Barshinger Life Science & Philosophy Building

Michael A. Hebert

Structural Option
Consultant: Dr. Hanagan
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Structural Technical Report #2

Pro-Con Structural Study of Alternate Floor Systems

Executive Summary

This technical report outlines a preliminary investigation of four alternative floor systems. Simplified design calculations and product catalogs were utilized in developing adequate systems for the required design loads. All floor systems were designed for a typical bay of size 20’x30’. After reasonable systems were designed, they were compared against each other in such categories as weight, depth, ease of construction, construction time, vibration damping potential, foundation impact, and lateral force distribution. Vertical members were not part of the preliminary analysis, but were still considered in the overall system comparison.

The following floor systems were analyzed:

Existing System:	Composite Deck w/ Composite Members
Alternative System #1:	Composite Deck w/ Open-Web Joists
Alternative System #2:	Two-Way Concrete Waffle Slab
Alternative System #3:	One-Way Concrete Pan Joist System
Alternative System #4:	Precast Hollow-Core Plank on Steel Frame

Preliminary analyses determined that only the Precast Hollow Core Plank (#4) system merits future in-depth analysis as a true alternative to the existing composite. This alternative was chosen primarily on the basis of overall depths and system weights that were similar to or less than the existing system. It did not prove as efficient as the existing system over all the categories, but Alternative System #4 was the most promising.

Building Design Loads

The building design loads were originally attained using the International Building Code (IBC), 2000 edition. The service loads for this report have been taken from the Structural General Notes of the design drawings.

<u>Live Loads</u>

Offices	50 psf + 20psf partitions
Laboratories	60 psf (use 70psf)
Public Spaces, Exit Corridors, Stairs, and Lobbies	100 psf

<u>Dead Loads</u>

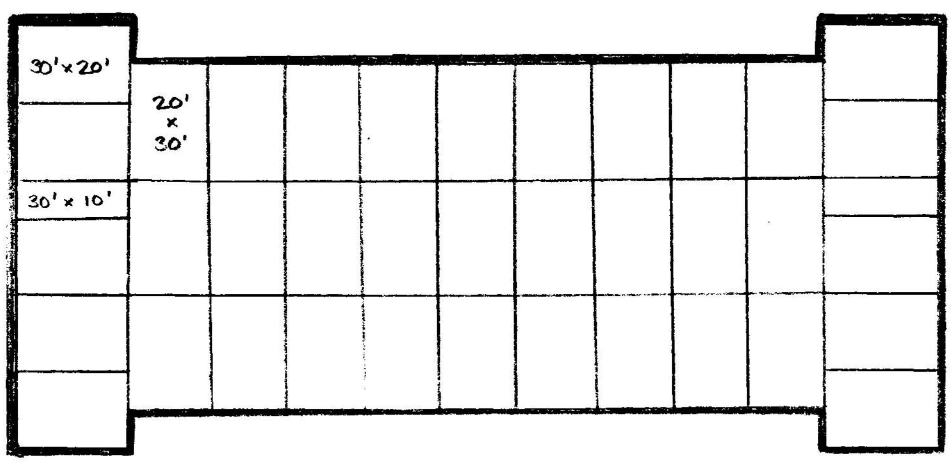
Mechanical/Ceiling	10 psf
Carpet/Miscellaneous	5 psf
Superimposed	40 psf

Total Service Load: 70 + 55 = **125 psf**

Total Factored Load: 1.2(55) + 1.6(70) = **178 psf**

Typical Floor Bay

The structural framing system of the building is divided into bays of a myriad of sizes and types (see figure below). However, in general the floor system seems to be focused on a 20'x30' module with a majority of the bays sized within two feet of either dimension. For the purpose of this report I will focus on a 20'x30' bay size for my alternative systems.

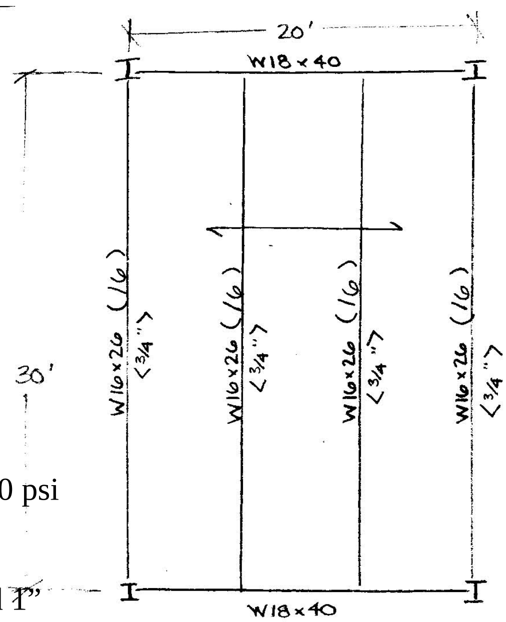


APPROXIMATE BAY LAYOUT

TO SHOW TYPICAL BAYS

Alternative Floor System Comparison

Existing System – Composite Slab & WF Members
The existing system is composite utilizing composite concrete deck bearing on composite wide-flange steel members. Normal weight concrete (145 pcf) is selected in lieu of lightweight concrete for its weight in vibration reduction.



Design Aids
LRFD Manual, 3rd Edition
USD

Design Loads
Live Load: 70 psf
Dead Load: 55 psf
1.6LL + 1.2DL = 178 psf

Span Length: 30’

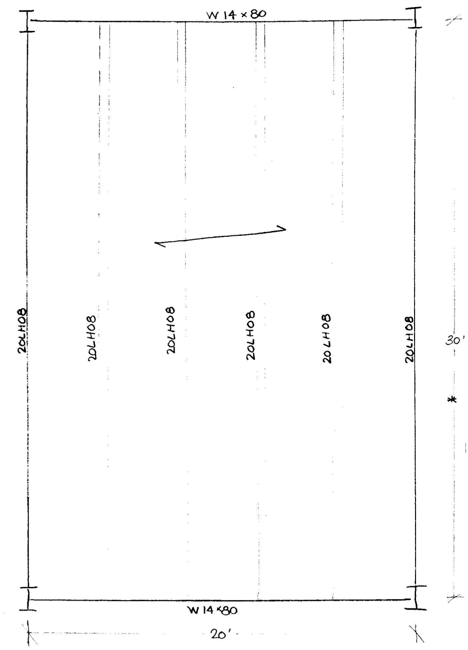
System Description
Slab: 6 ½” (4 ½” cover) NWC (150pcf) f'_c = 3500 psi
Deck: USD 2” B-LOK 18-gage
Shear Studs: ¾” diameter, 4 ½” long headed
Beams: A992 composite W16x26 (16), cambered 1”
Girders: A992 W18x40

Total System Weight: 73.6 psf
Total System Depth: 24.4”

Pros & Cons
- Composite floor systems are extremely versatile. The means and methods can be reproduced with relative ease and quickness.
- The composite action allows for a reduction in slab thickness and steel member sizes, creating both a lighter-weight and a shallower system than the non-composite alternative. The light-weight nature of this system is important considering the shallow spread footings. A heavier system would create a need for deeper and larger foundations, which would be difficult given the low allowable soil bearing value.
- The inherent stiffness of the composite system allows for better transmission of lateral loads and increased stability of the building.
- In this particular case, the designer increased the weight of the slab to improve vibration resistance given the delicate nature of laboratory facilities.

Alternative Floor System Comparison

Alternative System #1 – Composite Slab & Open-Web Joists
This system attempts to use composite decking with closely spaced open-web steel joists. Open web joists should allow for a lighter floor system, reducing column and foundation loads.



