/or lightweight concrete, note appropriate data.

Generally used on masonry and concrete bearing or reinforced concrete and steel framed structures.

The solid 4" slabs are used for light loads and short spans. The 6" to 12" thick hollow core units are used for longer spans and heavier loads. Cores may carry utilities.

Topping is used structurally for loads or rigidity and architecturally to level or slope surface.

Camber and deflection and change in direction of spans must be considered (door openings, etc.), especially untopped.

System Components		QUANTITY	UNIT	COST PER S.F.		
				MAT.	INST.	TOTAL
SYSTEM B1010 230 2000						
10' SPAN, 40 LBS S.F. WORKING LOAD, 2" TOPPING						
Precast prestressed concrete roof/floor slabs 4" thick, grouted		1.000	S.F.	4.42	2.60	7.02
Edge forms to 6" high on elevated slab, 4 uses		.100	L.F.	.02	.32	.34
Welded wire fabric 6 x 6 - W1.4 x W1.4 (10 x 10), 21 lb/csf, 10% lap		.010	C.S.F.	.22	.29	.51
Concrete ready mix, regular weight, 3000 psi		.170	C.F.	.56		.56
Place and vibrate concrete, elevated slab less than 6", pumped		.170	C.F.		.21	.21
Finishing floor, monolithic steel trowel finish for resilient tile		1.000	S.F.		.64	.64
Curing with sprayed membrane curing compound		.010	C.S.F.	.06	.07	.13
	TOTAL			5.28	4.13	9.41

B1010 230	**Precast Plank with 2" Concrete Topping**							
	SPAN (FT.)	SUPERIMPOSED LOAD (P.S.F.)	TOTAL DEPTH (IN.)	DEAD LOAD (P.S.F.)	TOTAL LOAD (P.S.F.)	COST PER S.F.		
						MAT.	INST.	TOTAL
2000	10	40	6	75	115	5.30	4.13	9.43
2100		75	8	75	150	6.30	3.76	10.06
2200		100	8	75	175	6.30	3.76	10.06
2500	15	40	8	75	115	6.30	3.76	10.06
2600		75	8	75	150	6.30	3.76	10.06
2700		100	8	75	175	6.30	3.76	10.06
2800	20	40	8	75	115	6.30	3.76	10.06
2900		75	8	75	150	6.30	3.76	10.06
3000		100	8	75	175	6.30	3.76	10.06
3100	25	40	8	75	115	6.30	3.76	10.06
3200		75	8	75	150	6.30	3.76	10.06
3300		100	10	80	180	6.85	3.48	10.33
3400	30	40	10	80	120	6.85	3.48	10.33
3500		75	10	80	155	6.85	3.48	10.33
3600		100	10	80	180	6.85	3.48	10.33
3700	35	40	12	95	135	6.75	3.26	10.01
3800		75	12	95	170	6.75	3.26	10.01
3900		100	14	95	195	7.60	3.09	10.69
4000	40	40	12	95	135	6.75	3.26	10.01
4500		75	14	95	170	7.60	3.09	10.69
5000	45	40	14	95	135	7.60	3.09	10.69

From linear interpolation: Total Cost/S.F. = $10.14

Alternate System #2: *Composite Steel Framing System*

Description: Table below lists costs per S.F. for floors using steel beams and girders, composite steel deck, concrete slab reinforced with W.W.F. and sprayed fiber fireproofing (non-asbestos) on the steel beams and girders and on the steel deck.

Composite steel deck varies from 2"–20 gauge to 3"–16 gauge galvanized. WWF 6 x 6 – W1.4 x W1.4 (10 x 10) Concrete f'c = 3 KSI. Steel trowel finish and cure.

Spandrels are assumed the same weight as interior beams and girders to allow for exterior wall loads and bracing or moment connections.

Design and Pricing Assumptions: Structural Steel is A36, high strength bolted.

