- Robert Whitaker
- Structural ~ Parfitt
- Parkview at Bloomfield Station
- Bloomfield, NJ
- 10-31-05

Structural Technical Report #2

By Robert Whitaker

Executive Summary

This report covers the comparative redesign of the Hambro® floor system currently used in Parkview at Bloomfield Station, a six story residential apartment in Bloomfield, New Jersey. This comparison encompasses gravity loading analysis for five different floor systems: bar joist with metal decking, hollow core planks, concrete pan joists, waffle flat slab and pre-stress concrete slab. There is a comparison table and an extensive calculation appendix attached at the end of this report.

The typical design bay size in Parkview is 30'-0" ± 1'-0" wide by 38'-0" long. There are no height restrictions for the building but a shorter height is desirable with a current ceiling-to-floor depth of 19". This ceiling-to-floor depth allows for six residential levels and a roof level with a total building height of just less than 89 feet. The Hambro System has a 3 hour fire rating and a low system weight of 40 pounds per square foot. This system also features a quick erection time, creating a lower overall floor system cost.

The best floor redesign to parallel the Hambro system is the hollow core plank floor system. The hollow care plank systems features shorter depths (10" + 3"to 6"), and a fast erection time. The hollow core plank system is also a less complex option overall and reasonably close in cost to the Hambro system. However, a change in supporting structure from lightgage shear walls to a steel or concrete lateral frame will be required, causing some changes to the existing architecture. This system has system weights nearly double the current floor weight, and will require larger foundations. Finally, additional fireproofing will need to be considered for the hollow core plank system which only has a 2 hour fire rating. While this floor system has drawbacks with respect to weight and support system, the hollow core plank system appears to be the most viable alternative to the current floor system.

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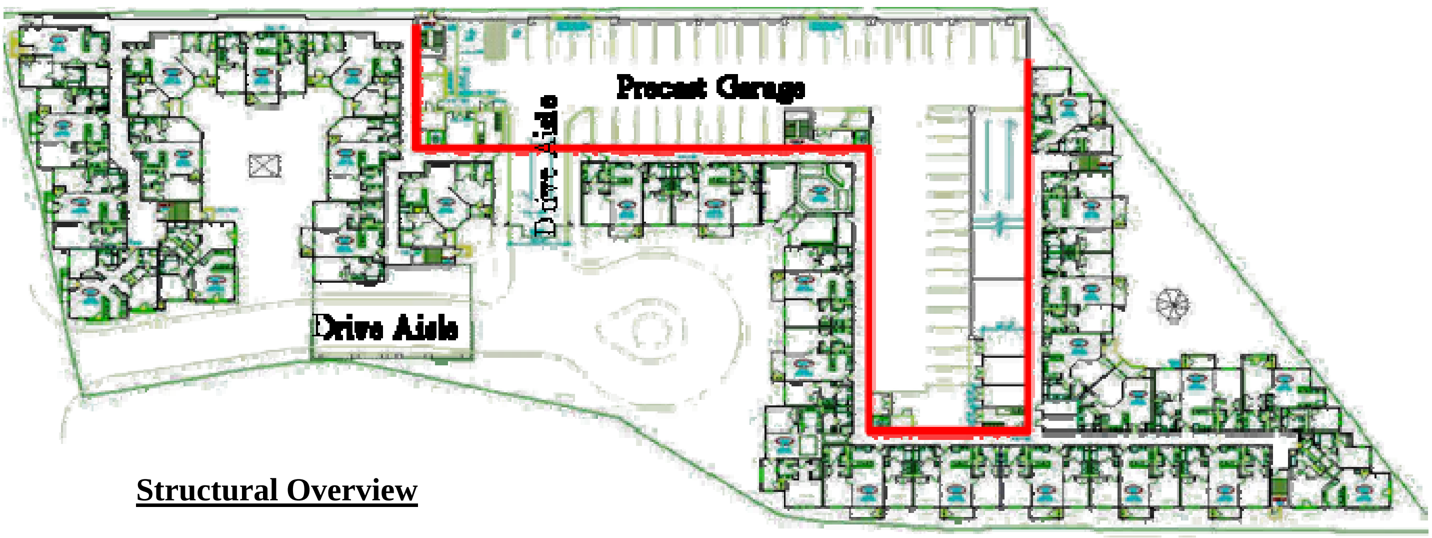
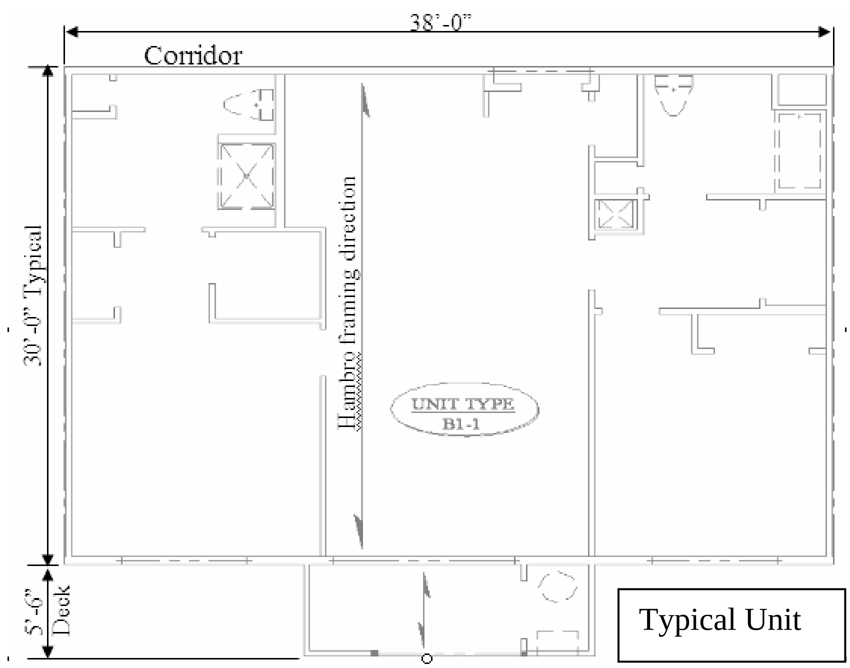


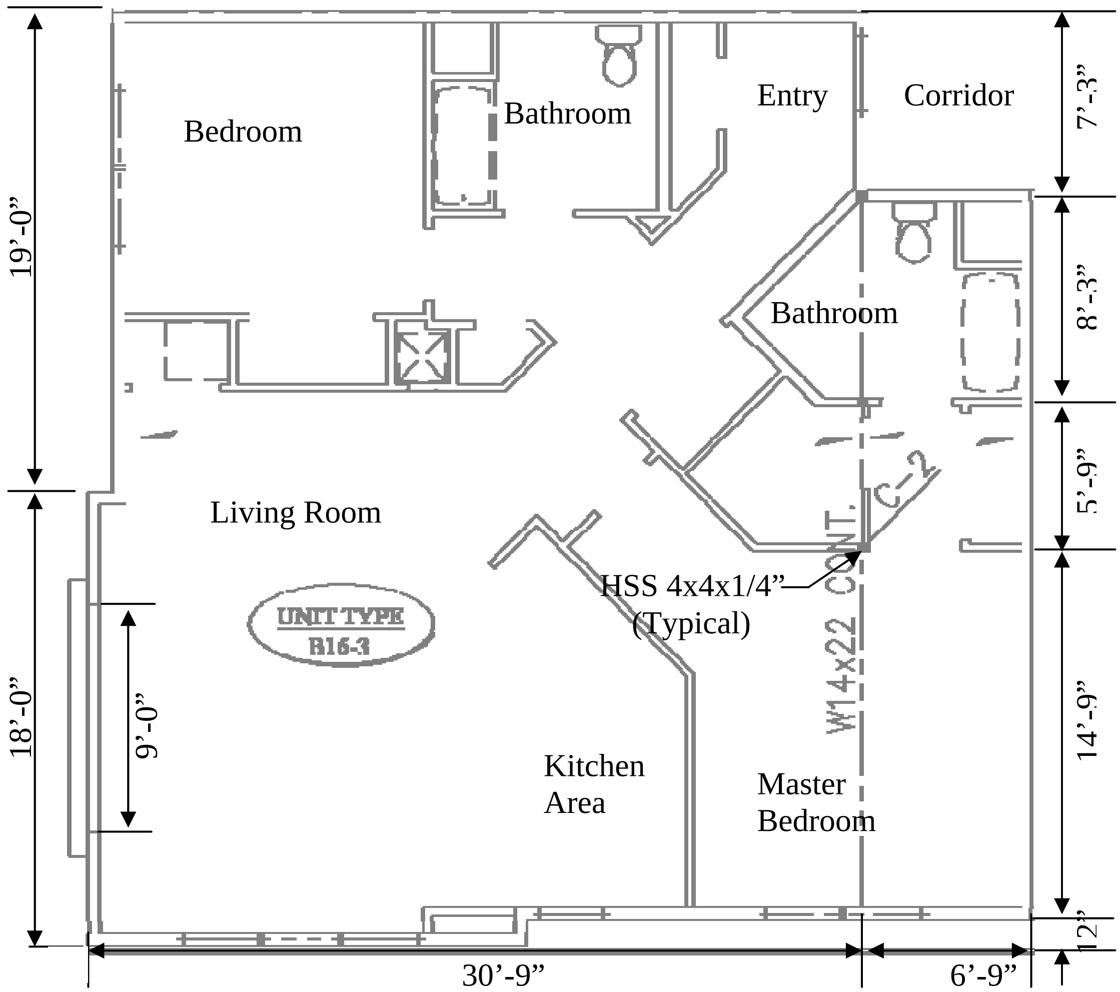
Structural Overview

Parkview at Bloomfield Station, a six story residential apartment building located in Bloomfield, New Jersey has a floor system design that consists of 16" Hambro® composite bar joists spaced at 4'-0" on center (oc). The precast parking garage, structurally separate from the main building, is not considered in the floor redesign. All six floors stack vertically, with the exception of the two drive aisle locations and the two entry units. Theses areas have the same basic framing elements but the bearing locations have been changed to accommodate the architectural features. The floor loading is the same for all six levels and consists of 40 pounds per square foot (psf) live load (LL) in the residential sections, and 100 psf live load for the corridor and public spaces such as the lobby and gym.



Typical Unit

The typical unit also has an additional 18 psf of dead load (DL) due to the suspended gypsum wall board ceiling, mechanical units and ductwork feeding the apartment, partition walls, and floor finishes. The floor is finished with carpet in the living room, hallways and bedrooms, and finished with tile and wood in the bathroom and kitchen areas with wood flooring at the main entry.

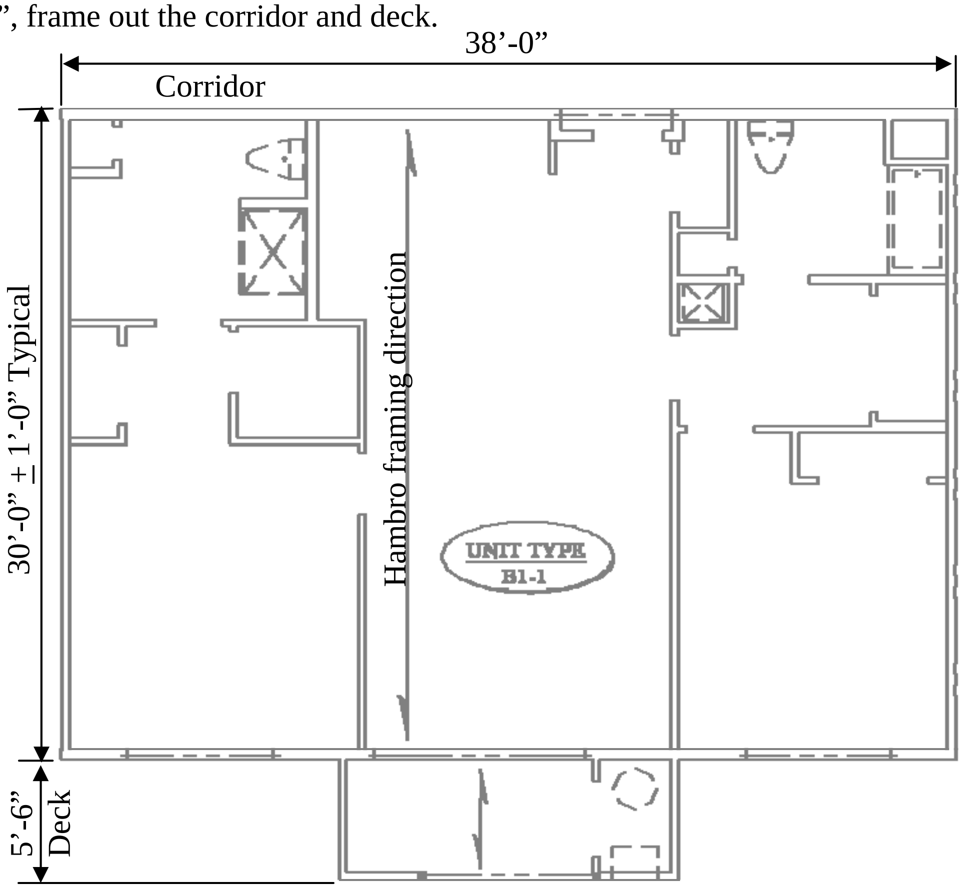


Corner Unit

Existing Floor Framing

The current floor framing at Parkview at Bloomfield Station spans from the exterior wall to the corridor wall (typically 30'-0" ± 1'-0"), and the framing in the corridor spans from the corridor wall to the exterior corridor wall (typically 6'). Sixteen inch Hambro joists at 48" oc with 3" topping compose the main floor framing (depth = 19"). Hambro RTC, top cord only members which are capable of holding a 100 psf live load for spans up to 8'-0", frame out the corridor and deck.