Design Aids
USD Catalog #303-16, 2002
New Columbia Joist Company Catalog, 2002

Design Service Loads
Live Load: 70 psf
Dead Load: 55 psf
Total Load: 125 psf

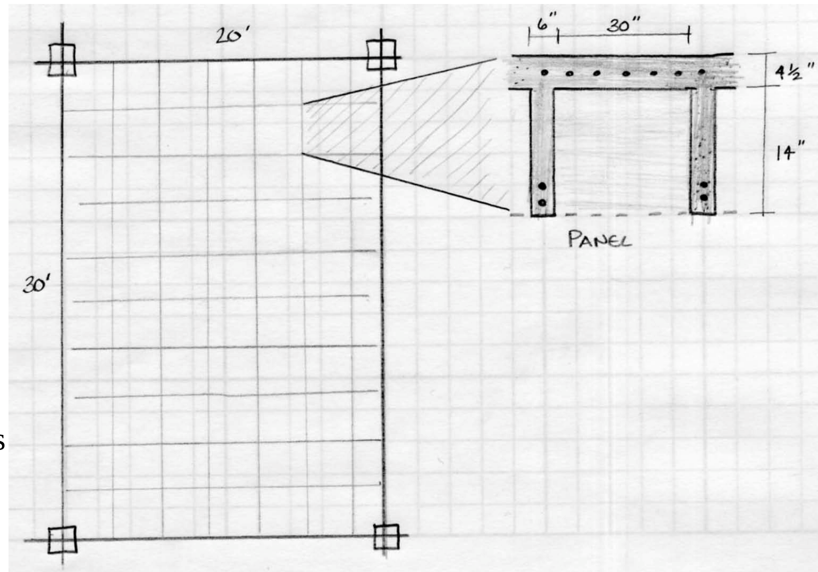
Span Length: 30'

Design Results
Slab: 4" (2 ½" cover) NWC (145pcf) $f'_c = 3000$ psi
Deck: USD 1 ½" B-LOK 22-gage
Joists: 20LH08 spaced 4'-0" o.c.
Girders: A992 W18x40 (same)

Total System Weight: 45.3 psf
Total System Depth: 24"

Pros & Cons
- When designed for depth efficiency, this system can be made very lightweight, drastically reducing the loads on the columns and the foundations. This particular system is nearly 40% lighter than the existing composite system.
- Construction time can be streamlined as the erection of this system is highly repetitive given a regular arrangement. However, the increased number of members will require more crane picks.
- Mechanical ductwork can be integrated through the open spaces in the webs, reducing the necessary plenum space.
- The major disadvantage of this system deals with vibration issues. Such a lightweight system will be highly susceptible to vibration issues, which are very undesirable given the intended use of the spaces.

Alternative System #2 – Two Way Waffle Slab System
This alternative will utilize a two-way waffle slab system. The typical bay size is 20'x30' for an acceptable l_1/l_2 ratio of 1.5. For the purpose of this report, the waffle slab will conservatively be designed for a 30'x30' bay.



Design Aids
CRSI Handbook

Design Loads
Live Load: 70psf
Dead Load: 55psf
1.6LL + 1.2 DL: 178 psf

Bay Size: 30'x30'

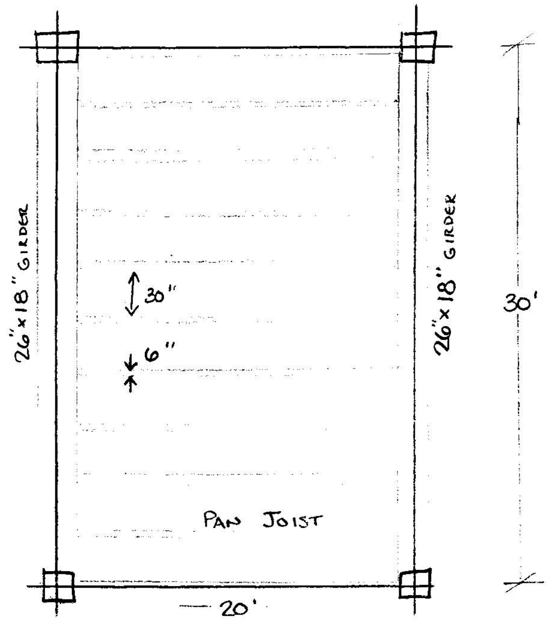
Design Results
f'_c = 4 ksi, Grade 60 Bars
Voids: 30" x 30"
Ribs: 6" wide x 14" deep
Total Slab Depth: 4.5"
Steel: 2.83 psf
(See Appendix C for complete reinforcing steel design.)
Factored Allowable Load = 200 psf > 178 psf

Total System Weight: 137 psf
Total System Depth: 18.5"

Pros & Cons
- Two-way flat plate systems can be quite fast and efficient when similar forms can be re-used and replicated multiple times. However, in general all-concrete superstructures typically have a longer construction period given the curing time requirements of the supporting members.
- A major advantage of this system is its vibration-damping properties that are very desirable for laboratory spaces.
- The extra weight of the all-concrete system would require larger columns and foundations, while also increasing the seismic load on the building.
- Another advantage of this system is its reduced depth, thereby increasing plenum space or decreasing the height requirements of the structure. A height change could improve the foundation and seismic requirements.

Alternative Floor System Comparison

Alternative System #3 – One Way Pan Joist System
This system utilizes one-way pan joists and concrete beams for an entirely cast-in-place concrete structure.



Design Aids
CRSI Handbook

Design Loads
Live Load: 70psf
Dead Load: 55psf
1.6LL + 1.2 DL: 178 psf

Span Length
Pan Joists: 20'
Girder: 30'

Design Results
f'_C = 4 ksi, Grade 60 Bars
Slab Depth: 4"
Pan Joists: 30" Form + 6" Rib @36" o.c.

Interior Span

Factored Usable Load: 218 psf > 178 psf

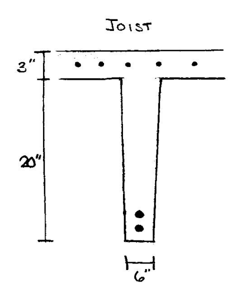
Exterior Span

Factored Usable Load: 228 psf > 178 psf

Girder: (b x h) = 26" x 18"

$w_{U, ALLOW}$ = 6.7 klf > $w_{U, DESIGN}$ = 5.76 klf

(See Appendix D for complete reinforcing steel design.)

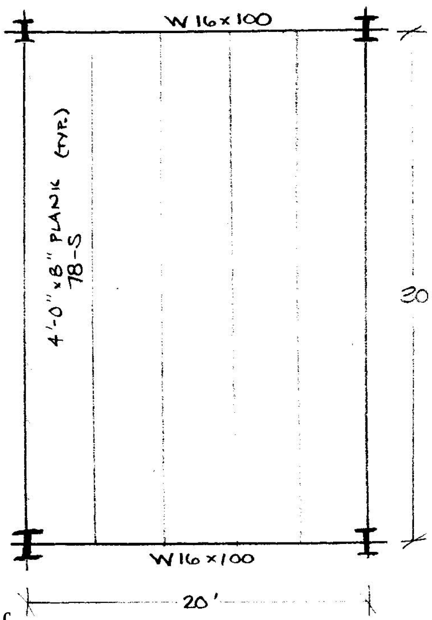


Total System Weight: 108 psf
Total System Depth: 26"

Pros & Cons
- Pan-joist construction can be quite fast and efficient when similar forms can be re-used and replicated multiple times. However, in general all-concrete superstructures typically have a longer construction period given the curing time requirements of the supporting members.
- A major advantage of this system is its vibration-damping properties that are very desirable for laboratory spaces.
- The extra weight of the all-concrete system would require larger columns and foundations, while also increasing the seismic load on the building.
- A further disadvantage of this system is the increased depth, thereby reducing plenum space or increasing the height of the structure. A height change would adversely affect the foundation design and seismic loads.

Alternative Floor System Comparison

Alternative System #4 – Hollow Core Precast Plank
This system utilizes hollow core precast planks with a 2” topping bearing on a wide flange steel frame. Lightweight concrete is used for the system to obtain a total system weight similar to that of the existing system.