System Components	QUANTITY	UNIT	COST PER S.F.		
			MAT.	INST.	TOTAL
SYSTEM B1010 254 0540					
W SHAPE BEAMS & DECK, FIREPROOFED, 15'X20', 5" SLAB, 40 PSF LOAD					
Structural steel	4.470	Lb.	4.03	1.40	5.43
Metal decking, non-cellular composite, galv 3" deep, 20 gage	1.050	S.F.	1.97	.81	2.78
Sheet metal edge closure form, 12", w/2 bends, 18 ga, galv	.058	L.F.	.19	.10	.29
Welded wire fabric 6 x 6 - W1.4 x W1.4 (10 x 10), 21 lb/CSF roll, 10% lap	1.000	S.F.	.22	.29	.51
Concrete ready mix, regular weight, 3000 psi	.011	C.Y.	.98		.98
Place and vibrate concrete, elevated slab less than 6", pumped	.011	C.Y.		.28	.28
Finishing floor, monolithic steel trowel finish for finish floor	1.000	S.F.		.70	.70
Curing with sprayed membrane curing compound	.010	C.S.F.	.06	.07	.13
Sprayed mineral fiber/cement for fireproof, 1" thick on decks	1.000	S.F.	.68	.93	1.61
Sprayed mineral fiber/cement for fireproof, 1" thick on beams	.615	S.F.	.28	.48	.76
TOTAL			8.41	5.06	13.47

10 254 | W Shape, Composite Deck, & Slab

BAY SIZE (FT.) BEAM X GIRD	SUPERIMPOSED LOAD (P.S.F.)	SLAB THICKNESS (IN.)	TOTAL DEPTH (FT.-IN.)	TOTAL LOAD (P.S.F.)	COST PER S.F.		
					MAT.	INST.	TOTAL
25x30	40	5	2-5	91	10.35	5.80	16.15
	75	5	2-5	128	12.55	6.50	19.05
	125	5	2-8	180	14.15	7.20	21.35
	200	5	2-11	259	17.60	8.30	25.90
30x25	40	5	2-5	92	11	6.05	17.05
	75	5	2-5	129	12.85	6.70	19.55
	125	5	2-8	181	14.60	7.40	22
	200	5-1/2	2-11	200	17.70	8.55	26.25
30x30	40	5	2-2	92	11.45	6.20	17.65
	75	5	2-5	129	13.30	6.90	20.20
	125	5	2-11	182	15.70	7.75	23.45
	200	5	3-2	263	21	9.70	30.70
30x35	40	5	2-5	94	12.45	6.55	19
	75	5	2-11	131	14.45	7.20	21.65
	125	5	3-2	183	16.80	8.10	24.90
	200	5-1/2	3-5-1/2	268	20.50	9.35	29.85
35x30	40	5	2-5	93	12	6.40	18.40
	75	5	2-8	130	14.30	7.25	21.55
	125	5	2-11	183	16.85	8.20	25.05
	200	5	3-5	262	20.50	9.60	30.10
35x35	40	5	2-8	94	12.85	6.55	19.40
	75	5	2-11	131	14.80	7.25	22.05
	125	5	3-5	184	17.70	8.30	26
	200	5-1/2	3-5-1/2	270	22.50	9.85	32.35
35x40	40	5	2-11	94	13.30	6.90	20.20
	75	5	3-2	131	15.40	7.65	23.05
	125	5	3-5	184	18.10	8.65	26.75
	200	5	3-5-1/2	264	23	10.40	33.40

From linear interpolation: for 82 psf, Total Cost/S.F. = $19.37

Alternate System #3: *Non-Composite Steel Framing System*
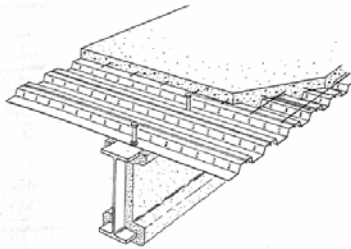
Description: Table below lists costs ($/S.F.) for a floor system using composite steel beams with welded shear studs, composite steel deck, and light weight concrete slab reinforced with W.W.F. Price includes sprayed fiber fireproofing on steel beams.