The Hambro floor system has a system weight of 40 psf based on the 3" thick concrete floor and the joist weight over the 4'-0" spacing. Because of the 3" thick concrete flooring, and the non-combustible nature of the steel, this system has a fire rating of 3 hrs based on Underwriter Laboratories (UL) testing. This 3 hour rating was one of the original reasons for the selection of Hambro joists as the flooring system, reducing the number of firewalls in the building.



Furthermore, since the formwork for the slab is built into the joists, the need for labor decreases and the overall cost of the system is greatly reduced. This system is very durable and only has problems, like most steel and concrete structures, when exposed to water or large temperature changes. Since this system is primarily an interior system, it should last as long as the building's life. This system also performs well in vibration and sound transmission; it has an Impact Isolation Class (IIC) of 30 and a Sound Transmission Class (STC) of 57[1].

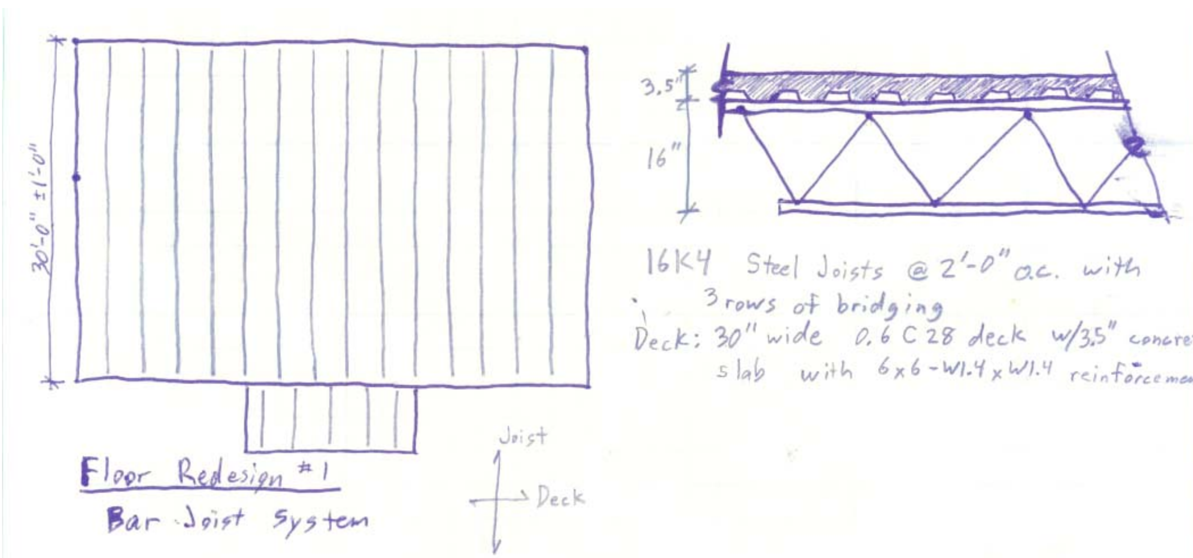
[1] www.hambrosystems.com
IIC is a rating designed to measure the impact sound isolation provided by floor/ceiling construction. The IIC of any assembly is strongly affected by and dependent upon the type of floor finish for its resistance to impact noise transmission.
STC is a rating that assigns a numerical value to the sound insulation provided by a partition separating rooms or areas. The rating is designed to match subjective impressions of the sound insulation provided against the sounds of speech, music, television, office machines and similar sources of airborne noise that are characteristic of offices and dwellings.

Alternate Floor Framing

The redesign of the flooring system at Parkview at Bloomfield Station encompasses gravity loading analysis for five different floor systems: bar joist with metal decking, hollow core planks, concrete pan joists, waffle flat slab, and pre-stressed concrete slab. These floor assemblies were then compared to determine which one provides the best solution for the building's floor system.

Alternate Floor Framing Option #1

The first floor redesign is looking into the impact of making the flooring system out of non-composite bar joists and metal decking. The 16" inch steel bar joists spaced at 24" oc with a 3½" concrete and metal deck system provides a comparison to the original floor system with a similar 19½" depth and a 3 hour fire rating. This system will not require any architectural changes because it is also able to use the same support system, lightgage steel walls, as the original Hambro joist system.



The bar joist system utilizes 16K4 steel joists at 2'-0" oc with 3 rows of bridging[2] and 30" wide 0.6C28 deck. The bar joist system also employs a 3.5" concrete slab with 6x6-W1.4xW1.4 welded wire fabric as slab reinforcement[3]. This system has a similar erection time to the Hambro arrangement but is more expensive due to the increased amount of material and time required to install twice as many joists. Moreover, the system weight is 48 psf, which is 8 psf heavier than the original design. Lastly, this new design should have approximately the same vibration and noise coefficient results as the current system. This is because sacrificing the system's rigidity by becoming non-composite is made up for by using twice as many joists. This system, though it will also last the life of the building, does not have any benefits beyond the existing Hambro system to lead to a more extensive analysis.

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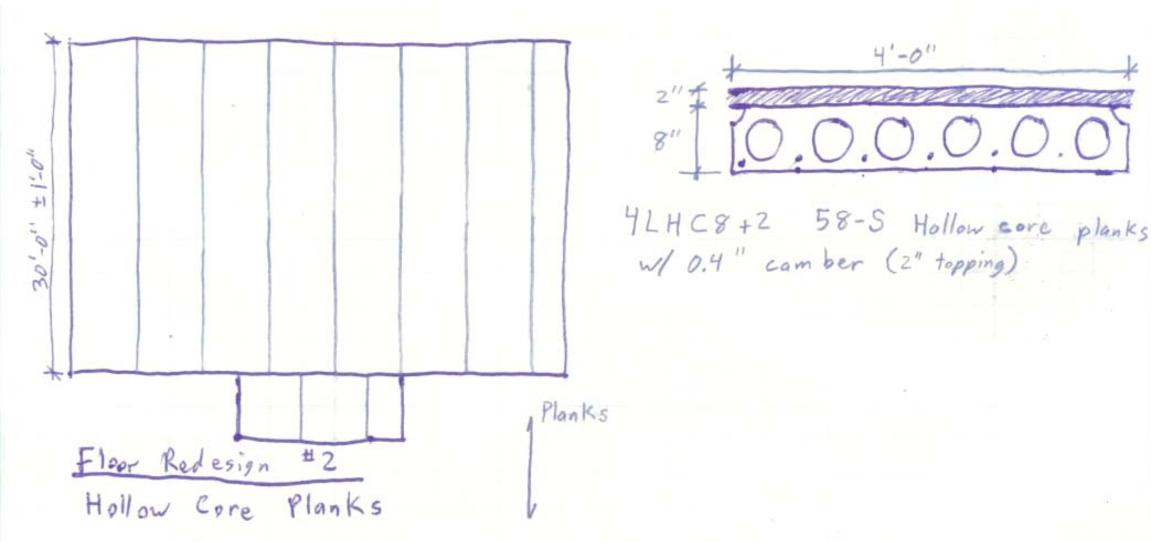
[2] The New Columbia Joist Company. http://www.njb-united.com/ncj.htm

[3] Nucor Corporation: Vulcraft Division. http://www.vulcraft.com/

Alternate Floor Framing Option #2

The second floor redesign is the use of 8" hollow core planks with 2" concrete topping, which is much thinner than the existing 19" system. The mechanical ductwork would need to be attached to the bottom of the panels adding 3"-6" to the system, unlike the current system where the ducts just pass through the web openings.

This system, while thinner overall, has a system weight of 81 psf, double that of the Hambro system. Because of this added weight and the required bearing length, the support system needs to be either a concrete frame or a W-shape steel frame. Both of these support systems affect the architectural layout of the apartment by requiring wall bump-outs at the column locations. This will also increase the required footing sizes and change the lateral resisting elements from shear walls to braced frames with lightgage infill.

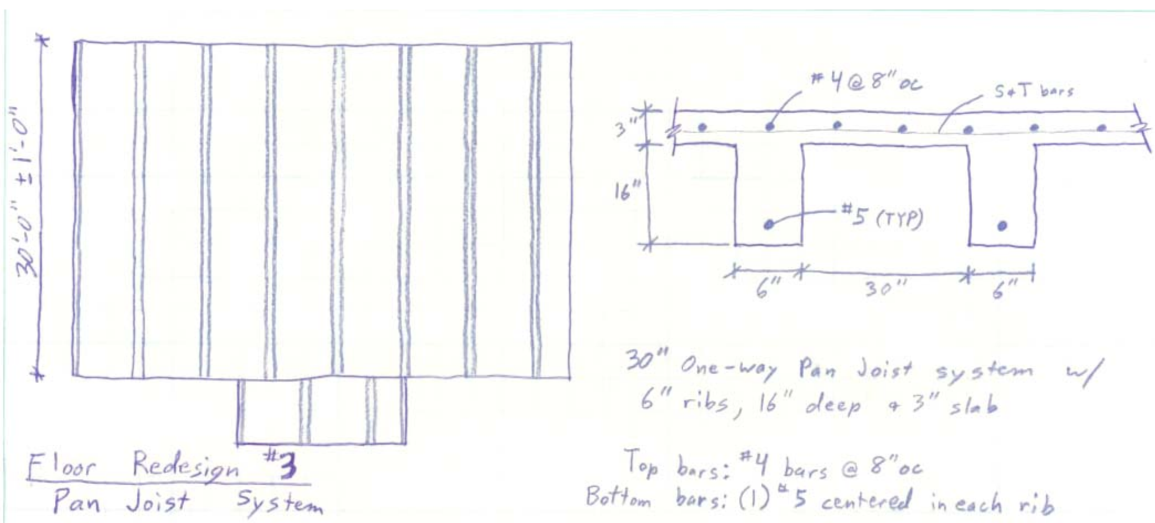


The overall cost of the hollow core plank system is comparative to the Hambro system due to its quick erection time and reduced on site labor requirement due to its precast nature. Having a fire rating of only 2 hours, this system is the lowest rated assembly analyzed and will need to have additional fireproofing added. However, it does have comparable IIC and STC to that in the Hambro system with values of 38 and 58 respectively. The reduction of ceiling-to-floor height will allow the building to have either higher finished ceilings or reduced building height by nearly 2 feet. Like the other designs, this system will last for the life of the building. While this floor system has its drawbacks with respect to weight and fireproofing, it appears to be a very viable alternative to the current floor system.

Alternate Floor Framing Option #3

The third floor redesign is a concrete pan joist system. It utilizes a 30” pan with 6” joists, and an overall depth of 19”. This depth equals the depth of the existing Hambro system but has some drawbacks associated with it. First, the Hambro system allows for easy access of ductwork through the system, yet for this system, concrete would need to be removed from certain areas, greatly increasing system costs and creating a weaker overall system. To avoid this complication the duct work could be placed below the system but at the cost of a much deeper system, 22” or more.