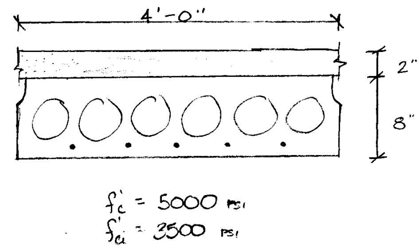


Design Aids
PCI Design Handbook, 5th Edition
LRFD Manual, 3rd Edition

Service Loads
Live Load: 70 psf
Dead Load: 55 psf
Total Load: 125 psf

Span Length: 30’

Design Results
Plank: 4’-0” x 8” Hollow Core (30’ span)
Topping: 2” Lightweight Concrete
Strand Designation: 78-S
Allowable Service Loads: 149 psf > 125 psf
Supporting Members: A992 W16x100 (20’ span)
$I = 1490 \text{ in}^4 > I_{REQ'D} = 1450 \text{ in}^4$
- $M_n = 746$ k-ft $> M_u = 389$ k-ft
- $V_n = 269$ k $> V_u = 78$ k



Total System Weight: 71.3 psf
Total System Depth: 27”

Pros & Cons
- § Precast plank systems are extremely quick and easy to erect. The effects of inclement weather do not affect the erection of precast planks like they would cast-in-place concrete systems.
- § Plank systems have substantial mass to provide good vibration damping. But, if the difference in weight with the existing system is substantial enough, the existing foundations would not be adequate.
- § One disadvantage of precast planks is their decreased ability to transfer lateral loads to the supporting columns.
- § Another advantage of precast planks is their good acoustical performance and their natural fire rating.

System Comparisons

The alternative systems will be compared with the existing system and each other in the table below. The categories for comparison have been limited to system depth, system weight, vibration damping potential, relative construction time, relative ease of construction, lateral force distribution performance, and foundation impact. A scale of 1 to 5 will be used to compare the systems, with 3 approximate to the existing system.

	Total Depth	**System Weight**	**Vibration Damping *(2x)***	**Construction Time**	**Ease of Construction**	**Lateral Distribution Performance**	**Foundation Impact *(2x)***	**Sum of Ratings**
Existing Comp. WF	**3**	**3**	**6**	**3**	**3**	**3**	**6**	**27**
#1 Bar Joists	**3**	**1**	**10**	**4**	**4**	**3**	**4**	**28**
#2 Waffle Slab	**2**	**5**	**4**	**5**	**4**	**2**	**10**	**34**
#3 Pan Joists	**3**	**5**	**4**	**5**	**3**	**2**	**10**	**32**
#4 Planks	**3**	**3**	**6**	**2**	**2**	**4**	**6**	**27**

Much Better Than Existing	Somewhat Better Than Existing	Equal to Existing	Somewhat Worse Than Existing	Much Worse Than Existing
1	**2**	**3**	**4**	**5**

Conclusions

I decided to double count the vibration damping potential and the foundation impact in my analysis due to their extreme importance in this structure. The building site contains pinnacled limestone in the sub-grade, which lead the geotechnical engineers to limit the allowable soil bearing pressure to 3000 pounds per square foot (psf). This realization all but eliminates the heavy all-concrete structural systems. The building contains numerous vibration sensitive laboratory spaces. The mass of the existing system had to be increased by the use of normal weight concrete in order to meet the desired vibration limitations. When these factors are considered, it is fairly evident that the existing system has been carefully engineered to meet the delicate balance that is required of this structure.

Based on the comparison chart on the previous page, I would only consider the precast hollow-core plank system (Alternative #4) for further investigation. In the head-to-head comparison, this system outperformed the existing system overall. The original structural engineers discounted this system due to its increased depth and weight, but my analysis has shown that it can be fairly close in size to the existing composite system.

The open-web joist system (Alternative #1) was discounted due to its inherent similarity to the existing system and its extremely poor vibration damping potential. It did not score badly in comparison, but I do not feel it is unique enough to truly merit further investigation. Any attempt to add mass to the system would certainly create a large difference in overall system depth.

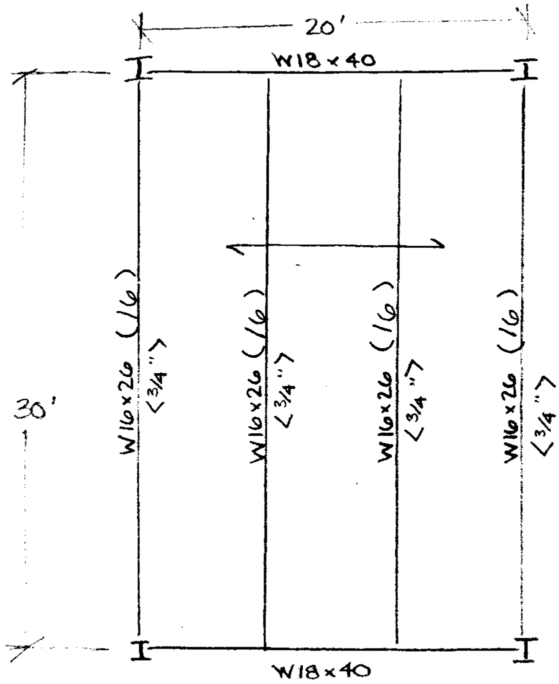
A post-tensioned slab system also seemed to have potential as an alternative. In principle, post-tensioned slabs can be lighter and thinner than conventional slab. These features would have made this another potentially viable alternative. However, due to my limited experience with this system, I decided not to pursue it. But, I still believe it merits mentioning as another possibility.

Appendix

Appendix	Description
A	**Existing Framing Plan**
B	**Alternative #1: Open Web Joists w/ Composite Deck**
C	**Alternative #2: Two-Way Flat Slab**
D	**Alternative #3: One-Way Pan Joist**
E	**Alternative #4: Precast Hollow-Core Plank**

Appendix A

EXISTING SYSTEM



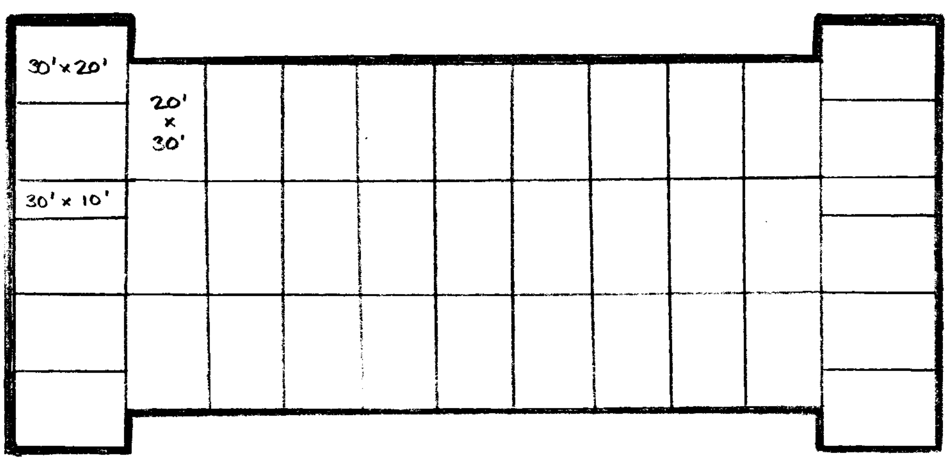
2½" B-LOK 18 GA. COMPOSITE DECK

4" COVER NORMAL WEIGHT CONCRETE (150 PCF)

6½" TOTAL DEPTH SLAB

SYSTEM DEPTH : 24.3"
SYSTEM WT : 71.3 PSF

f'_c = 3500 PSI
f_y = 60 KSI (REBAR)
A992 W-MEMBERS



APPROXIMATE BAY LAYOUT

TO SHOW TYPICAL BAYS

ALTERNATIVE SYSTEM #1

- COMPOSITE DECK ON OPEN WEB STEEL JOIST

DESIGN CONDITIONS

DL : 55 PSF
LL : 70 PSF

COMPOSITE DECK DESIGN (USD CATALOG #303-16, 2002)

NEED 4" SLAB DEPTH FOR 2 & 3 HR FIRE RATINGS
(2 ½" COVER IS MINIMUM)

- TRY B-LOK 1.5" x 12" DECK $f'_c = 3$ KSI NWC (145 PCF)

FOR 5' SPAN : MAX SERVICE LL = 400 PSF > 70 PSF OK

TRY 22 GAGE : MAX 3 SPAN 6.57'
MAX 1 SPAN 4.86'

WT = 39 PSF < 40 PSF ASSUMED

USE B-LOK 1.5" COMPOSITE DECK (2 ½" SLAB COVER)

JOIST DESIGN (USE 4' SPACING OF JOISTS)