Design and Pricing Assumptions:
Structural steel is A36, high strength bolted.
Composite steel deck varies from 22 gauge to 16 gauge, galvanized.

Shear Studs are 3/4".
W.W.F., 6 x 6 – W1.4 x W1.4 (10 x 10)
Concrete f'c = 3 KSI, lightweight.
Steel trowel finish and cure.
Fireproofing is sprayed fiber (non-asbestos).

Spandrels are assumed the same as interior beams and girders to allow for exterior wall loads and bracing or moment connections.

System Components	QUANTITY	UNIT	MAT.	INST.	TOTAL
SYSTEM B1010 256 2400					
20X25 BAY, 40 PSF S. LOAD, 5-1/2" SLAB, 17-1/2" TOTAL THICKNESS					
Structural steel	4.320	Lb.	4.23	1.47	5.70
Welded shear connectors 3/4" diameter 4-7/8" long	.163	Ea.	.09	.25	.34
Metal decking, non-cellular composite, galv. 3" deep, 22 gauge	1.050	S.F.	1.76	.75	2.51
Sheet metal edge closure form, 12", w/2 bends, 18 ga, galv	.045	L.F.	.15	.08	.23
Welded wire fabric rolls, 6 x 6 - W1.4 x W1.4 (10 x 10), 21 lb/csf	1.000	S.F.	.22	.29	.51
Concrete ready mix, light weight, 3,000 PSI	.333	C.F.	2		2
Place and vibrate concrete, elevated slab less than 6", pumped	.333	C.F.		.41	.41
Finishing floor, monolithic steel trowel finish for finish floor	1.000	S.F.		.70	.70
Curing with sprayed membrane curing compound	.010	C.S.F.	.06	.07	.13
Shores, erect and strip vertical to 10' high	.020	Ea.		.33	.33
Sprayed mineral fiber/cement for fireproof, 1" thick on beams	.483	S.F.	.22	.38	.60
TOTAL			8.73	4.73	13.46

B1010 256	Composite Beams, Deck & Slab						
	BAY SIZE (FT.)	SUPERIMPOSED LOAD (P.S.F.)	SLAB THICKNESS (IN.)	TOTAL DEPTH (FT.-IN.)	TOTAL LOAD (P.S.F.)	COST PER S.F.		
						MAT.	INST.	TOTAL

BAY SIZE (FT.)	SUPERIMPOSED LOAD (P.S.F.)	SLAB THICKNESS (IN.)	TOTAL DEPTH (FT.-IN.)	TOTAL LOAD (P.S.F.)	MAT.	INST.	TOTAL
20x25	40	5-1/2	1 - 5-1/2	80	8.75	4.73	13.48
RB1010-100	75	5-1/2	1 - 9-1/2	115	9.10	4.73	13.83
	125	5-1/2	1 - 9-1/2	167	11.05	5.55	16.60
	200	6-1/4	1 - 11-1/2	251	12.40	6	18.40
25x25	40	5-1/2	1 - 9-1/2	82	8.65	4.49	13.14
	75	5-1/2	1 - 11-1/2	118	9.60	4.56	14.16
	125	5-1/2	2 - 2-1/2	169	10	4.94	14.94
	200	6-1/4	2 - 6-1/4	252	13.45	5.80	19.25
25x30	40	5-1/2	1 - 11-1/2	83	8.85	4.47	13.32
	75	5-1/2	1 - 11-1/2	119	9.50	4.52	14.02
	125	5-1/2	1 - 11-1/2	170	10.95	5.10	16.05
	200	6-1/4	2 - 6-1/4	252	13.50	5.80	19.30
30x30	40	5-1/2	1 - 11-1/2	81	8.80	4.61	13.41
	75	5-1/2	2 - 2-1/2	116	9.50	4.83	14.33
	125	5-1/2	2 - 5-1/2	168	11.45	5.40	16.85
	200	6-1/4	2 - 9-1/4	252	13.65	6.25	19.90
30x35	40	5-1/2	2 - 2-1/2	82	9.20	4.78	13.98
	75	5-1/2	2 - 5-1/2	117	10	4.88	14.88
	125	5-1/2	2 - 5-1/2	169	11.75	5.55	17.30
	200	6-1/4	2 - 9-1/4	254	13.75	6.30	20.05
35x35	40	5-1/2	2 - 5-1/2	84	9.85	4.79	14.64
	75	5-1/2	2 - 5-1/2	121	11.20	5.15	16.35