Additionally, this system has a system weight of 78 psf, nearly double the existing system, and therefore requires a larger support and foundation system. Since the floor system will be completely concrete, the lightgage bearing walls will not suffice due to material interactions and strength considerations. A concrete beam and column system will need to be introduced as the gravity and lateral load carrying element, affecting the existing architectural layout by requiring bump-outs at column locations. Finally, the cost of the system is greatly increased due to the time needed to place the concrete column forms and for the even placement of the pans along the span.



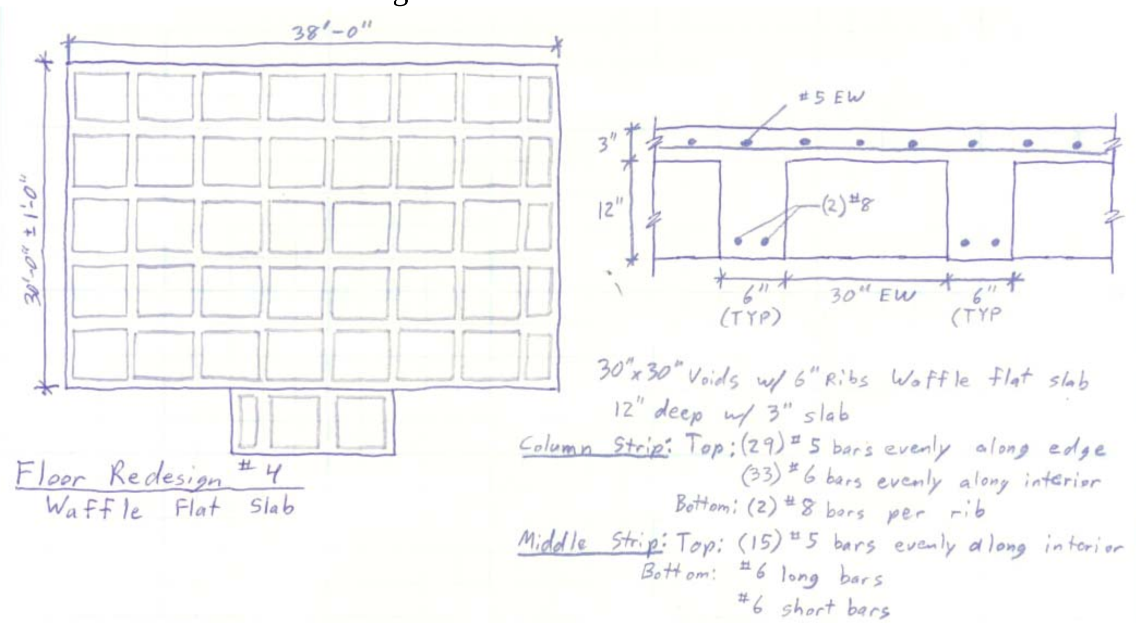
Due to its thickness, the pan joist system provides a 3 hour fire rating and effectively damps out noise and vibrations in the system. Furthermore, with the mechanical equipment having to pass below the joists, there is little chance for water penetration into the concrete, making this a very durable floor.

Strength wise this is a good choice for a floor, yet the excessive weight in addition to its large depth make this a less viable solution for this building. This floor system will not need to be analyzed more extensively due to the nature of the building requirements of Parkview at Bloomfield Station.

Alternate Floor Framing Option #4

The fourth redesign is a 15” deep 2-way concrete waffle flat slab. This floor, like the previous floor option, is composed solely of concrete and will need to be supported by a concrete frame system. Since this is a 2-way system, the column sizes will be slightly smaller due to load sharing, creating slightly less intrusion on the existing architectural layout. In addition, beams along the column line aid in the gravity and lateral load carrying capacity of the frame.

This system will support the mechanical ductwork below the joists, attached just like the ductwork in the concrete joist system. Even with this additional 3”to 6”, it will be comparable in depth to the Hambro floor. Furthermore, since the mechanical equipment is located below the joists, water damage to the concrete will be prevented and will allow this floor to outlive the building life.



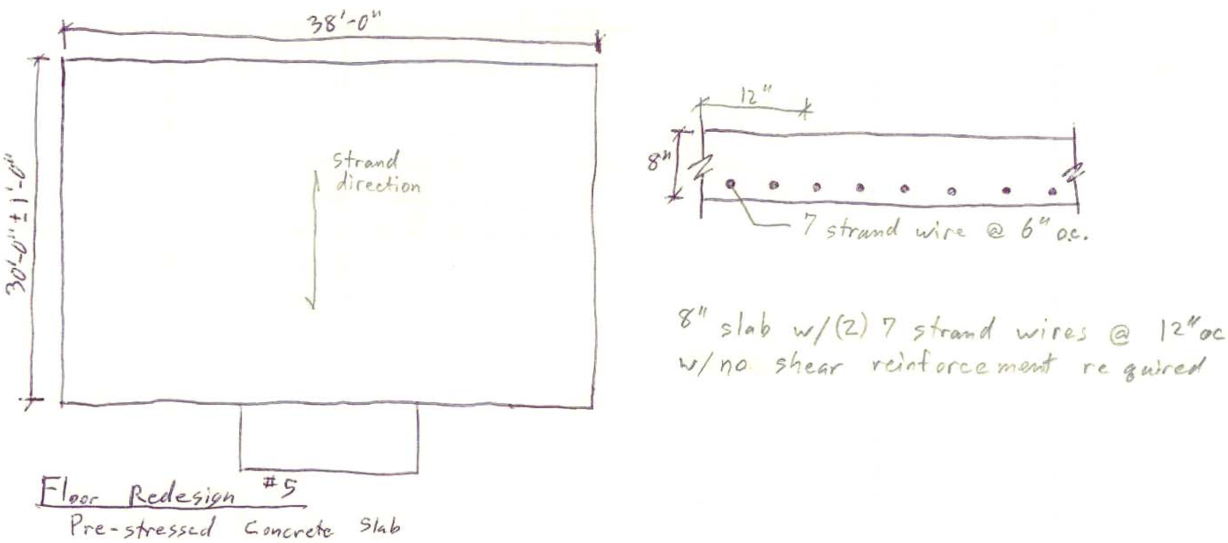
Since this system is composed of concrete joists in both directions it allows for excellent strength carrying characteristics. However, it is the heaviest of the five designs, having a total weight of 90 psf and requiring a much larger foundation. This floor system is not only the heaviest, but also has the slowest erection time due to the alignment of formwork in both directions. This time consuming procedure has led this floor system to have the highest price tag of all five systems in consideration. However, the heavy floor system does have its advantages as a damping system by not only reducing sound but also greatly reducing floor vibrations. Fire rating is also not a problem due to its mass, easily obtaining a 3 hour fire rating.

Based on serviceability requirements this is a good design, however, it does not appear to be a good solution on many other levels. Its primary downfall is its excessive weight and moderate depth. These 2 factors combined with the time consuming aspect of layout led to the conclusion that this system does not need any further investigation.

Alternate Floor Framing Option #5

The fifth floor redesign is an 8" deep 1-way pre-stressed concrete slab. The mechanical ductwork would need to be attached to the bottom of the panels adding 3"-6" to the system, making the overall depth 14" at most, a difference of 5" minimum from the Hambro system.

This system, while thinner overall, has a system weight of 100 psf, two and a half times the weight of the Hambro system. This added weight, along with the required end supports means that the support system needs to be a concrete frame. This support system affects the architectural layout of the apartment by requiring wall bump-outs at the column locations. This load difference will also increase the required footing sizes and change the lateral resisting elements from shear walls to braced frames with lightgage infill. It will also reduce the ability to put slab penetrations at certain locations due to the pre-stressed cables.



The overall cost of the pre-stressed system is much higher than the Hambro system due to its complexity and specialization. It would require specialized machines to be onsite for the tensioning and engineering oversight. However, the system does have a fire rating of 3 hours and also has comparable IIC and STC to that in the Hambro system due to its rigidity. The reduction of ceiling-to-floor height will allows the building to have either higher finished ceilings or reduced building height by nearly 3 feet. This system, like the others will last for the life of the building. While this floor system has excellent depth characteristics, its drawbacks with respect to weight and specialization make it a poor alternative to the current floor system. It will not need to be investigated as a potential floor system any further.

Alternate Floor Framing Comparison

Floor Redesign		UL Rating	Durability of System Based On	Dead Load of System	Support System	
Option		*Hr*	*Replacement Time*	*psf*	*Width*	*Type*
Exist.	Hambro	3	Building life	40	6”	Steel Stud Wall
1	Bar Joist	3	Building life	48	6”	Steel Stud Wall
2	Hollow Core	2	Building life	81	>6”	Steel Beams & Col.
3	Conc. Joist	3	Building life	78	>8”	Conc. Beams & Col.
4	Waffle Slab	2	Building life	89	>8”	Conc. Beams & Col.
5	Pre-Stressed	3	Building life	100	>8”	Conc. Beams & Col.

Floor Redesign		Depth	Floor Requires Architectural Wall Canges	System Cost: 1-5	System Complexity 1-5	Erection Time 1-5	Viability of Floor System? 1-5
Option		*inch*	*Y/N*	*5=Cheap*	*5=Simple*	*5=Fast*	*5=Practical*
Exist.	Hambro	19	no changes to wall	4	4	4	5
1	Bar Joist	19.5	no changes to wall	3	5	3	4
2	Hollow Core	10+	yes, steel beams	3	5	4	5
3	Conc. Joist	19+	yes, concrete frame	2	3	2	2
4	Waffle Slab	15+	yes, concrete frame	1	2	1	2
5	Pre-Stressed	8+	yes, concrete frame	1	1	1	1

While the bar joist and hollow core plank systems both rank high, the best floor redesign to parallel the Hambro system is the hollow core plank floor system. The bar joist system is close in design to the Hambro system yet lacks any extended benefits that would make it a better choice. Since it shows no extended benefits it will not need to be considered further, despite its high viability.

The hollow core plank system features a shorter depth (10” + 3” to 6”), and a fast erection time. This system is also a less complex option overall and reasonably close in cost to the Hambro system. However, a change in supporting structure from lightgage walls to a steel or concrete frame will be required, causing some changes to the existing architecture. It also has a system weight nearly double the current floor weight, and will require larger foundations. Finally, additional fireproofing will need to be considered since the hollow core plank system only has a 2 hour fire rating. Yet despite these slight setbacks to the overall floor system, it appears that this system is a viable solution for Parkview at Bloomfield Station’s flooring needs.

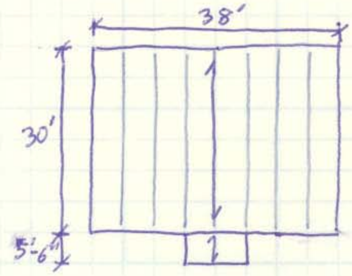
Appendix Tech Report 2

Table of Contents:

1a. Existing Conditions, and Re-Designs 1 & 2

Over view

Loads, Origional Framing, & Redesign #1 & #2



Origional Framing
16" Hambro Joists @ 4' o.c.