TL = 1.2(55) + 1.6(70) = 178 PSF ⇒ 712 PLF
LL = 1.6(70) = 112 PSF ⇒ 448 PLF

(NEW COLUMBIA JOIST COMPANY CATALOG, 2002)

SPAN : 30'

- TRY 20LH08 (DEPTH 20")

TL_{ALLOW} = 760 PLF > 712 PLF OK
LL_{ALLOW} = 468 PLF > 448 PLF OK

JOIST WT = 19 PLF ⇒ NEW TL = 712 + 1.2(19) = 735 PLF < 760
OK

USE 20LH08 4' O.C. WITH B-LOK 1 ½" x 12" DECK (2 ½" COVER)

WT / AREA = 39 PSF + 19/4 PSF = 44 PSF
TOTAL DEPTH = 4" + 20 = 24"

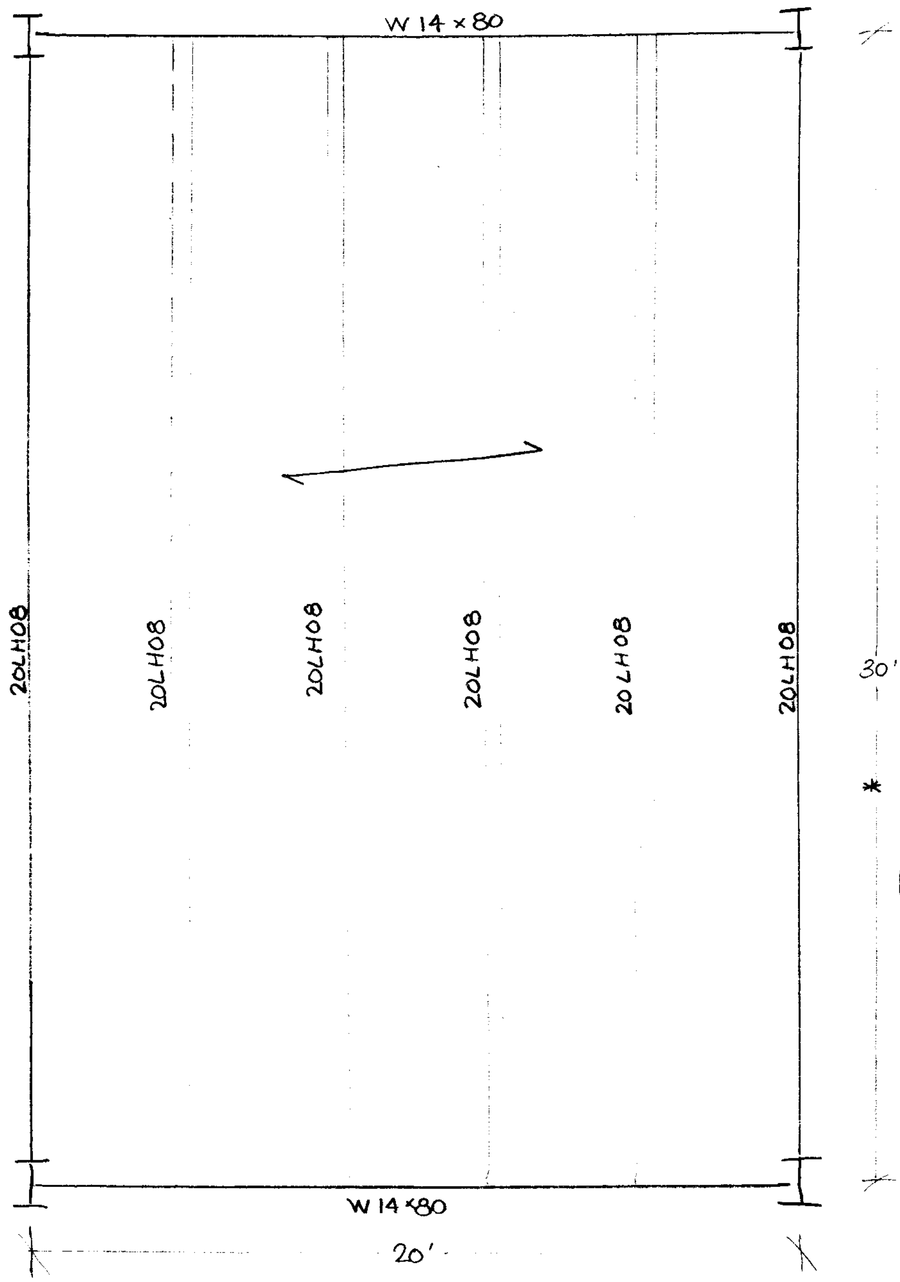
Tech # 2

Mike Hebert

Appendix B

10/31/05

Alternative System #1 – Layout



* B-LOK 1.5" composite deck (4" total slab depth)

Appendix C

ALTERNATIVE SYSTEM #2

- TWO-WAY CONCRETE SLAB SYSTEM

$l_1/l_2 = 1.5 < 2$ OK FOR TWO-WAY SYSTEM

DESIGN CONDITIONS

DL : 55 PSF
LL : 70 PSF
$1.6LL + 1.2DL = 178$ PSF

30' × 30' BAY TO BE CONSERVATIVE (ANALYZE EDGE PANELS)

CRSI HANDBOOK

$\omega_u = 200$ PSF > 178 PSF OK

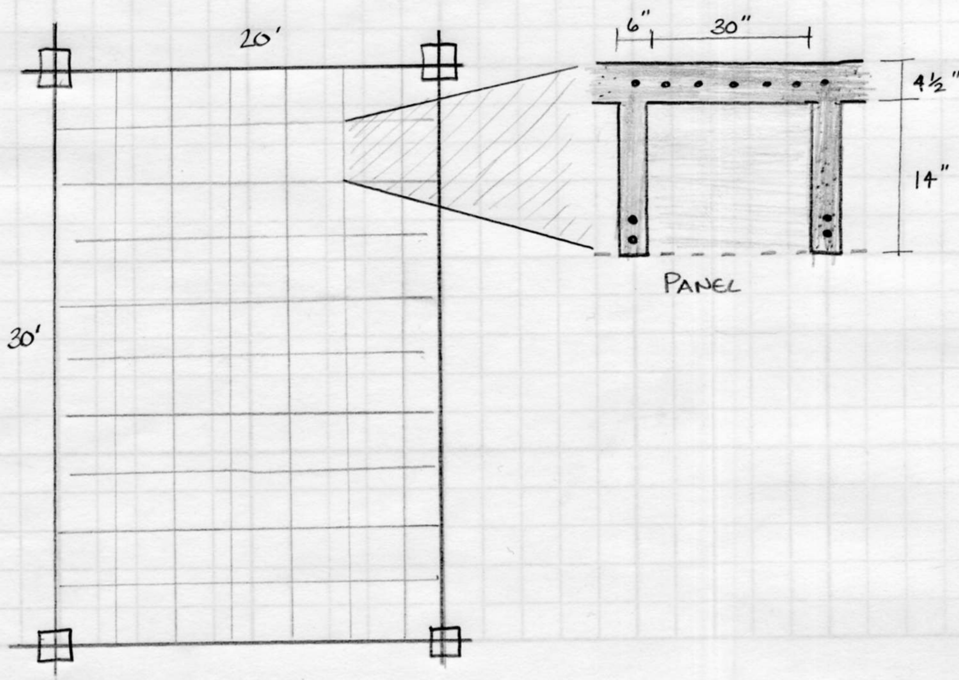
+ WAFFLE SLAB : (p 11-32) TOTAL DEPTH = 18.5"
  TOTAL WT = (0.913)(150) = 137 PSF

- FLAT SLAB SYSTEM : (p 10-23) TOTAL DEPTH = 18.5"
  TOTAL WT = 136.8 PSF

* NEITHER SYSTEM APPEARS MORE EFFICIENT THAN THE OTHER, SO I WILL USE WAFFLE SLAB IN MY REPORT

SEE ATTACHED CRSI EXCERPT FOR REINFORCING DETAILS.