Left margin reference numbers: 2400, 2500, 2750, 2900, 3000, 3100, 3200, 3300, 3400, 3600, 3900, 4000, 4200, 4400, 4500, 4700, 4900, 5100, 5300, 5500, 5750, 6000

From linear interpolation: for 82 psf, Total Cost/S.F. = $14.30

Alternate System #4: *One-Way Concrete Joist System*
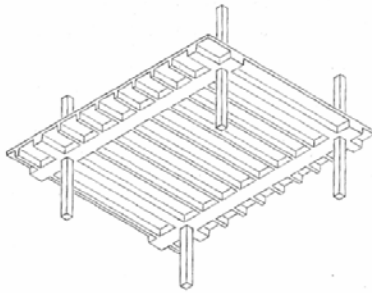
General: Combination of thin concrete slab and monolithic ribs at uniform spacing to reduce dead weight and increase rigidity. The ribs (or joists) are arranged parallel in one direction between supports.

Square end joists simplify forming. Tapered ends can increase span or provide for heavy load.

Costs for multiple span joists are provided in this section. Single span joist costs are not provided here.

Design and Pricing Assumptions:
Concrete f'c = 4 KSI, normal weight placed by concrete pump.
Reinforcement, fy = 60 KSI.
Forms, four use.
   4-1/2" slab.
   30" pans, sq. ends (except for shear req.).
   6" rib thickness.
   Distribution ribs as required.
Finish, steel trowel.
Curing, spray on membrane.
Based on 4 bay x 4 bay structure.

System Components	QUANTITY	UNIT	COST PER S.F.		
			MAT.	INST.	TOTAL
SYSTEM B1010 226 2000					
15'X15' BAY, 40 PSF, S. LOAD 12" MIN. COLUMN					
Forms in place, floor slab with 30" metal pans, 4 use	.905	S.F.	2.70	4.51	7.21
Forms in place, exterior spandrel, 12" wide, 4 uses	.170	SFCA	.21	1.37	1.58
Forms in place, interior beam. 12" wide, 4 uses	.095	SFCA	.13	.63	.76
Edge forms, 7"-12" high on elevated slab, 4 uses	.010	L.F.	.01	.05	.06
Reinforcing in place, elevated slabs #4 to #7	.628	Lb.	.29	.22	.51
Concrete ready mix, regular weight, 4000 psi	.555	C.F.	1.90		1.90
Place and vibrate concrete, elevated slab, 6" to 10" pump	.555	C.F.		.57	.57
Finish floor, monolithic steel trowel finish for finish floor	1.000	S.F.		.70	.70
Cure with sprayed membrane curing compound	.010	S.F.	.06	.07	.13
TOTAL			5.30	8.12	13.42