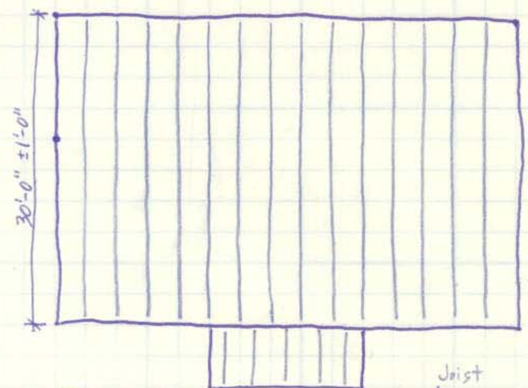
ASCE 7 Table 4-1

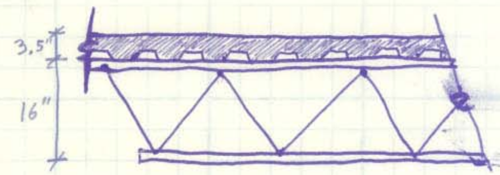
LL = corridor = 100 psf
LL = residential = 40 psf
LL = balcony = 60 psf

ASCE 7 Table 3-1

DL = Finishes = carpet (85%) = 3 psf
= tile (10%) = 16 psf
= wood floor (5%) = 4 psf
} 4.35 psf

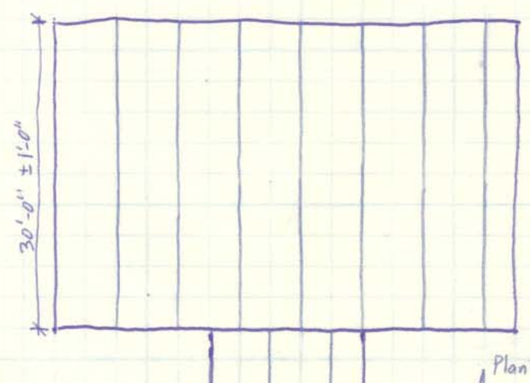
DL = ceiling = GWB = 4 psf
DL = mechanical = 4 psf
DL = partition walls = 5.2 psf
DL_{Total} = 17.55 psf + DL_{system}

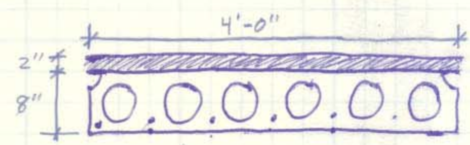




16K4 Steel Joists @ 2'-0" o.c. with
3 rows of bridging
Deck: 30" wide 0.6 C 28 deck w/3.5" concrete
slab with 6x6-W1.4xW1.4 reinforcement

Floor Redesign #1
Bar Joist System

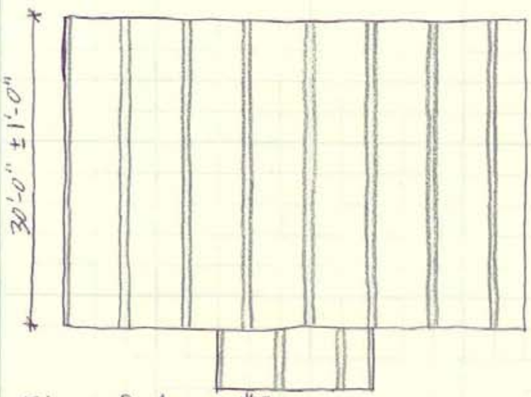


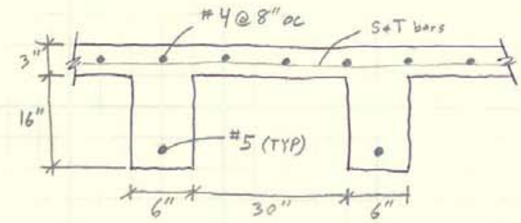


4LHC8+2 58-S Hollow core planks
w/ 0.4" camber (2" topping)

Floor Redesign #2
Hollow Core Planks

1b. Re-Designs 3& 4 and Summary

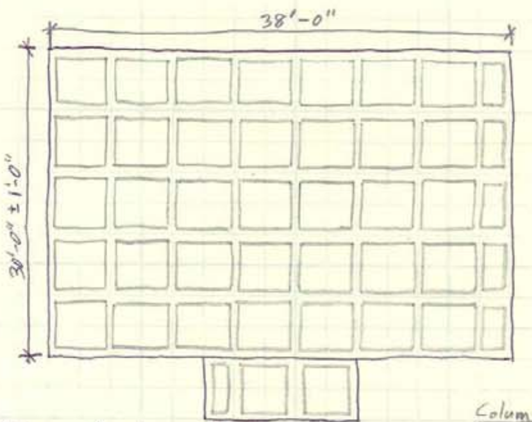


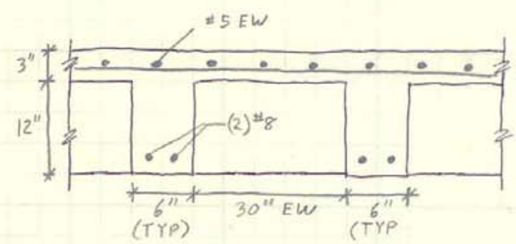


30" One-way Pan Joist system w/
6" ribs, 16" deep + 3" slab

Floor Redesign #3
Pan Joist System

Top bars: #4 bars @ 8" oc
Bottom bars: (1) #5 centered in each rib



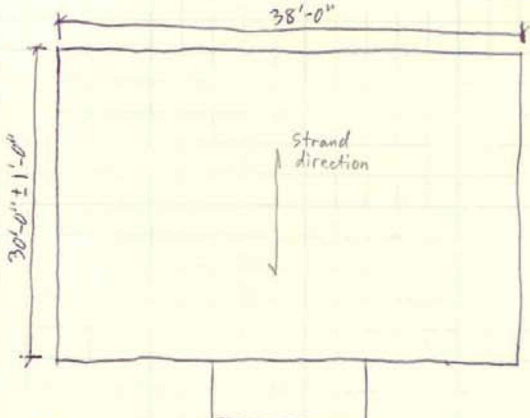


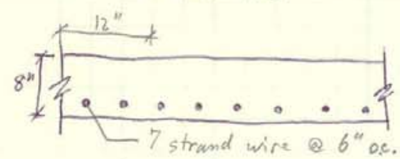
30"x30" Voids w/ 6" Ribs Waffle flat slab
12" deep w/ 3" slab

Column Strip: Top; (29) #5 bars evenly along edge
(33) #6 bars evenly along interior
Bottom: (2) #8 bars per rib

Floor Redesign #4
Waffle Flat Slab

Middle Strip: Top: (15) #5 bars evenly along interior
Bottom: #6 long bars
#6 short bars





8" slab w/ (2) 7 strand wires @ 12" oc
w/ no shear reinforcement required

Floor Redesign #5
Pre-stressed Concrete Slab

1c. Comparative Summary

Floor Redesign		UL Rating	Durability of System Based On	Dead Load of System	Support System	
Option		*Hr*	*Replacement Time*	*psf*	*Width*	*Type*
Exist.	Hambro	3	Building life	40	6”	Steel Stud Wall
1	Bar Joist	3	Building life	48	6”	Steel Stud Wall
2	Hollow Core	2	Building life	81	>6”	Steel Beams & Col.
3	Conc. Joist	3	Building life	78	>8”	Conc. Beams & Col.
4	Waffle Slab	2	Building life	89	>8”	Conc. Beams & Col.
5	Pre-Stressed	3	Building life	100	>8”	Conc. Beams & Col.

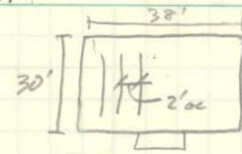
Floor Redesign		Depth	Floor Requires Architectural Wall Canges	System Cost: 1-5	System Complexity 1-5	Erection Time 1-5	Viability of Floor System? 1-5
Option		*inch*	*Y/N*	*5=Cheap*	*5=Simple*	*5=Fast*	*5=Practical*
Exist.	Hambro	19	no changes to wall	4	4	4	5
1	Bar Joist	19.5	no changes to wall	3	5	3	4
2	Hollow Core	10+	yes, steel beams	3	5	4	5
3	Conc. Joist	19+	yes, concrete frame	2	3	2	2
4	Waffle Slab	15+	yes, concrete frame	1	2	1	2
5	Pre-Stressed	8+	yes, concrete frame	1	1	1	1

2a. #1 – Bar Joist System

Floor Redesign #1 Bar Joist System ASD

Span = 31' > 30' typ to cover all cases

@ 2'-0" oc w/ 2" slab



LL = 40 psf
DL = 17.55 + $\frac{3.5"}{12"/ft}$ (150 pcf) + 8 plf $\left(\frac{1}{2'oc}\right)$ = 65.3 psf
TL = 105.3 psf

∴ try 16K5 from New Columbia Joist Company

allowable plf @ 2'oc
TL = 228 plf ≥ 105.3 (2') = 210.6 plf ∴ ok
LL = 114 plf ≥ 40(2') = 80 plf ∴ ok
needs 3 rows of bridging

16K5 steel Joists @ 2'-0" oc w/ 3 rows of bridging

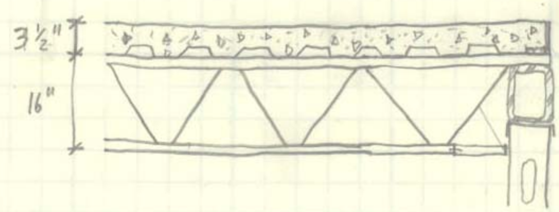
Decking

Try Vulcraft 0.6C, C5V Conform decking, 28 gage, non-composite
clear span = 2'-0", 3.5" total slab depth, 9/16" deep deck (t = 1.5" total)
↑ fire rating min

Actual Load = (40 psf) + (47.6 psf) = 87.6 psf

3 span @ 2' spacing
0.6C28 w/ 3.5" slab or 6x6-W1.4xW1.4 : 400 psf ≥ 92.8 psf ∴ ok — doesn't meet T&S req.
deck only: 186 psf = $\frac{l}{240}$ ≥ 92.8 psf ∴ no shoring needed
Allowable span: 2'-7" ≥ 2'-0" ∴ ok
W1 = 177 psf > 41 psf slab + deck weight ∴ ok

30" wide 0.6C28 w/ 3.5" slab w/ 6x6-W1.4xW1.4



UL 3hr rating G523

2a. #1 – Bar Joist Chart

STANDARD LOAD TABLE
FOR OPEN WEB STEEL JOISTS, K-SERIES

Based on a Maximum Allowable Tensile Stress of 30 ksi
Adopted by the Steel Joist Institute November 4, 1985;
Revised to May 1, 2000 – Effective August 1, 2002

The black figures in the following table give the TOTAL safe uniformly distributed load-carrying capacities, in pounds per linear foot, of K-Series Steel Joists. The weight of DEAD loads, including the joists, must be deducted to determine the LIVE load-carrying capacities of the joists. Sloped parallel-chord joists shall use span as defined by the length along the slope.

The figures shown in RED in this load table are the LIVE loads per linear foot of joist which will produce an approximate deflection of 1/360 of the span. LIVE loads which will produce a deflection of 1/240 of the span may be obtained by multiplying the figures in RED by 1.5. In no case shall the TOTAL load capacity of the joists be exceeded.

The approximate joist weights per linear foot shown in these tables do not include accessories.

The approximate moment of inertia of the joist, in inches[4] is; $I_j = 26.767(W_{LL})(L^3)(10^{-6})$, where W_{LL} = RED figure in the Load Table and L = (Span - .33) in feet.

For the proper handling of concentrated and/or varying loads, see Section 5.5 in the Recommended Code of Standard Practice for Steel Joists and Joist Girders.

Where the joist span exceeds the unshaded area of the load table, the row of bridging nearest the mid-span shall be diagonal bridging with bolted connections at the chords and intersections.

STANDARD LOAD TABLE/OPEN WEB STEEL JOISTS, K-SERIES
Based on a Maximum Allowable Tensile Stress of 30 ksi

Joist Designation	8K1	10K1	12K1	12K3	12K5	14K1	14K3	14K4	14K6	16K2	16K3	16K4	16K5	16K6	16K7	16K9
Depth (in.)	8	10	12	12	12	14	14	14	14	16	16	16	16	16	16	16
Approx. Wt (lbs./ft.)	5.1	5.0	5.0	5.7	7.1	5.2	6.0	6.7	7.7	5.5	6.3	7.0	7.5	8.1	8.6	10.0
Span (ft.) ↓																
8	550 550															
9	550 550															
10	550 480	550 550														
11	532 377	550 542														
12	444 288	550 455	550 550	550 550	550 550											
13	377 225	479 363	550 510	550 510	550 510											
14	324 179	412 289	500 425	550 463	550 463	550 550	550 550	550 550	550 550							
15	281 145	358 234	434 344	543 428	550 434	511 475	550 507	550 507	550 507							
16	246 119	313 192	380 282	476 351	550 396	448 390	550 467	550 467	550 467	550 550	550 550	550 550	550 550	550 550	550 550	550 550
17		277 159	336 234	420 291	550 366	395 324	495 404	550 443	550 443	512 488	550 526	550 526	550 526	550 526	550 526	550 526
18		246 134	299 197	374 245	507 317	352 272	441 339	530 397	550 408	456 409	508 456	550 490	550 490	550 490	550 490	550 490
19		221 113	268 167	335 207	454 269	315 230	395 287	475 336	550 383	408 347	455 386	547 452	550 455	550 455	550 455	550 455
20		199 97	241 142	302 177	409 230	284 197	356 246	428 287	525 347	368 297	410 330	493 386	550 426	550 426	550 426	550 426
21			218 123	273 153	370 198	257 170	322 212	388 248	475 299	333 255	371 285	447 333	503 373	548 405	550 406	550 406
22			199 106	249 132	337 172	234 147	293 184	353 215	432 259	303 222	337 247	406 289	458 323	498 351	550 385	550 385
23			181 93	227 116	308 150	214 128	268 160	322 188	395 226	277 194	308 216	371 252	418 282	455 307	507 339	550 363
24			166 81	208 101	282 132	196 113	245 141	295 165	362 199	254 170	283 189	340 221	384 248	418 269	465 298	550 346
25						180 100	226 124	272 145	334 175	234 150	260 167	313 195	353 219	384 238	428 263	514 311
26						166 88	209 110	251 129	308 156	216 133	240 148	289 173	326 194	355 211	395 233	474 276
27						154 79	193 98	233 115	285 139	200 119	223 132	268 155	302 173	329 188	366 208	439 246
28						143 70	180 88	216 103	265 124	186 106	207 118	249 138	281 155	306 168	340 186	408 220
29										173 95	193 106	232 124	261 139	285 151	317 167	380 198
30										161 86	180 96	216 112	244 126	266 137	296 151	355 178
31										151 78	168 87	203 101	228 114	249 124	277 137	332 161
32										142 71	158 79	190 92	214 103	233 112	259 124	311 147