LAYOUT



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

f'_c = 4,000 psi
Grade 60 Bars

SQUARE EDGE PANELS

Total Depth = 18½ in. Rib Depth = 14 in. Total Slab Depth = 4½ 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.)	γ_f	(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)	+M Bot. (ft-k)	−M Int. (ft-k)
24'- 0" D= 9.500 RIB NOT ON COLUMN LINE 0.898 CF/SF	50	2.07	12	0.660		18-#5+ 0	4	1-#4 and 1-#5	18-#5	4	#4	#5	7-#5	92	185	248
	100	2.07	12	0.686		18-#5+ 0	4	1-#4 and 1-#5	18-#5	4	#4	#5	7-#5	113	226	304
	150	2.12	12	0.712		18-#5+ 0	4	2-#5	18-#5	4	#4	#5	7-#5	134	294	360
	200	2.19	12	0.738		18-#5+ 0	4	1-#5 and 1-#6	18-#5	4	#4	#5	7-#5	154	364	415
	300	2.57	12	0.791		18-#5+ 0	4	1-#6 and 1-#7	18-#5	4	#5	#6	7-#5	195	496	526
	400	3.00	12	0.843		18-#5+ 0	4	1-#7 and 1-#8	20-#5	4	#6	#6	7-#5	237	624	637
	500	3.44	12 *	0.642		18-#5+ 0	4	2-#8	17-#6	4	#6	#7	8-#5	278	751	748
27'- 0" D= 9.500 RIB NOT ON COLUMN LINE 0.876 CF/SF	50	2.10	13	0.695		20-#5+ 0	4	2-#5	20-#5	5	#4	#5	8-#5	130	261	351
	100	2.17	13	0.726		20-#5+ 0	4	1-#5 and 1-#6	20-#5	5	#4	#5	8-#5	160	320	431
	150	2.27	13	0.756		20-#5+ 0	4	2-#6	20-#5	5	#4	#5	8-#5	189	413	510
	200	2.54	13	0.787		20-#5+ 0	4	2-#7	20-#5	5	#5	#5	8-#5	219	513	589
	300	3.07	13 *	0.848		20-#5+ 0	4	2-#8	24-#5	5	#6	#6	8-#5	278	701	748
	400	3.87	13 *	0.640		20-#5+ 0	4	2-#9	21-#6	5	#6	#7	10-#5	337	884	907
	500	4.49	13 *	0.640		20-#5+ 0	4	1-#9 and 1-#10	18-#7	5	#7	#7	8-#6	396	1065	1065
30'- 0" D=12.500 RIB ON COLUMN LINE 0.913 CF/SF	50	2.10	15	0.706		22-#5+ 0	5	2-#5	22-#5	5	#4	#5	9-#5	182	363	489
	100	2.17	15	0.742		22-#5+ 0	5	1-#5 and 1-#6	22-#5	5	#4	#5	9-#5	222	444	597
	150	2.43	15	0.778		22-#5+ 0	5	1-#6 and 1-#7	23-#5	5	#5	#5	9-#5	262	561	706
	200	2.83	15	0.821		22-#5+ 1	5	2-#7	26-#5	5	#6	#6	9-#5	302	699	814
	300	3.71	15 *	0.909		22-#5+ 6	5	1-#8 and 1-#9	24-#6	5	#6	#7	11-#5	383	956	1031
	400	4.57	15 *	0.637		22-#5+ 4	5	1-#9 and 1-#10	21-#7	5	#7	#8	10-#6	464	1207	1248
	500	5.37	19 *	0.633	4 S 6 1	23-#5+ 4	5	2-#10	19-#8	5	#8	#8	11-#6	536	1423	1444
33'- 0" D=12.500 RIB ON COLUMN LINE 0.892 CF/SF	50	2.30	16	0.748		25-#5+ 0	5	2-#6	25-#5	6	#4	#5	10-#5	240	480	646
	100	2.49	16	0.788		25-#5+ 0	5	1-#6 and 1-#7	25-#5	6	#5	#5	10-#5	294	587	790
	150	2.77	16 *	0.839		25-#5+ 2	5	2-#7	30-#5	6	#5	#6	10-#5	347	730	935
	200	3.33	16 *	0.888		25-#5+ 5	5	2-#8	25-#6	6	#6	#6	12-#5	401	915	1080
	300	4.51	16 *	0.636	4 S 6 1	25-#5+ 4	5	1-#9 and 1-#10	24-#7	6	#7	#7	10-#6	509	1256	1370
36'- 0" D=12.500 RIB ON COLUMN LINE 0.876 CF/SF	50	2.38	18	0.757		27-#5+ 0	5	1-#6 and 1-#7	27-#5	7	#4	#5	11-#5	308	617	830
	100	2.76	18	0.809		27-#5+ 1	5	1-#7 and 1-#8	33-#5	7	#5	#5	11-#5	378	756	1017
	150	3.15	18 *	0.870		27-#5+ 5	5	2-#8	28-#6	7	#5	#6	13-#5	448	898	1205
	200	3.82	18 *	0.634		27-#5+ 2	5	2-#9	24-#7	7	#6	#6	15-#5	517	1140	1392

SQUARE INTERIOR PANELS

Total Depth = 18½ in. Rib Depth = 14 in. Total Slab Depth = 4½ 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.)	(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
24'- 0"	50	2.04	12		4	1-#4 and 1-#5	18-#5	4	#4	#5	7-#5
	100	2.04	12		4	1-#4 and 1-#5	18-#5	4	#4	#5	7-#5
	150	2.04	12		4	1-#4 and 1-#5	18-#5	4	#4	#5	7-#5
	200	2.04	12		4	1-#4 and 1-#5	18-#5	4	#4	#5	7-#5
	300	2.25	12		4	1-#5 and 1-#6	18-#5	4	#4	#5	7-#5
	400	2.55	12	4 S 6 1	4	2-#6	19-#5	4	#5	#5	7-#5
	500	2.97	12 *	4 S 6 1	4	1-#6 and 1-#7	16-#6	4	#5	#6	7-#5
27'- 0"	50	2.04	13		4	1-#4 and 1-#5	20-#5	5	#4	#5	8-#5
	100	2.04	13		4	1-#4 and 1-#5	20-#5	5	#4	#5	8-#5
	150	2.12	13		4	2-#5	20-#5	5	#4	#5	8-#5
	200	2.23	13	4 S 6 1	4	1-#5 and 1-#6	20-#5	5	#4	#5	8-#5
	300	2.56	13	4 S 6 1	4	1-#6 and 1-#7	22-#5	5	#4	#5	8-#5
	400	3.39	13 *	4 S 6 1	4	1-#7 and 1-#8	19-#6	5	#5	#6	9-#5
	500	4.05	13 *	4 S 6 2	4	2-#8	23-#6	5	#6	#6	8-#6
30'- 0"	50	2.03	15		5	1-#4 and 1-#5	22-#5	5	#4	#5	9-#5
	100	2.03	15		5	1-#4 and 1-#5	22-#5	5	#4	#5	9-#5
	150	2.12	15		5	2-#5	22-#5	5	#4	#5	9-#5
	200	2.43	15		5	2-#6	24-#5	5	#4	#5	9-#5
	300	3.26	15 *	4 S 6 1	5	2-#7	22-#6	5	#5	#6	10-#5
	400	3.95	15 *	4 S 6 1	5	1-#7 and 1-#8	20-#7	5	#6	#6	9-#6
	500	4.90	16 *	4 S 6 2	5	1-#8 and 1-#9	23-#7	5	#7	#7	10-#6
33'- 0"	50	2.15	16		5	2-#5	25-#5	6	#4	#5	10-#5
	100	2.26	16		5	1-#5 and 1-#6	25-#5	6	#4	#5	10-#5
	150	2.46	16	4 S 6 1	5	2-#6	28-#5	6	#4	#5	10-#5
	200	2.94	16 *	4 S 6 1	5	1-#6 and 1-#7	23-#6	6	#5	#5	11-#5
	300	4.07	16 *	4 S 6 1	5	2-#8	22-#7	6	#6	#6	10-#6
36'- 0"	50	2.24	18		5	1-#5 and 1-#6	27-#5	7	#4	#5	11-#5
	100	2.46	18	4 S 6 1	5	2-#6	31-#5	7	#4	#5	11-#5
	150	2.80	18	4 S 6 1	5	1-#6 and 1-#7	26-#6	7	#4	#5	12-#5
	200	3.46	18 *	4 S 6 1	5	1-#7 and 1-#8	30-#6	7	#5	#5	10-#6