B1010 226		Cast in Place Multispan Joist Slab						
	BAY SIZE (FT.)	SUPERIMPOSED LOAD (P.S.F.)	MINIMUM COL. SIZE (IN.)	RIB DEPTH (IN.)	TOTAL LOAD (P.S.F.)	COST PER S.F.		
						MAT.	INST.	TOTAL
5400	25 x 30	40	14	12	125	5.80	8.25	14.05
5600		75	16	12	160	6	8.50	14.50
5800		125	18	12	210	6.40	9.10	15.50
6000		200	20	14	291	6.90	9.55	16.45
6200	30 x 30	40	14	14	131	6.10	8.40	14.50
6400		75	18	14	166	6.25	8.65	14.90
6600		125	20	14	216	6.65	9.10	15.75
6700		200	24	16	297	7.10	9.45	16.55
6900	30 x 35	40	16	14	131	6.25	8.75	15
7000		75	18	14	166	6.40	8.80	15.20
7100		125	22	14	216	6.50	9.25	15.75
7200		200	26	16	297	7.20	9.75	16.95
7400	35 x 35	40	16	16	137	6.40	8.65	15.05
7500		75	20	16	172	6.75	8.95	15.70
7600		125	24	16	222	6.80	8.95	15.75
7700		200	26	20	309	7.40	9.60	17
8000	35 x 40	40	18	16	137	6.60	8.95	15.55
8100		75	22	16	172	6.90	9.30	16.20
8300		125	26	16	222	6.95	9.20	16.15
8400		200	30	20	309	7.60	9.65	17.25
8750	40 x 40	40	18	20	149	7.05	8.90	15.95
8800		75	24	20	184	7.25	9.15	16.40
8900		125	26	20	234	7.55	9.50	17.05
9100	40 x 45	40	20	20	149	7.35	9.25	16.60
9500		75	24	20	184	7.40	9.35	16.75
9800		125	28	20	234	7.65	9.65	17.30

Through linear interpolation: for 82 psf, Total Cost/S.F. = $14.64

Alternate System #5: *Two-Way Flat Plate System with Drop Panels*
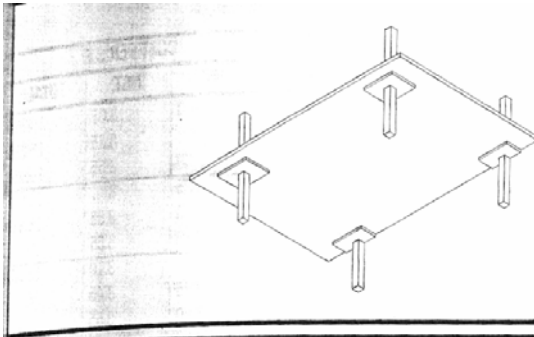
General: Flat Slab: Solid uniform depth concrete two-way slabs with drop panels at columns and no column capitals.

Design and Pricing Assumptions:
Concrete f'c = 3 KSI, placed by concrete pump.
Reinforcement, fy = 60 KSI.
Forms, four use.
Finish, steel trowel.
Curing, spray on membrane.
Based on 4 bay x 4 bay structure.

System Components	QUANTITY	UNIT	COST PER S.F.		
			MAT.	INST.	TOTAL
SYSTEM B1010 222 1700					
15'X15' BAY 40 PSF S. LOAD, 12" MIN. COL. 6" SLAB, 1-1/2" DROP, 117 PSF					
Forms in place, flat slab with drop panels, to 15' high, 4 uses	.993	S.F.	1.58	4.55	6.13
Forms in place, exterior spandrel, 12" wide, 4 uses	.034	SFCA	.04	.27	.31
Reinforcing in place, elevated slabs #4 to #7	1.588	Lb.	.73	.56	1.29
Concrete ready mix, regular weight, 3000 psi	.513	C.F.	1.69		1.69
Place and vibrate concrete, elevated slab, 6" to 10" pump	.513	C.F.		.53	.53
Finish floor, monolithic steel trowel finish for finish floor	1.000	S.F.		.70	.70
Cure with sprayed membrane curing compound	.010	C.S.F.	.06	.07	.13
TOTAL			4.10	6.68	10.78