2a. #1 – Deck Chart

VULCRAFT

0.6 C, CSV CONFORM

30″ or 35″ or 36″ *

* Check availability with plant

9/16″

NON-COMPOSITE

MAXIMUM CONSTRUCTION CLEAR SPANS (S.D.I. CRITERIA)

Total Slab Depth	Deck Type	Weight PSF	NW Concrete N=9 145 PCF			Weight PSF	LW Concrete N=14 110 PCF		
			1 Span	2 Span	3 Span		1 Span	2 Span	3 Span
2" (t=1 1/2")	0.6C28	23	2- 3	2- 10	2- 11	17	2- 4	3- 0	3- 0
	0.6C26	23	2- 8	3- 5	3- 5	18	2- 9	3- 6	3- 7
	0.6C24	23	3- 4	4- 3	4- 4	18	3- 6	4- 6	4- 7
	0.6C22	23	3- 10	5- 0	5- 1	18	4- 1	5- 4	5- 4
2 1/2" (t=2")	0.6C28	29	2- 2	2- 9	2- 10	22	2- 3	2- 10	2- 11
	0.6C26	29	2- 6	3- 3	3- 4	22	2- 8	3- 5	3- 6
	0.6C24	29	3- 2	4- 1	4- 2	22	3- 4	4- 4	4- 4
	0.6C22	29	3- 8	4- 9	4- 10	23	3- 11	5- 1	5- 2
3" (t=2 1/2")	0.6C28	35	2- 1	2- 8	2- 8	27	2- 2	2- 10	2- 10
	0.6C26	35	2- 5	3- 2	3- 2	27	2- 7	3- 4	3- 4
	0.6C24	35	3- 0	3- 11	4- 0	27	3- 2	4- 2	4- 2
	0.6C22	36	3- 6	4- 7	4- 7	27	3- 9	4- 10	4- 11
3 1/2" (t=3")	0.6C28	41	2- 0	2- 7	2- 7	31	2- 1	2- 9	2- 9
	0.6C26	41	2- 4	3- 0	3- 1	31	2- 6	3- 3	3- 3
	0.6C24	41	2- 10	3- 9	3- 10	32	3- 1	4- 0	4- 1
	0.6C22	42	3- 4	4- 5	4- 5	32	3- 7	4- 8	4- 9
4" (t=3 1/2")	0.6C28	47	1- 11	2- 6	2- 7	36	2- 1	2- 8	2- 8
	0.6C26	47	2- 3	2- 11	3- 0	36	2- 5	3- 2	3- 2
	0.6C24	47	2- 9	3- 8	3- 8	36	3- 0	3- 11	3- 11
	0.6C22	48	3- 2	4- 3	4- 3	36	3- 5	4- 6	4- 7
4 1/2" (t=4")	0.6C28	53	1- 10	2- 5	2- 6	40	2- 0	2- 7	2- 8
	0.6C26	53	2- 2	2- 10	2- 11	40	2- 4	3- 1	3- 1
	0.6C24	53	2- 8	3- 6	3- 7	41	2- 10	3- 9	3- 10
	0.6C22	54	3- 1	4- 1	4- 2	41	3- 4	4- 5	4- 5
5" (t=4 1/2")	0.6C28	59	1- 10	2- 5	2- 5	45	1- 11	2- 6	2- 7
	0.6C26	59	2- 1	2- 9	2- 10	45	2- 3	3- 0	3- 0
	0.6C24	59	2- 7	3- 5	3- 6	45	2- 10	3- 8	3- 9
	0.6C22	60	3- 0	3- 11	4- 0	46	3- 3	4- 3	4- 4

REINFORCED CONCRETE SLAB ALLOWABLE LOADS

Total Slab Depth	Reinforcement W.W.F.	As	Superimposed Uniform Load (psf) — 3 Span Condition, Clear Span (ft.-in.)										
			2- 0	2- 3	2- 6	2- 9	3- 0	3- 3	3- 6	3- 9	4- 0	4- 6	5- 0
2" (t=1 1/2")	6X6-W1.4XW1.4	0.028*	194	153	124	103	86	74	63				
	6X6-W2.1XW2.1	0.042	285	225	183	151	127	108	93				
	6X6-W2.9XW2.9	0.058	384	304	246	203	171	146	125				
2 1/2" (t=2")	6X6-W1.4XW1.4	0.028*	268	212	172	142	119	102	88	76	67	53	
	6X6-W2.1XW2.1	0.042	396	313	254	210	176	150	129	113	99	78	
	6X6-W2.9XW2.9	0.058	400	400	344	284	239	204	176	153	134	106	
3" (t=2 1/2")	6X6-W1.4XW1.4	0.028*	342	271	219	181	152	130	112	97	86	68	
	6X6-W2.1XW2.1	0.042*	400	400	325	268	226	192	166	144	127	100	
	6X6-W2.9XW2.9	0.058	400	400	400	366	307	262	226	197	173	137	
3 1/2" (t=3")	6X6-W2.1XW2.1	0.042*	400	400	396	327	275	234	202	176	155		
	6X6-W2.9XW2.9	0.058*	400	400	400	400	375	320	276	240	211		
	4X4-W2.9XW2.9	0.087	400	400	400	400	400	400	400	353	310		
4" (t=3 1/2")	6X6-W2.1XW2.1	0.042*	400	400	400	384	322	275	237	206	181		
	6X6-W2.9XW2.9	0.058*	400	400	400	400	400	372	321	280	246		
	4X4-W2.9XW2.9	0.087	400	400	400	400	400	400	400	400	358		
4 1/2" (t=4")	6X6-W2.9XW2.9	0.058*	400	400	400	400	400	400	359	313	275		
	4X4-W2.9XW2.9	0.087	400	400	400	400	400	400	400	400	400		
	4X4-W4.0XW4.0	0.120	400	400	400	400	400	400	400	400	400		
5" (t=4 1/2")	6X6-W2.9XW2.9	0.058*	400	400	400	400	400	400	396	345	303		
	4X4-W2.9XW2.9	0.087*	400	400	400	400	400	400	400	400	400		
	4X4-W4.0XW4.0	0.120	400	400	400	400	400	400	400	400	400		
			0.6C28		0.6C26		0.6C24			0.6C22			

NOTES:
1. * As does not meet A.C.I. criterion for temperature and shrinkage.
2. Recommended conform types are based upon S.D.I. criteria and normal weight concrete.
3. Superimposed loads are based upon three span conditions and A.C.I. moment coefficients.
4. Load values for single span and double spans are to be reduced.
5. Superimposed load values in bold type require that mesh be draped. See page 19.
6. Vulcraft's painted or galvanized form deck can be considered as permanent support in most building applications. See page 19. If uncoated form deck is used, deduct the weight of the slab from the allowable superimposed uniform loads.

2b. #2 – Hollow Core Plank System

Floor Redesign #2 Hollow Core Planks

span = 31'-0" w/ 2" topping PCI handbook p. 2-26

LL = 40 psf

$DL = DL_{self} + DL_{topping} = 81\,psf$ ← included in tables

$DL = DL_{mech} + DL_{finishes} + DL_{ceiling} = 4.35 + 4 + 4 + 5.2 = 17.6\,psf \Rightarrow 18\,psf$

superimposed service load = 40 + 18 = 58 psf

try 4HC8 + 2 58-S

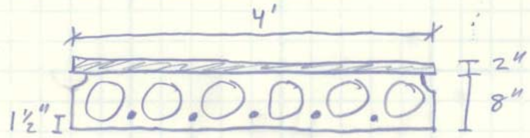
Safe superimposed service load = 71 psf > 58 psf ∴ ok

camber ≈ 0.4"

Use 4LHC8 + 2 58-S Hollow core planks w/ 0.4" camber (4'-0" x 8" x 30'-1' long) (2" topping)

$f'_c = 5000\,psi$

$f'_{ci} = 3500\,psi$



$A = 215\,in^2$

$I = 3071\,in^4$

2b. #2 – PCI Chart

Strand Pattern Designation

76–S

- S = straight
- Diameter of strand in 16ths
- No. of strand (7)

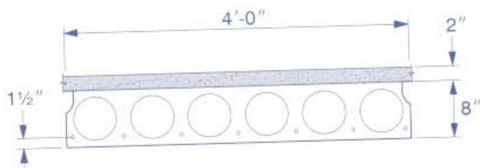
Safe loads shown include dead load of 10 psf for untopped members and 15 psf for topped members. Remainder is live load. Long-time cambers include superimposed dead load but do not include live load.

Capacity of sections of other configurations are similar. For precise values, see local hollow-core manufacturer.

HOLLOW-CORE

4′-0″ x 8″

Normal Weight Concrete



f'_c = 5,000 psi

f'_{ci} = 3,500 psi

Section Properties

		Untopped		Topped	
A	=	215	in²	—	
I	=	1,666	in⁴	3,071	in⁴
y_b	=	4.00	in.	5.29	in.
y_t	=	4.00	in.	4.71	in.
S_b	=	416	in³	580	in³
S_t	=	416	in³	652	in³
b_w	=	12.00	in.	12.00	in.
wt	=	224	plf	324	plf
		56	psf	81	psf
V/S	=	1.92	in.		

Key
- 335 — Safe superimposed service load, psf
- 0.2 — Estimated camber at erection, in.
- 0.3 — Estimated long-time camber, in.

4HC8

No Topping

Table of safe superimposed service load (psf) and cambers (in.)

Strand Designation Code	Span, ft																						
	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
66-S	335	286	246	213	185	162	141	124	109	96	85	75	66	58	50	44	38	33					
	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.1	0.0	0.0	−0.1	−0.2					
	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.1	0.0	−0.1	−0.2	−0.3	−0.5	−0.7					
76-S	375	337	291	252	220	193	170	150	133	118	105	93	83	73	65	58	51	45	39	34			
	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.1	0.0	−0.1	−0.2			
	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.2	0.1	0.0	−0.1	−0.2	−0.4	−0.6	−0.8			
58-S	372	342	317	296	275	255	225	200	179	160	143	128	115	104	93	84	76	68	61	55	49	44	39
	0.3	0.3	0.4	0.4	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.5	0.5	0.5	0.4	0.3	0.2	0.1	0.0	−0.1
	0.4	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.5	0.4	0.3	0.2	0.0	−0.2	−0.4	−0.6	−0.9
68-S		351	326	302	284	266	250	236	218	196	176	159	143	130	117	107	97	88	80	72	65	59	54
		0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.7	0.7	0.6	0.5	0.4
		0.6	0.6	0.7	0.8	0.8	0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.8	0.7	0.6	0.4	0.2	0.0	−0.2
78-S		360	335	311	290	272	256	242	229	215	205	188	170	154	141	128	117	106	97	89	81	74	67
		0.5	0.6	0.6	0.7	0.7	0.8	0.9	0.9	1.0	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.0	0.9	0.9
		0.7	0.8	0.8	0.9	1.0	1.0	1.1	1.2	1.2	1.3	1.3	1.3	1.3	1.3	1.3	1.2	1.2	1.1	1.0	0.9	0.7	0.5

4HC8+2

2″ Normal Weight Topping

Table of safe superimposed service load (psf) and cambers (in.)