(Continued on next page)

See the notes on Page 11-19.

f'_c = 4,000 psi
Grade 60 Bars

FLAT SLAB SYSTEM

SQUARE EDGE PANEL With Drop Panels
No Beams

SPAN c.-c. $\ell_1 = \ell_2$ (ft)	Factored Superimposed Load (psf)	Square Drop Panel Depth (in.)	Square Drop Panel Width (ft)	(3) Square Column Size (in.)	(3) Square Column γ_f	Reinforcing Bars (E. W.) Column Strip (1) Top Ext.	+	Column Strip (1) Bottom	Column Strip (1) Top Int.	Middle Strip Bottom	Middle Strip Top Int.	Total Steel (psf)	Moments Edge (−) (ft-k)	Moments Bot. (+) (ft-k)	Moments Int. (−) (ft-k)
						h = 10 in. = TOTAL SLAB DEPTH BETWEEN DROP PANELS									
25	100	5.50	8.33	12	0.776	12-#5	2	10-#6	14-#5	9-#5	9-#5	2.39	130.1	260.2	350.3
25	200	5.50	8.33	15	0.809	12-#5	4	13-#6	13-#6	12-#5	10-#5	2.95	171.3	342.6	461.2
25	300	7.00	8.33	18	0.664	12-#5	1	17-#6	15-#6	15-#5	9-#6	3.59	212.4	424.7	571.8
25	400	8.50	8.33	19	0.632	12-#5	1	15-#7	12-#7	10-#7	15-#5	4.25	254.3	508.6	684.6
25	500	8.50	10.00	21	0.744	13-#5	3	11-#9	26-#5	15-#6	10-#7	4.97	295.4	590.8	795.3
26	100	5.50	8.67	12	0.810	12-#5	3	11-#6	16-#5	11-#5	10-#5	2.60	146.8	293.7	395.3
26	200	7.00	8.67	15	0.704	12-#5	1	11-#7	14-#6	10-#6	12-#5	3.17	194.0	388.0	522.3
26	300	8.50	8.67	18	0.633	12-#5	1	11-#8	15-#6	9-#7	15-#5	3.88	240.6	481.1	647.6
26	400	8.50	8.67	19	0.745	13-#5	3	13-#8	18-#6	11-#7	9-#7	4.73	287.7	575.5	774.7
26	500	8.50	10.40	24	0.745	15-#5	4	13-#9	12-#8	10-#8	14-#6	5.49	330.9	661.8	890.9
27	100	7.00	9.00	12	0.746	12-#5	2	18-#5	16-#5	12-#5	10-#5	2.63	165.4	330.8	445.4
27	200	7.00	9.00	15	0.804	12-#5	5	17-#6	15-#6	11-#6	13-#5	3.37	218.2	436.3	587.4
27	300	8.50	9.00	18	0.674	12-#5	2	16-#7	13-#7	19-#5	16-#5	4.12	270.7	541.5	728.9
27	400	8.50	10.80	22	0.756	14-#5	5	12-#9	12-#8	10-#8	19-#5	5.09	321.6	643.2	865.8
27	500	8.50	10.80	27	0.682	16-#5	3	17-#8	13-#8	9-#9	9-#8	5.78	366.6	733.3	987.1
28	100	7.00	9.33	12	0.784	13-#5	2	14-#6	18-#5	13-#5	11-#5	2.76	185.0	370.0	498.1
28	200	8.50	9.33	16	0.714	13-#5	3	11-#8	15-#6	17-#5	15-#5	3.56	243.2	486.4	654.8
28	300	8.50	9.33	19	0.757	13-#5	5	11-#9	14-#7	12-#7	10-#7	4.56	302.4	604.8	814.1
28	400	8.50	11.20	25	0.692	16-#5	3	17-#8	13-#8	11-#8	12-#7	5.47	357.1	714.3	961.5
29	100	8.50	9.67	12	0.737	13-#5	2	22-#5	18-#5	15-#5	12-#5	2.91	206.7	413.4	556.5
29	200	8.50	9.67	16	0.758	13-#5	4	12-#8	13-#7	19-#5	16-#5	3.81	271.2	542.5	730.3
29	300	8.50	9.67	22	0.718	15-#5	4	20-#7	16-#7	10-#8	20-#5	4.92	334.3	668.6	900.1
29	400	8.50	11.60	28	0.639	17-#5	2	15-#9	14-#8	12-#8	10-#8	5.83	392.7	785.4	1057.3
30	100	8.50	10.00	12	0.774	14-#5	2	10-#8	20-#5	16-#5	10-#6	3.16	229.4	458.8	617.6
30	200	8.50	10.00	18	0.744	14-#5	4	11-#9	14-#7	21-#5	10-#7	4.16	299.6	599.1	806.5
30	300	8.50	10.00	24	0.675	16-#5	3	17-#8	14-#8	11-#8	12-#7	5.24	369.5	739.1	994.9

SQUARE INTERIOR PANEL With Drop Panels(2)
No Beams

SPAN c.-c. $\ell_1 = \ell_2$ (ft)	Factored Superimposed Load (psf)	(3) Square Column Size (in.)	Reinforcing Bars (E. W.) Column Strip Top	Column Strip Bottom	Middle Strip Top	Middle Strip Bottom	Total Steel (psf)	Concrete (cu. ft / sq. ft)
		h = 10 in. = TOTAL SLAB DEPTH BETWEEN DROP PANELS						
25	100	12	13-#5	9-#5	9-#5	9-#5	2.19	0.884
25	200	18	12-#6	12-#5	10-#5	9-#5	2.63	0.884
25	300	21	14-#6	15-#5	12-#5	10-#5	3.10	0.898
25	400	23	15-#6	18-#5	10-#6	12-#5	3.63	0.912
25	500	25	13-#7	15-#6	16-#5	10-#6	4.26	0.947
26	100	12	15-#5	11-#5	10-#5	10-#5	2.40	0.884
26	200	18	17-#5	14-#5	11-#5	10-#5	2.73	0.898
26	300	21	14-#6	9-#7	13-#5	11-#5	3.31	0.912
26	400	23	13-#7	11-#7	16-#5	10-#6	4.17	0.912
26	500	25	27-#5	10-#8	10-#7	16-#5	4.65	0.947
27	100	12	15-#5	12-#5	10-#5	10-#5	2.37	0.898
27	200	18	14-#6	11-#6	12-#5	10-#5	2.92	0.898
27	300	21	12-#7	19-#5	15-#5	9-#6	3.56	0.912
27	400	24	26-#5	10-#8	10-#7	15-#5	4.35	0.947
27	500	27	16-#7	11-#8	11-#7	18-#5	5.02	0.947
28	100	12	17-#5	13-#5	10-#5	10-#5	2.42	0.898
28	200	19	14-#6	17-#5	13-#5	12-#5	3.02	0.912
28	300	21	13-#7	22-#5	12-#6	10-#6	3.85	0.912
28	400	24	16-#7	11-#8	20-#5	12-#6	4.71	0.947
29	100	12	17-#5	15-#5	12-#5	11-#5	2.58	0.912
29	200	19	16-#6	19-#5	15-#5	13-#5	3.27	0.912
29	300	21	15-#7	10-#8	10-#7	16-#5	4.34	0.912
29	400	26	13-#8	12-#8	12-#7	10-#7	5.06	0.947
30	100	12	14-#6	12-#6	13-#5	11-#5	2.77	0.912
30	200	19	18-#6	22-#5	12-#6	10-#6	3.57	0.912
30	300	21	16-#7	11-#8	11-#7	18-#5	4.56	0.912

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

Alternative System # 3

- Pan Joists (20' span)

Pan Joist Design

Start with 30" forms + 6" ribs @ 36" o.c.