B1010 222		Cast in Place Flat Slab with Drop Panels						
	BAY SIZE (FT.)	SUPERIMPOSED LOAD (P.S.F.)	MINIMUM COL. SIZE (IN.)	SLAB & DROP (IN.)	TOTAL LOAD (P.S.F.)	COST PER S.F.		
						MAT.	INST.	TOTAL
1700	15 x 15	40	12	6 - 1-1/2	117	4.10	6.65	10.75
1720	RB1010 -010	75	12	6 - 2-1/2	153	4.19	6.75	10.94
1760		125	14	6 - 3-1/2	205	4.38	6.90	11.28
1780		200	16	6 - 4-1/2	281	4.61	7.05	11.66
1840	15 x 20	40	12	6-1/2 - 2	124	4.37	6.80	11.17
1860	RB1010 -100	75	14	6-1/2 - 4	162	4.56	6.95	11.51
1880		125	16	6-1/2 - 5	213	4.84	7.10	11.94
1900		200	18	6-1/2 - 6	293	4.97	7.20	12.17
1960	20 x 20	40	12	7 - 3	132	4.59	6.90	11.49
1980		75	16	7 - 4	168	4.86	7.05	11.91
2000		125	18	7 - 6	221	5.40	7.30	12.70
2100		200	20	8 - 6-1/2	309	5.50	7.40	12.90
2300	20 x 25	40	12	8 - 5	147	5.10	7.15	12.25
2400		75	18	8 - 6-1/2	184	5.50	7.45	12.95
2600		125	20	8 - 8	236	6	7.75	13.75
2800		200	22	8-1/2 - 8-1/2	323	6.20	7.90	14.10
3200	25 x 25	40	12	8-1/2 - 5-1/2	154	5.35	7.25	12.60
3400		75	18	8-1/2 - 7	191	5.65	7.50	13.15
4000		125	20	8-1/2 - 8-1/2	243	6.05	7.80	13.85
4400		200	24	9 - 8-1/2	329	6.35	7.95	14.30
5000	25 x 30	40	14	9-1/2 - 7	168	5.80	7.50	13.30
5200		75	18	9-1/2 - 7	203	6.20	7.80	14
5600		125	22	9-1/2 - 8	256	6.50	8	14.50
5800		200	24	10 - 10	342	6.90	8.25	15.15
6400	30 x 30	40	14	10-1/2 - 7-1/2	182	6.30	7.75	14.05

65

Through interpolation: for 82 psf, Total Cost/S.F. = $14.07

APPENDIX H:

List of Resources

Hollow Core Slab System

Precast/Prestressed Concrete Products and Building Systems. Nitterhouse Concrete Products,
2005. <http://www.nitterhouse.com>.

PCI Design Handbook: Precast and Prestressed Concrete. Fifth Edition. Precast/Prestressed
Concrete Institute, 1999.

Girder-Slab Design Guide. Volume 1.2. Girder-Slab Technologies, LLC, 2005.
<http://www.girder-slab.com/design/design.asp>.

Composite and Non-Composite Steel Deck/Concrete Slab Systems

United Steel Deck Design Manual and Catalog of Products. Catalog #303-16. United Steel
Deck, Inc., 2002.

RAM Structural System. Computer software. Version 8.0. Ram International, Inc., 2002.

Manual of Steel Construction: Load and Resistance Factor Design. Third Edition. American
Institute of Steel Construction, Inc., 2001.

One-Way Composite Joist System

CRSI Design Handbook 1996. Concrete Reinforcing Steel Institute, 1996.

Two-Way Flat Plate Concrete Slab System

ACI Building Code Requirements for Structural Concrete and Commentary. ACI Standard 318-
02. American Concrete Institute Committee, 2002.

General Resources

R.S. Means Assemblies Cost Data. 30th Annual Edition. Reed Construction Data, 2005.

Underwriters Laboratories Online Certifications Directory. Underwriters Laboratories, 2005.
<http://database.ul.com/cgi-bin/XYV/template/LISEXT/1FRAME/index.htm>.