Strand Designation Code	Span, ft																						
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
66-S	309	267	231	201	175	153	133	117	102	89	77	67	55	44	33								
	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.1	0.0	0.0	−0.1								
	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.0	−0.1	−0.2	−0.3	−0.4	−0.6	−0.7	−0.9								
76-S		316	275	241	211	185	163	144	127	112	99	87	74	62	50	40	31						
		0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.1	0.0	−0.1						
		0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.1	0.0	−0.1	−0.2	−0.4	−0.5	−0.7	−0.9	−1.2						
58-S			352	317	279	248	220	196	174	156	139	124	111	98	84	71	60	50	40	32			
			0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.5	0.5	0.5	0.4	0.3	0.2	0.1	0.0			
			0.5	0.5	0.5	0.5	0.5	0.4	0.4	0.3	0.3	0.2	0.1	−0.1	−0.2	−0.4	−0.6	−0.9	−1.2	−1.5			
68-S				337	316	297	268	239	215	193	173	156	141	127	114	100	87	75	64	54	45	36	
				0.6	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.7	0.7	0.6	0.5	0.4	0.2	
				0.6	0.6	0.7	0.7	0.7	0.6	0.6	0.6	0.5	0.4	0.3	0.2	0.0	−0.2	−0.4	−0.6	−0.9	−1.2	−1.6	
78-S				346	325	306	286	271	252	227	205	186	168	152	138	124	111	98	86	76	66	56	47
				0.7	0.8	0.9	0.9	1.0	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.0	0.9	0.9	0.7	0.6
				0.8	0.8	0.8	0.9	0.9	0.9	0.9	0.9	0.8	0.8	0.7	0.6	0.5	0.3	0.1	−0.1	−0.3	−0.6	−0.9	−1.3

Strength based on strain compatibility; bottom tension limited to $6\sqrt{f'_c}$; see pages 2-2–2-6 for explanation.

2c. #3 – Concrete Pan Joist System

Floor Redesign #3 Skip Joist System

span = 31'-0 > 30' ± 1'-0" CRSI Handbook 2002

LL = 40 psf

superimposed DL = $DL_{mech} + DL_{FLR} + DL_{clg}$ = 18 psf

factored superimposed load = 1.2 (18 psf) + 1.6 (40 psf) = 85.6 psf

try 30" Form w/ 6" rib. c/c is 36", 16" deep + 3" slab $f'_c = 4000$ psi

#4 bars @ 8" oc top

#5 bars bottom

ext. span @ 31' weight of bars = 1.04 psf above bars only

allowable 115 psf > 85.6 psf ∴ ok

deflection coefficient: 11.119

$$\Delta_L = \frac{Coeff.\,(w_{LL})}{I_g\left(\frac{I_{cr}}{I_{cg}}\right)} = \frac{11.119\,(40\text{ psf})}{7127(.199)} = 0.314 \leq \frac{\ell}{480} = \frac{31 \cdot 12}{480} = 0.775 \therefore ok$$

w_{LL} = 40 psf

w_{conc} = 78 psf

$$\frac{\ell_n}{h} = \frac{31'}{19" \cdot \frac{1'}{12}} = 19.58 > 18.5 \therefore \text{ approx method}$$

$$\Delta_{LL} = \frac{40\text{psf}}{\left(\frac{85.6}{1.6}\right)}\left(\frac{31' \cdot 12}{480}\right) = 0.5796" \nleq \frac{\ell_n}{750} = \frac{31 \cdot 12}{750} = 0.496" \therefore \text{fails @ } \frac{\ell}{750}$$

$$\frac{\ell}{x} = \frac{31 \cdot 12}{x} = 0.5796" \Rightarrow 0.5796" = \frac{\ell}{641} \leq \frac{\ell}{480} \therefore ok$$

31' span

30" One-way Pan Joist w/ 6" ribs, 16" deep + 3" slab

Top bars: #4 bars @ 8" oc

Bottom bars: (1) #5 centered in each rib

2c. #3 – CRSI Chart

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

16" Deep Rib + 3.0" Top Slab = 19.0" Total Depth

BOTTOM BARS	#4 #5	#5 #5	#5 #6	#6 #6	#6 #7	#7 #7	#7 #8	#8 #8	#8 #9	#9 #9	Deflection Coeff. (3)
Steel (psf)	.57	.70	.85	1.00	1.18	1.36	1.57	1.78	2.02	2.27	
CLEAR SPAN	FACTORED USABLE SUPERIMPOSED LOAD (PSF)										
21'-0"	134	186	246	307	380	454					3.602
	0	0	0	0	0	0					
22'-0"	112	160	215	270	337	404	482	540*			4.339
	0	0	0	0	0	0	0	561			
23'-0"	93	137	187	238	299	360	431	504			5.183
	0	0	0	0	0	0	0	0			
24'-0"	77	117	163	209	265	322	387	454			6.145
	0	0	0	0	0	0	0	0			
25'-0"	62	99	141	184	236	288	348	409	465*	479*	7.235
	0	0	0	0	0	0	0	0	474	489*	
26'-0"	49	83	123	162	210	258	314	370	430	453*	8.464
	0	0	0	0	0	0	0	0	0	460*	
27'-0"		69	106	142	187	231	283	335	391	430*	9.844
		0	0	0	0	0	0	0	0	433*	
28'-0"		57	91	125	166	207	255	304	356	409	11.385
		0	0	0	0	0	0	0	0	0	
29'-0"		45	77	109	147	186	231	276	324	374	13.101
		0	0	0	0	0	0	0	0	0	
30'-0"			65	95	130	167	208	251	296	342	15.004
			0	0	0	0	0	0	0	0	
31'-0"			54	82	115	149	188	228	270	314	17.106
			0	0	0	0	0	0	0	0	
32'-0"			44	70	101	133	170	207	247	287	19.423
			0	0	0	0	0	0	0	0	
33'-0"				59	89	119	153	188	226	264	21.967
				0	0	0	0	0	0	0	
34'-0"				49	77	105	138	171	206	242	24.753
				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 ≥ $\ell_n/16$).
(4) Exclusive of bridging joist and tapered ends.
*Controlled by shear capacity. +Capacity at elastic deflection = $\ell_n/360$.

PROPERTIES FOR DESIGN (CONCRETE .52 CF/SF)(4)

POSITIVE MOMENT										
STEEL (SQ. IN.) AREA	.51	.62	.75	.88	1.04	1.20	1.39	1.58	1.79	2.00
STEEL PERCENT	.08	.10	.12	.14	.16	.19	.22	.25	.29	.32
DEPTH, D IN.	17.69	17.69	17.63	17.63	17.56	17.56	17.50	17.50	17.44	17.44
+ICR/IGR	.153	.184	.217	.251	.290	.329	.372	.416	.460	.506

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

16" Deep Rib + 3.0" Top Slab = 19.0" Total Depth

BOTTOM BARS	#4 #5	#5 #5	#5 #6	#6 #6	#6 #7	#7 #7	#7 #8	#8 #8	#8 #9	#9 #9	Deflection Coeff. (3)
Steel (psf)	.55	.68	.83	.97	1.15	1.33	1.53	1.73	1.97	2.21	
CLEAR SPAN	FACTORED USABLE SUPERIMPOSED LOAD (PSF)										
21'-0"	120	171	230	289	360	432					3.702
	0	0	0	0	0	0					
22'-0"	99	146	199	253	318	383	459	536			4.460
	0	0	0	0	0	0	0	0			
23'-0"	81	123	172	222	281	341	410	480			5.327
	0	0	0	0	0	0	0	0			
24'-0"	65	104	149	194	248	304	367	432			6.316
	0	0	0	0	0	0	0	0			
25'-0"	51	86	128	170	220	271	329	389	452	513*	7.436
	0	0	0	0	0	0	0	0	0	517	
26'-0"		71	109	148	194	241	295	351	409	469	8.700
		0	0	0	0	0	0	0	0	0	
27'-0"		57	93	129	172	215	266	317	371	427	10.117
		0	0	0	0	0	0	0	0	0	
28'-0"		45	78	112	151	192	239	286	337	388	11.701
		0	0	0	0	0	0	0	0	0	
29'-0"			65	96	133	171	215	259	306	354	13.465
			0	0	0	0	0	0	0	0	
30'-0"			53	82	117	152	193	234	278	323	15.420
			0	0	0	0	0	0	0	0	
31'-0"			42	69	102	135	173	212	253	295	17.581
			0	0	0	0	0	0	0	0	
32'-0"				58	89	120	155	192	230	270	19.962
				0	0	0	0	0	0	0	
33'-0"				48	76	106	139	173	210	247	22.577
				0	0	0	0	0	0	0	
34'-0"					65	93	124	157	191	226	25.440
					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 ≥ $\ell_n/16$).
(4) Exclusive of bridging joist and tapered ends.
*Controlled by shear capacity. +Capacity at elastic deflection = $\ell_n/360$.

PROPERTIES FOR DESIGN (CONCRETE .55 CF/SF)(4)

POSITIVE MOMENT										
STEEL (SQ. IN.) AREA	.51	.62	.75	.88	1.04	1.20	1.39	1.58	1.79	2.00
STEEL PERCENT	.08	.09	.12	.13	.16	.18	.21	.24	.28	.31
DEPTH, D IN.	17.69	17.69	17.63	17.63	17.56	17.56	17.50	17.50	17.44	17.44
+ICR/IGR	.139	.166	.197	.227	.262	.298	.337	.377	.417	.459

2d. #4 – Waffle Flat Slab System

Floor Redesign #4 Waffle Flat Slab

2way span = 38'-0"

CRSI Handbook 2002

LL = 40 psf

super imposed DL = 18 psf

Factored: 1.2 (18psf) + 1.6 (40psf) = 85.6 psf

Try Waffle Flat Slab System 30"x30" Voids; 6" ribs @36" $f'_c = 4000\,psi$

d = 15"

39'-0" span 100 psf > 85.6 psf ∴ ok

steel (psf) = 3.46 psf

edge col. 24" square w/ shear reinforcement

col. strip
- top: (29) #5 bars spaced evenly along edge
- bottom: (2) #8 per rib
- top interior: (33) #6 bars spaced evenly

middle strip
- Bottom: #6 long bars
  #6 short bars
- Top interior: (15) #5 bars

Moments

edge: $M^- = 412'k$

Midspan: $M^+ = 825'k$

interior: $M^- = 1110'k$

$w_{DL} = 90\,psf$

30"x30" voids: 6" ribs @ 36" Waffle Flat slab 12" deep w/ 3" slab

2d. #4 – CRSI Chart

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

f'_c = 4,000 psi
Grade 60 Bars

SQUARE EDGE PANELS

Total Depth = 15 in. Rib Depth = 12 in. Total Slab Depth = 3 in.