4" minimum slab thickness for fire rating

Design Loads

$w_u = 1.2(55) + 1.6(70) = 178$ psf

CRSI Handbook

$w_u = 178$ psf , $f'_c = 4000$ psi , $f_y = 60000$ ksi , span = 20'

p8-25 End span - 30" form + 6" rib @ 36" o.c.
Factored usable : 218 psf
#4 @ 7" o.c. top bars
2-#6 bottom bars

Interior span
Factored usable : 228 psf
#5 @ 11" o.c. top bars
2-#5 bottom bars

> 30" form + 6" rib
> 20" deep rib + 4" slab

Girder Design (Assume 20" × 20" columns)

Self-wt
Ribs : 6" × 20" × 150/144 = 125 plf
Slab : 4/12 × 150 × 36/12 = 150 plf
Total : 275 plf

w_u/joist = 1.2(275 plf) + 178 (3) = 864 plf

$w_{u,girder}$ = 864 × 20' ÷ 3' = 5.76 klf on girder

Span = 30'

(h×b) = 26" × 18" → w_u = 6.7 klf > 5.76 klf ok

Reinf. Bottom - 2 # 11
Top - 3 # 14

Appendix D

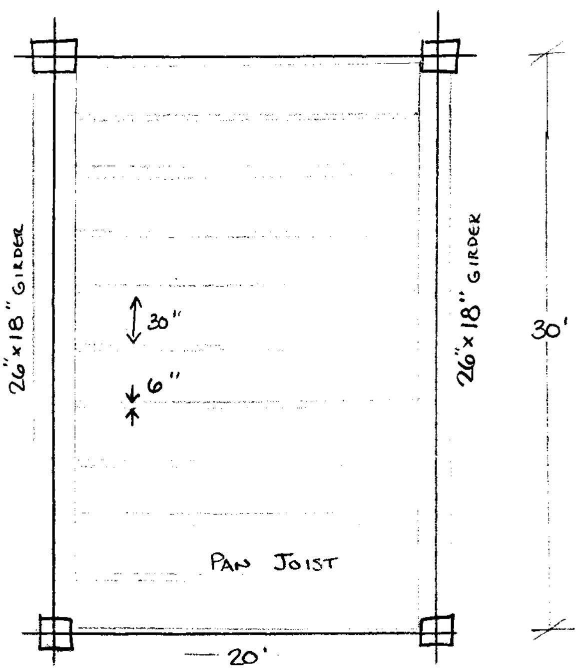
Alternative System #3 (cont'd)

Check $+\phi M_n = 568'^k$, $-\phi M_n = 602'^k$ $> M_u = \dfrac{567(30)^2}{16} = 319'^k$ OK

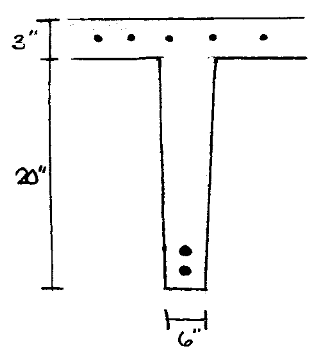
Self-wt $= \dfrac{(26 \times 18 \times \frac{150}{144})}{30} + \dfrac{275}{3} = 108$ PSF

Total depth: 26"

Bay Layout



Joist



$f'_c = 4$ ksi
$f_y = 60$ ksi

STANDARD ONE-WAY JOISTS [1] MULTIPLE SPANS	30" Forms + 6" Rib @ 36" c.-c. [2] FACTORED USABLE SUPERIMPOSED LOAD (PSF)	f'_c = 4,000 psi f_y = 60,000 psi

20" Deep Rib + 3.0" Top Slab = 23.0" Total Depth

TOP BARS Size @	# 4 10	# 4 8	# 4 7	# 5 9	# 6 11	End Span Defl. Coeff.	# 4 9	# 5 11	# 5 9.5	# 5 8	# 6 9	Int. Span Defl. Coeff.
BOTTOM BARS # #	# 5 # 5	# 5 # 6	# 6 # 6	# 6 # 7	# 7 # 7		# 4 # 5	# 5 # 5	# 5 # 6	# 6 # 6	# 6 # 7	
Steel (psf)	.85	1.04	1.23	1.44	1.69	(3)	.93	1.18	1.38	1.66	2.01	(3)
CLEAR SPAN	END SPAN						INTERIOR SPAN					
30'-0"	117	167	218	278	334*	9.752	165	228	301	375	395*	6.001
	0	0	0	0	340		0	0	0	0	458*	
31'-0"	101	148	196	253	310	11.119	147	206	274	343	374*	6.842
	0	0	0	0	0		0	0	0	0	426	
32'-0"	87	131	176	229	283	12.625	130	185	249	314	355*	7.769
	0	0	0	0	0		0	0	0	0	391	
33'-0"	74	16	158	208	259	14.278	114	166	226	287	337*	8.787
	0	0	0	0	0		0	0	0	0	360	
34'-0"	63	102	141	188	236	16.089	100	149	206	263	320*	9.901
	0	0	0	0	0		0	0	0	0	332	
35'-0"	52	89	126	171	216	18.067	88	134	187	241	305*	11.118
	0	0	0	0	0		0	0	0	0	306	
36'-0"	42	77	112	154	197	20.222	76	119	170	221	282	12.445
	0	0	0	0	0		0	0	0	0	0	
37'-0"		66	99	139	180	22.565	65	106	154	202	261	13.886
		0	0	0	0		0	0	0	0	0	
38'-0"		56	87	125	164	25.105	55	94	139	185	240	15.449
		0	0	0	0		0	0	0	0	0	
39'-0"		47	76	112	149	27.853	46	83	126	169	222	17.141
		0	0	0	0		0	0	0	0	0	
40'-0"			66	101	135	30.822		72	113	155	204	18.967
			0	0	0			0	0	0	0	
41'-0"			57	90	123	34.022		63	102	141	188	20.936
			0	0	0			0	0	0	0	
42'-0"			48	79	111	37.464		54	91	128	174	23.055
			0	0	0			0	0	0	0	
43'-0"			40	70	100	41.162		45	81	117	160	25.330
			0	0	0			0	0	0	0	

(1) For gross section properties, see Table 8-1.
(2) First load is for standard square joist ends; second load is for special tapered joist ends.
(3) Computation of deflection is not required above horizonal line (thickness ≥ $\ell_n/18.5$ for end spans, $\ell_n/21$ for interior spans).
(4) Exclusive of bridging joists and tapered ends.
*Controlled by shear capacity. +Capacity at elastic deflection = $\ell_n/360$.

PROPERTIES FOR DESIGN (CONCRETE .60 CF/SF) [4]

NEGATIVE MOMENT												
STEEL AREA (SQ. IN.)	.72	.90	1.03	1.24	1.44		.80	1.01	1.17	1.39	1.76	
STEEL % (UNIFORM)	.42	.53	.61	.73	.85		.47	.60	.69	.82	1.04	
(TAPERED)	.26	.32	.37	.45	.52		.29	.37	.42	.50	.64	
EFF. DEPTH, IN.	21.8	21.8	21.8	21.7	21.6		21.8	21.7	21.7	21.7	21.6	
– ICR/IGR	.149	.179	.199	.228	.254		.162	.195	.219	.250	.295	
POSITIVE MOMENT												
STEEL AREA (SQ. IN.)	.62	.75	.88	1.04	1.20		.51	.62	.75	.88	1.04	
STEEL %	.08	.10	.11	.13	.15		.07	.08	.10	.11	.13	
EFF. DEPTH, IN.	21.7	21.6	21.6	21.6	21.6		21.7	21.7	21.6	21.6	21.6	
+ICR/IGR	.160	.190	.220	.255	.290		.134	.160	.190	.220	.255	

STANDARD ONE-WAY JOISTS [1] MULTIPLE SPANS	30" Forms + 7" Rib @ 37" c.-c. [2] FACTORED USABLE SUPERIMPOSED LOAD (PSF)