Span c.-c. Columns $\ell_1 = \ell_2$ (ft)	Factored Super-imposed Load (psf)	(1) Steel (psf)	Square Edge Column: $c_1 = c_2$ (in.)	Square Edge Column: γ_f	Square Edge Column: (2) Stirrups	Column Strip: Top Edge No.-size +	Column Strip: Bottom No. Ribs	Column Strip: Bottom Bars per Rib	Column Strip: Top Interior No.-size	Middle Strip: Bottom No. Ribs	Middle Strip: Bottom Long Bars	Middle Strip: Bottom Short Bars	Middle Strip: Top Interior No.-size	Moments: −M Edge (ft-k)	Moments: +M Bot. (ft-k)	Moments: −M Int. (ft-k)
21'- 0" D= 9.500 RIB NOT ON COLUMN LINE 0.720 CF/SF	50	1.84	12	0.674		15-#5+ 0	4	2-#4	15-#5	3	#4	#4	6-#5	51	101	136
	100	1.84	12	0.700		15-#5+ 0	4	2-#4	15-#5	3	#4	#4	6-#5	64	134	173
	150	1.95	12	0.726		15-#5+ 0	4	1-#4 and 1-#5	15-#5	3	#4	#5	6-#5	78	182	210
	200	2.01	12	0.752		15-#5+ 0	4	2-#5	15-#5	3	#4	#5	6-#5	92	226	247
	300	2.42	12	0.803		15-#5+ 0	4	2-#6	15-#5	3	#5	#6	6-#5	119	311	320
	400	2.77	12 *	0.855		15-#5+ 0	4	1-#6 and 1-#7	16-#5	3	#6	#7	6-#5	146	395	394
	500	3.29	12 *	0.637		15-#5+ 0	4	1-#7 and 1-#8	14-#6	3	#7	#7	6-#5	173	477	467
24'- 0" D= 9.500 RIB NOT ON COLUMN LINE 0.692 CF/SF	50	1.87	12	0.750		18-#5+ 0	4	2-#4	18-#5	4	#4	#4	7-#5	75	150	203
	100	1.92	12	0.779		18-#5+ 0	4	1-#4 and 1-#5	18-#5	4	#4	#4	7-#5	96	200	258
	150	2.14	12	0.807		18-#5+ 0	4	1-#5 and 1-#6	18-#5	4	#4	#5	7-#5	117	271	314
	200	2.32	12	0.835		18-#5+ 0	4	2-#6	18-#5	4	#5	#5	7-#5	137	337	369
	300	2.97	12 *	0.892		18-#5+ 0	4	1-#7 and 1-#8	20-#5	4	#6	#6	7-#5	178	466	480
	400	3.44	12 *	0.637		18-#5+ 0	4	2-#8	17-#6	4	#6	#7	8-#5	220	593	591
	500	4.31	15 *	0.633		18-#5+ 0	4	2-#9	20-#6	4	#7	#8	7-#6	258	709	695
27'- 0" D= 9.500 RIB NOT ON COLUMN LINE 0.673 CF/SF	50	1.96	13	0.776		20-#5+ 0	4	2-#5	20-#5	5	#4	#4	8-#5	106	213	286
	100	2.06	13	0.809		20-#5+ 0	4	1-#5 and 1-#6	20-#5	5	#4	#4	8-#5	136	277	366
	150	2.35	13	0.843		20-#5+ 0	4	1-#6 and 1-#7	20-#5	5	#4	#5	8-#5	165	380	445
	200	2.76	13 *	0.876		20-#5+ 0	4	1-#7 and 1-#8	21-#5	5	#5	#6	8-#5	195	474	524
	300	3.54	13 *	0.635		20-#5+ 0	4	1-#8 and 1-#9	20-#6	5	#6	#7	9-#5	254	658	683
	400	4.50	17 *	0.630		20-#5+ 1	4	1-#9 and 1-#10	25-#6	5	#7	#7	8-#6	309	827	831
	500	5.06	21 *	0.626	4 S 6 1	20-#5+ 1	4	2-#10	29-#6	5	#7	#8	9-#6	356	921	958
30'- 0" D=12.500 RIB ON COLUMN LINE 0.705 CF/SF	50	1.96	15	0.782		22-#5+ 0	5	2-#5	22-#5	5	#4	#4	9-#5	148	296	399
	100	2.24	15	0.829		22-#5+ 1	5	2-#6	22-#5	5	#4	#5	9-#5	188	377	507
	150	2.68	15 *	0.882		22-#5+ 4	5	2-#7	25-#5	5	#5	#6	9-#5	229	512	616
	200	3.18	15 *	0.924		22-#5+ 7	5	1-#7 and 1-#8	21-#6	5	#6	#6	10-#5	269	640	724
	300	4.36	19 *	0.628		22-#5+ 3	5	2-#9	28-#6	5	#7	#8	9-#6	345	881	930
	400	5.04	23 *	0.625	4 S 6 1	22-#5+ 5	5	1-#9 and 1-#10	34-#6	5	#8	#8	11-#6	414	1010	1114
33'- 0" D=12.500 RIB ON COLUMN LINE 0.687 CF/SF	50	2.25	16	0.814		25-#5+ 0	5	2-#6	25-#5	6	#4	#5	10-#5	196	391	526
	100	2.46	16 *	0.868		25-#5+ 2	5	1-#6 and 1-#7	28-#5	6	#5	#5	10-#5	249	499	671
	150	3.18	16 *	0.917		25-#5+ 5	5	2-#8	24-#6	6	#6	#6	11-#5	303	662	816
	200	3.76	18 *	0.629		25-#5+ 2	5	1-#8 and 1-#9	28-#6	6	#6	#7	13-#5	355	827	956
	300	4.96	24 *	0.624	4 S 6 1	25-#5+ 5	5	2-#10	37-#6	6	#7	#8	12-#6	451	1066	1213
36'- 0" D=12.500 RIB ON COLUMN LINE 0.673 CF/SF	50	2.34	18	0.825		27-#5+ 1	5	1-#6 and 1-#7	28-#5	7	#4	#5	11-#5	251	502	676
	100	2.89	18 *	0.893		27-#5+ 6	5	1-#7 and 1-#8	26-#6	7	#5	#5	12-#5	321	642	864
	150	3.60	19 *	0.628		27-#5+ 3	5	1-#8 and 1-#9	31-#6	7	#6	#6	10-#6	389	798	1049
	200	4.36	23 *	0.625	4 S 6 1	27-#5+ 4	5	1-#9 and 1-#10	37-#6	7	#6	#7	12-#6	454	1003	1223
39'- 0" D=15.500 RIB NOT ON COLUMN LINE 0.697 CF/SF	50	2.72	19 *	0.877		29-#5+ 8	6	2-#7	36-#5	7	#5	#6	12-#5	325	649	874
	100	3.46	20 *	0.916		29-#5+11	6	2-#8	33-#6	7	#6	#6	15-#5	412	825	1110
	150	4.03	24 *	0.624		29-#5+ 7	6	1-#8 and 1-#9	40-#6	7	#6	#7	13-#6	496	992	1336

SQUARE INTERIOR PANELS

Total Depth = 15 in. Rib Depth = 12 in. Total Slab Depth = 3 in.

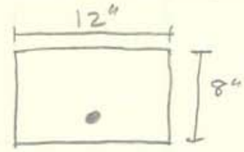
Span c.-c. Columns $\ell_1 = \ell_2$ (ft)	Factored Super-imposed Load (psf)	(1) Steel (psf)	Square Interior Column: $c_1 = c_2$ (in.)	Square Interior Column: (2) Stirrups	Column Strip: Bottom No. Ribs	Column Strip: Bottom Bars per Rib	Column Strip: Top Interior No.-size	Middle Strip: Bottom No. Ribs	Middle Strip: Bottom Long Bars	Middle Strip: Bottom Short Bars	Middle Strip: Top Interior No.-size
21'- 0"	50	1.82	12		4	2-#4	15-#5	3	#4	#4	6-#5
	100	1.82	12		4	2-#4	15-#5	3	#4	#4	6-#5
	150	1.82	12		4	2-#4	15-#5	3	#4	#4	6-#5
	200	1.82	12		4	2-#4	15-#5	3	#4	#4	6-#5
	300	2.11	12		4	2-#5	15-#5	3	#4	#5	6-#5
	400	2.35	12	4 S 6 1	4	1-#5 and 1-#6	15-#5	3	#5	#5	6-#5
	500	2.73	12 *	4 S 6 1	4	2-#6	18-#5	3	#5	#6	6-#5
24'- 0"	50	1.86	12		4	2-#4	18-#5	4	#4	#4	7-#5
	100	1.86	12		4	2-#4	18-#5	4	#4	#4	7-#5
	150	1.95	12		4	1-#4 and 1-#5	18-#5	4	#4	#4	7-#5
	200	2.05	12		4	2-#5	18-#5	4	#4	#4	7-#5
	300	2.49	12 *	4 S 6 1	4	2-#6	18-#5	4	#5	#5	7-#5
	400	2.97	12 *	4 S 6 1	4	1-#6 and 1-#7	16-#6	4	#5	#6	7-#5
	500	3.76	12 *	4 S 6 1	4	1-#7 and 1-#8	19-#6	4	#6	#6	9-#5
27'- 0"	50	1.86	13		4	2-#4	20-#5	5	#4	#4	8-#5
	100	1.94	13		4	1-#4 and 1-#5	20-#5	5	#4	#4	8-#5
	150	2.13	13	4 S 6 1	4	1-#5 and 1-#6	20-#5	5	#4	#4	8-#5
	200	2.33	13	4 S 6 1	4	2-#6	20-#5	5	#4	#5	8-#5
	300	2.99	13 *	4 S 6 1	4	2-#7	26-#5	5	#5	#5	8-#5
	400	4.05	13 *	4 S 6 2	4	2-#8	23-#6	5	#6	#6	8-#6
	500	4.58	18 *	4 S 6 2	4	1-#8 and 1-#9	27-#6	5	#6	#6	9-#6
30'- 0"	50	1.85	15		5	2-#4	22-#5	5	#4	#4	9-#5
	100	2.03	15		5	2-#5	22-#5	5	#4	#4	9-#5
	150	2.28	15		5	1-#5 and 1-#6	23-#5	5	#4	#5	9-#5
	200	2.84	15 *	4 S 6 1	5	1-#6 and 1-#7	28-#5	5	#5	#5	9-#5
	300	3.86	15 *	4 S 6 1	5	1-#7 and 1-#8	26-#6	5	#6	#6	12-#5
	400	4.53	20 *	4 S 6 2	5	2-#8	31-#6	5	#6	#7	10-#6
33'- 0"	50	2.06	16		5	2-#5	25-#5	6	#4	#4	10-#5
	100	2.16	16	4 S 6 1	5	1-#5 and 1-#6	25-#5	6	#4	#4	10-#5
	150	2.69	16 *	4 S 6 1	5	1-#6 and 1-#7	31-#5	6	#4	#5	10-#5
	200	3.35	16 *	4 S 6 1	5	2-#7	26-#6	6	#5	#6	12-#5
	300	4.39	19 *	4 S 6 2	5	2-#8	35-#6	6	#6	#6	11-#6
36'- 0"	50	2.14	18		5	1-#5 and 1-#6	27-#5	7	#4	#4	11-#5
	100	2.64	18 *	4 S 6 1	5	1-#6 and 1-#7	33-#5	7	#4	#5	11-#5
	150	3.24	18 *	4 S 6 1	5	2-#7	29-#6	7	#5	#5	13-#5
	200	3.99	18 *	4 S 6 2	5	2-#8	35-#6	7	#5	#6	11-#6
39'- 0"	50	2.37	19		6	1-#5 and 1-#6	33-#5	7	#4	#5	12-#5
	100	3.13	19 *	4 S 6 1	6	1-#6 and 1-#7	31-#6	7	#5	#5	14-#5
	150	3.73	19 *	4 S 6 1	6	2-#7	38-#6	7	#5	#6	12-#6

See the notes on Page 11-19.

2e. #5 – Pre-Stress Slab

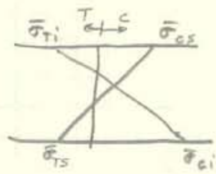
Floor Redesign #5 | Prestressed Slab

Unit strip method.



$L = 31'$
$w_{LL} = 40\ plf$
$w_{DL} = 100 + 18\ plf = 118\ plf$
$f'_c = 4000\ psi$
$f'_{ci} = 3500\ psi$

$\Omega = 0.838$
$I = \frac{1}{12}(8)^3(12) = 512\ in^4$
$A = 96\ in^2$



$\bar{\sigma}_{Ti} = -3\sqrt{f'_{ci}} = -3\sqrt{3500} = -177.5\ psi$
$\bar{\sigma}_{ci} = 0.6\ f'_{ci} = 0.6(3500) = 2100\ psi$
$\sigma_{cs} = 0.6\ f'_c = 0.6(4000) = 2400\ psi$
$\sigma_{cs\ sus} = 0.45\ f'_c = 0.45(4000) = 1800\ psi$
$\sigma_{TS} = -7.5\sqrt{f'_c} = -7.5\sqrt{4000} = -474.3\ psi$

$y_t = y_b = 4"$ $\qquad$ $d_{c\ min} = cover = 1.5"$

8" slab w/ (2) 7-strand wire ($A_s = 0.153\ in^2$) per 12" and no shear reinforcement.

2e. #5 – Feasibility Domain

Robert Whitaker			k_b (in)	1.78	σ_{ti} (ksi)	-0.178
CE 543			k_t (in)	-1.07	σ_{ci} (ksi)	2.1
	L (ft)	*31*	Z_b (in^3)	102.4	σ_{ts} (ksi)	-0.474
	w_{LL} (plf)	*40*	Z_t (in^3)	170.667	σ_{cs} (ksi)	2.4
	w_{GL} (plf)	*118*	η	0.838	$\sigma_{cs\ sus}$ (ksi)	1.8
	w_{SDL} (plf)	*0*	I (in^4)	512	y_t (in)	3
end(*)	M_{min} (" k)	0	M_{min} ("k)	170.097	y_b (in)	5
	M_{max} (" k)	0	M_{max} ("k)	227.757	$(d_c)_{min}$ (in)	1.5
	M_{sus} (" k)	0	M_{sus} (" k	170.1	$(ec)_{MP}$ (in)	3.5
			A_c (in²)	96	f_{pu} (ksi)	270
Intersection of line			f'c (psi)	4000	f_{pi} (ksi)	216
IV	and	V	f'ci (psi)	3500	f_{py} (ksi)	243
			Fi_{min} (k)	46.8239	f_{pe} (ksi)	181.01
			Calculated			

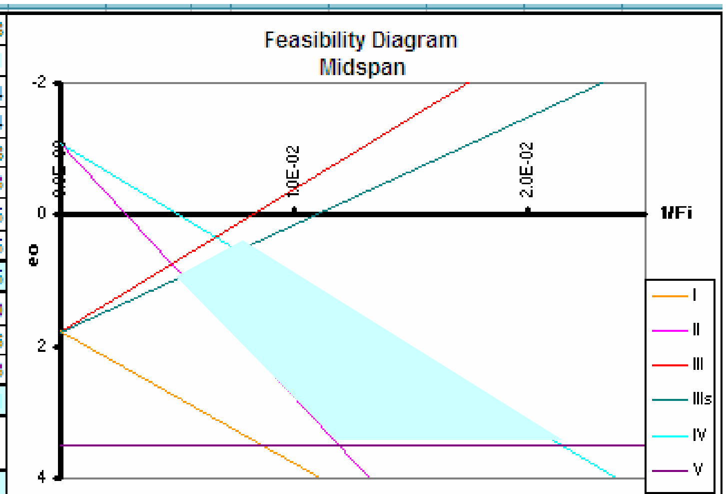
M(+)		midspan
I	$e_o<k_b+(1/F_i)*(M_{min}-\sigma_{ti}*Z_t)$ =	1.78 + (1/Fi) * 200.39
II	$e_o<k_t+(1/F_i)*(M_{min}+\sigma_{ci}*Z_b)$ =	-1.07 + (1/Fi) * 385.14
III	$e_o>k_b+(1/F_i)*(M_{max}-\sigma_{cs}*Z_t)/\eta$ =	1.78 + (1/Fi) * -217
IIIs	$e_o>k_b+(1/F_i)*(M_{sus}-\sigma_{cs\ sus}*Z_t)/\eta$ =	1.78 + (1/Fi) * -163.6
IV	$e_o>k_t+(1/Fi)*(M_{max}+\sigma_{ts}*Z_b)/\eta$ =	-1.07 + (1/Fi) * 213.83
V	$e_o<(e_c)_{mp}$ =	3.5

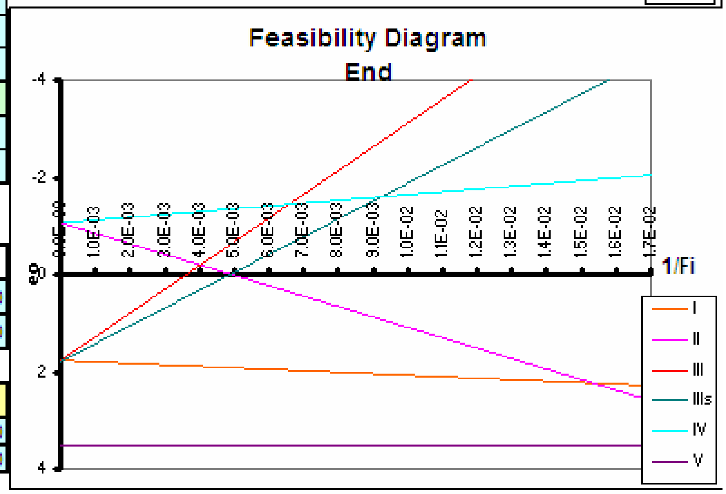
Midspan M(+)

1/Fi	I	II	III	IIIs	IV	V
-0.01	-0.2	-4.91804	3.94774	3.41385	-3.20	3.50
0.05	11.8	18.19018	-9.072	-6.4026	9.62	3.50

End M(+)

1/Fi	I	II	III	IIIs	IV	V
-0.01	1.5	-3.21707	6.66561	5.44365	-0.49	3.50
0.05	3.3	9.685333	-22.661	-16.552	-3.96	3.50



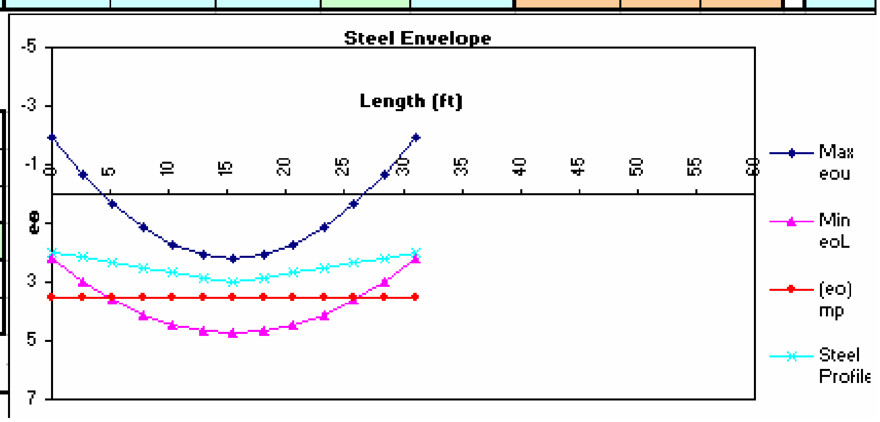


2e. #5 – Tendon Profile

Robert Whitaker	W_{min} plf	118	W_{LL} plf	40	L (ft)	31	Fi_{min} (k)	46.824	$strand_{min}$	2
Distributed Load	W_{max} plf	158	W_{GL} plf	118	e_1 (in)	2	Fi (ksi)	66.096	# strand	2
M(x)=wx(l-x)/2	W_{sus} plf	118	W_{SDL} plf	0	e_2 (in)	3	As_1 (in^2)	0.153	Aps (in^2)	0.306

M_{min} (" k)	M_{max} (" k)	M_{sus} (" K)	Dist (ft)	I eo<	II eo<	III eo>	III-sust eo>	IV eo>	Min eo_L	Max eo_u	$(eo)_{mp}$	Steel Profile
0	0	0.0	0	2.24	2.19	-5.62	-3.77	-1.94	2.19	-1.94	3.50	2.00
52.0	69.6	52.0	2.6	3.02	2.97	-4.36	-2.83	-0.69	2.97	-0.69	3.50	2.17
94.5	126.5	94.5	5.2	3.67	3.62	-3.33	-2.06	0.34	3.62	0.34	3.50	2.33
127.6	170.8	127.6	7.8	4.17	4.12	-2.53	-1.47	1.14	4.12	1.14	3.50	2.50
151.2	202.5	151.2	10	4.52	4.47	-1.96	-1.04	1.71	4.47	1.71	3.50	2.67
165.4	221.4	165.4	13	4.74	4.69	-1.62	-0.78	2.05	4.69	2.05	3.50	2.83
170.1	227.8	170.1	16	4.81	4.76	-1.51	-0.70	2.17	4.76	2.17	3.50	3.00
165.4	221.4	165.4	18	4.74	4.69	-1.62	-0.78	2.05	4.69	2.05	3.50	2.83
151.2	202.5	151.2	21	4.52	4.47	-1.96	-1.04	1.71	4.47	1.71	3.50	2.67
127.6	170.8	127.6	23	4.17	4.12	-2.53	-1.47	1.14	4.12	1.14	3.50	2.50
94.5	126.5	94.5	26	3.67	3.62	-3.33	-2.06	0.34	3.62	0.34	3.50	2.33
52.0	69.6	52.0	28	3.02	2.97	-4.36	-2.83	-0.69	2.97	-0.69	3.50	2.17
0.0	0.0	0.0	31	2.24	2.19	-5.62	-3.77	-1.94	2.19	-1.94	3.50	2.00

M(+)	
I	$e_o<k_b+(1/F_i)*(M_{min}-\sigma_{ti}*Z_t)$
II	$e_o<k_t+(1/F_i)*(M_{min}+\sigma_{ci}*Z_b)$
III	$e_o>k_b+(1/F_i)*(M_{max}-\sigma_{cs}*Z_t)/\eta$
IIIs	$e_o>k_b+(1/F_i)*(M_{sus}-\sigma_{cs\ sus}*Z_t)/\eta$
IV	$e_o>k_t+(1/Fi)*(M_{max}+\sigma_{ts}*Z_b)/\eta$
V	$e_o<(e_o)_{mp}$



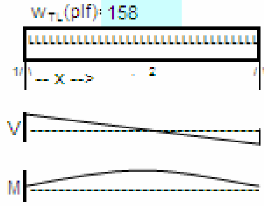
2e. #5 – Shear Reinforcement

(other section properties on FD sheet)

Robert Whitaker
CE 543

w_{LL} (plf)	40		
w_{GL} (plf)	118		
w_{SDL}(plf)	0		
L (ft)	31	h (in)	8
f'c (psi)	4000		
e_1 (in)	2	e_2(in)	3
b_w (in)	12		
λ	1	Φ	0.75

w_{TL}(plf): 158



V_{max} (k)=	2.449	F (k) =	55.388
M_{max}("k)=	227.76	α ($_{deg}$)=	0.308

Prestress Strands

7 Wire Strand (Grade 270)			
f_{py} (ksi)	243	#strand	2
A_{1ps}(in²)	0.153	A_{ps}(in²)	0.306

Stirrups

# 3 'U'-shape	
f_y (ksi)	60
A_v(in²)	0.22

e_o (in)	x (ft)	d_p	V_G (k)	V_{LL} (k)	V_{SDL} (k)	ΔV_u (k)	V_u (k)	V_p (k)	V_{ci} (k)	$V_{ci\,min}$ (k)	V_{cw} (k)	V_c (k)	A_v (in²)	A_v (in²)	A_v (in²	A_{vmin}(in²	A_v
2.02	####	6.4	1.79	0.6	0.00	0.97	3.12	0.298	54.82	8.26	30.59	*30.6*	n/a	n/a	n/a	0.00	ok
2.20	3.1	6.4	1.46	0.5	0.00	0.79	2.55	0.298	8.17	8.26	30.59	*8.3*	n/a	n/a	n/a	0.00	ok
2.40	6.2	6.4	1.10	0.4	0.00	0.60	1.91	0.298	5.24	8.26	30.59	*8.3*	n/a	n/a	n/a	0.00	ok
2.60	9.3	6.4	0.73	0.2	0.00	0.40	1.27	0.298	4.15	8.26	30.59	*8.3*	n/a	n/a	n/a	0.00	ok
2.80	12.4	6.4	0.37	0.1	0.00	0.20	0.64	0.298	3.48	8.26	30.59	*8.3*	n/a	n/a	n/a	0.00	ok
3.00	15.5	6.4	0.00	0.0	0.00	0.00	0.00	0.298	2.91	8.26	30.59	*8.3*	n/a	n/a	n/a	0.00	ok

* dp of prestress steel

x (ft)	$S_{MX\,no}$	$S_{MX\,yes}$	$M_{(x)}$("k)	ΔM_{cr}("k)	ΔM_u("k)	$V_{s\,max}$(k)	V_s (k)	$V_s<V_{sm}$	$V_u<.5\Phi V_c$	S (in)	V_{s2} (k)	4f'c^.5bd	S_{MAX}
####	6	3	9.7	202.7	3.9253	38.86	-26.43	ok	no V reinf	N/A	n/a	19429	3
3	n/a	n/a	82.0	158.6	33.212	38.86	-4.86	ok	no V reinf	N/A	n/a	19429	n/a
6	n/a	n/a	145.8	122.0	59.044	38.86	-5.71	ok	no V reinf	N/A	n/a	19429	n/a
9	n/a	n/a	191.3	99.1	77.495	38.86	-6.56	ok	no V reinf	N/A	n/a	19429	n/a
12	n/a	n/a	218.6	89.7	88.566	38.86	-7.41	ok	no V reinf	N/A	n/a	19429	n/a
16	n/a	n/a	227.8	94.0	92.256	38.86	-8.26	ok	no V reinf	N/A	n/a	19429	n/a

x (ft)	#stirrups	per	Spacing (in)
0.333	0	per	3
3.1	0	per	0
6.2	0	per	0
9.3	0	per	0
12.4	0	per	0
15.5	0	per	0