20" Deep Rib + 3.0 Top Slab = 23.0 Total Depth

TOP BARS Size @	# 5 12	# 5 11	# 5 9.5	# 5 8	# 6 9.5	End Span Defl. Coeff.	# 5 12	# 5 9.5	# 5 8	# [illegible] 7
BOTTOM BARS # #	# 5 # 6	# 6 # 6	# 6 # 7	# 7 # 7	# 7 # 8		# 5 # 5	# 5 # 6	# 6 # 6	[illegible]
Steel (psf)	1.03	1.20	1.40	1.63	1.89	(3)	1.11	1.36	1.63	[illegible]
CLEAR SPAN	END SPAN						INTERIOR SPAN			
30'-0"	152	201	261	321	376*	10.023	212	282	354	[illegible]
	0	0	0	0	390		0	0	0	[illegible]
31'-0"	134	180	235	292	354*	11.428	190	256	323	[illegible]
	0	0	0	0	357		0	0	0	
32'-0"	117	161	213	265	326	12.975	170	232	295	[illegible]
	0	0	0	0	0		0	0	0	
33'-0"	102	143	192	241	299	14.675	151	210	269	[illegible]
	0	0	0	0	0		0	0	0	
34'-0"	88	127	173	220	274	16.536	135	190	246	[illegible]
	0	0	0	0	0		0	0	0	
35'-0"	76	112	156	200	251	18.569	120	172	224	[illegible]
	0	0	0	0	0		0	0	0	
36'-0"	64	99	140	181	230	20.784	106	155	205	[illegible]
	0	0	0	0	0		0	0	0	
37'-0"	54	86	125	165	210	23.191	93	139	187	[illegible]
	0	0	0	0	0		0	0	0	
38'-0"	44	75	112	149	192	25.802	81	125	170	[illegible]
	0	0	0	0	0		0	0	0	
39'-0"		64	99	135	176	28.627	70	112	154	[illegible]
		0	0	0	0		0	0	0	
40'-0"		54	88	121	160	31.678	60	100	140	[illegible]
		0	0	0	0		0	0	0	
41'-0"		45	77	109	146	34.967	51	89	127	[illegible]
		0	0	0	0		0	0	0	
42'-0"			67	97	133	38.505	42	78	115	[illegible]
			0	0	0		0	0	0	
43'-0"			58	87	121	42.305		68	103	[illegible]
			0	0	0			0	0	

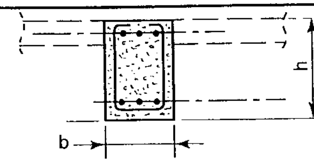
(1) For gross section properties, see Table 8-1.
(2) First load is for standard square joist ends; second load is for special tapered joist e[illegible]
(3) Computation of deflection is not required above horizonal line (thickness ≥ ℓ_n 18.5 [illegible]
$\ell_n/21$ for interior spans).
(4) Exclusive of bridging joists and tapered ends.
*Controlled by shear capacity. +Capacity at elastic deflection = ℓ_n [illegible]

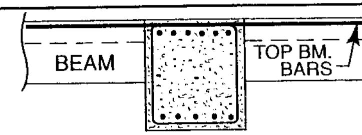
PROPERTIES FOR DESIGN (CONCRETE .64 CF/SF) [4]

NEGATIVE MOMENT										
STEEL AREA (SQ. IN.)	.96	1.04	1.21	1.43	1.71		.96	1.21	1.43	[illegible]
STEEL % (UNIFORM)	.50	.55	.63	.75	.90		.50	.63	.75	[illegible]
(TAPERED)	.32	.35	.40	.48	.57		.32	.40	.48	[illegible]
EFF. DEPTH, IN.	21.7	21.7	21.7	21.7	21.6		21.7	21.7	21.7	[illegible]
– ICR/IGR	.174	.186	.209	.239	.272		.174	.209	.239	[illegible]
POSITIVE MOMENT										
STEEL AREA (SQ. IN.)	.75	.88	1.04	1.20	1.39		.62	.75	.88	[illegible]
STEEL %	.09	.11	.13	.15	.17		.08	.09	.11	[illegible]
EFF. DEPTH, IN.	21.6	21.6	21.6	21.6	21.5		21.7	21.6	21.6	[illegible]
+ICR/IGR	.173	.200	.231	.263	.298		.146	.173	.200	[illegible]

$f'_c = 4{,}000$ psi
$f_y = 60{,}000$ psi

RECTANGULAR BEAMS, END SPANS





TOTAL CAPACITY $U = 1.4D + 1.7L$(3)

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

(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.

MIKE HEBER
10/31/05

ALTERNATIVE SYSTEM # 4

- HOLLOW - CORE PRECAST PLANK ON STEEL FRAME

SERVICE LOADS

LL = 70 PSF
DL = 55 PSF

TL = 125 PSF

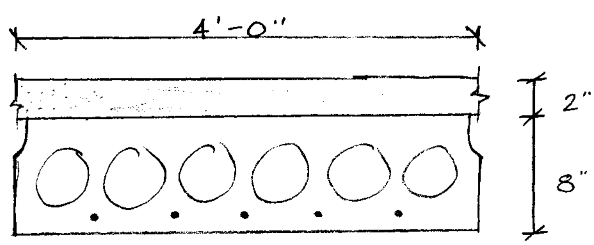
SPAN

30 FT (SAME AS BEAM SPAN FOR EXISTING SYSTEM)

- PCI DESIGN HANDBOOK, 5TH EDITION (p 2-27)
  - USE LIGHT WEIGHT CONCRETE FOR A SYSTEM WEIGHT SIMILAR TO THE EXISTING SYSTEM FOR VIBRATION REASONS.

USE 4'-0" x 8" PLANKS w/ 2" TOPPING
STRAND DESIGNATION CODE : 78-S

ALLOWABLE SERVICE LOADS: 149 PSF > 125 PSF OK



f'_c = 5000 PSI
f'_{ci} = 3500 PSI

SYSTEM WEIGHT : 68 PSF

Mike Hebert
10/31/05

Alternative System # 4 (cont'd)

- Hollow-core precast plank on steel frame
- LRFD Manual, 3rd Edition

- $w_u = 1.2(55 + 68) + 1.6(70) = 259.6$ psf

  $\Rightarrow (259.6)(30') = 7788$ plf

- Span length : 20'

- Deflection controls : $\left(\frac{\ell}{360} = \frac{20 \times 12}{360} = 0.67'' \right)$

$$I_{REQ'D} = \frac{5}{384} \frac{(7.788)(20)^4(1728)}{(29000)(0.67)} = 1450 \text{ in}^4$$

Table 5-2 LRFD Manual
Try W16 × 100

$I = 1490 \text{ in}^4 > I_{REQ'D} = 1450 \text{ in}^4$ OK

$\phi M_{px} = \phi M_n = 746$ k-ft

$M_u = \frac{w\ell^2}{8} = \frac{(7.788)(20)^2}{8} = 389.4$ 'k < 746 'k OK

$\phi V_n = 269$ k

$V_u = \frac{w\ell}{2} = \frac{(7.788)(20)}{2} = 77.9$ k < 269 k OK

> Use 4'-0" × 8" planks w/ 2" lightweight topping in conjunction w/ W16 × 100 end support beams.

Total system weight : $68 + \frac{(100 \times 20)}{(20 \times 30)} = \underline{71.3 \text{ psf}}$

Total system depth : $8 + 2 + 17 = \underline{27''}$

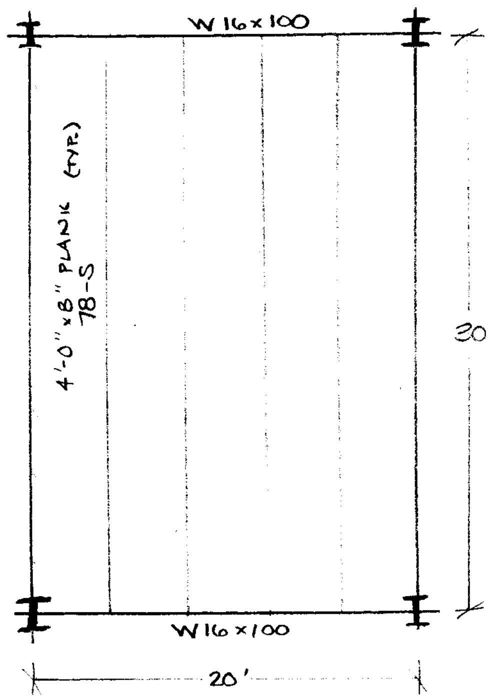
TECH # 2

MIKE HEBERT

Appendix E

10/31/05

ALTERNATIVE SYSTEM # 4 - LAYOUT



2" TOPPING SLAB