St. Elizabeth Hospital Boardman Campus Inpatient Facility

Boardman, Ohio

Josh Behun

Structural Option

Technical Report #2
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Table of Contents

Executive Summary

The purpose of this report is to analyze the current floor system in place at the St. Elizabeth Hospital Inpatient Facility and compare it against a few possible alternative systems, determining if another system may be a more reasonable solution, and if so, by what means.

Existing Floor System

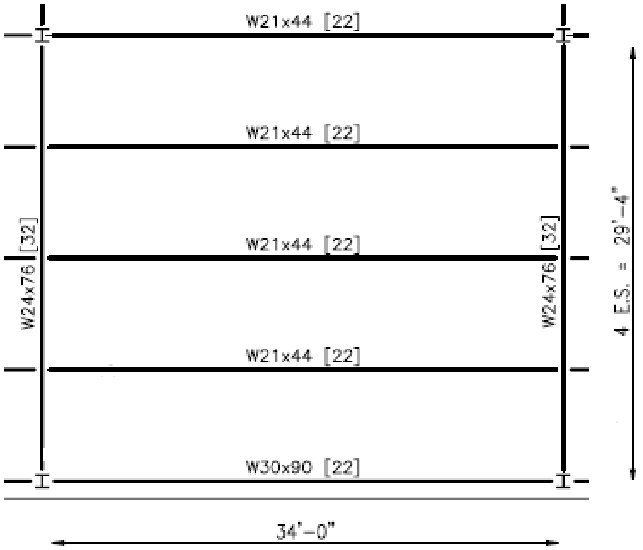
The current floor system of the St. Elizabeth Boardman Hospital is a two-way slab system comprised of a 4" light weight concrete slab on 2" – 20 gage galvanized composite decking with 5" long ¾" diameter shear studs and a 6x6-W2.1xW2.1 welded wire fabric reinforcement system. The framing for the buildings super majority of the beams for the floor framing are 21" in depth with a typical span of 34', while the girders for the building are sized on average at W30x90 where the façade is brick and W18x40 where the outer façade is the aluminum panel curtain wall system. The floor to floor height of each story two through seven is 14'-8" tall, while the floor to floor height for the ground floor is 15'-4" in height.

Alternative Systems

The alternative systems that have been analyzed for comparison are as follows:

- Non-composite lightweight slab on steel framing.
- Two-way slab with drop panels.
- Hollowcore planks on steel framing.
- Waffle slab.

The alternative systems analyzed were calculated using the typical 34'x 29'-4" bay shown here.



Conclusion

Due to the building's shape and layout it seems as though a concrete structural system would not be an acceptable alternative without making some minor, if not substantial, changes to the building plan and column grid system. Though the concrete design alternatives do offer smaller floor thicknesses, building height doesn't seem to pose an issue for the hospital's location. The best system for the existing design appears to be the one currently in place. Steel framing systems allow for much more flexibility in design and can be built to suit most situations. Though some analysis and design to resist vibration concerns as well as additional fireproofing must be accounted for with steel designs, to meet the architectural layout provided steel would be most effective.

Structural System Overview

Foundation

The foundation for the St. Elizabeth Hospital Inpatient Facility consists of 16” diameter auger cast grout injected piles with a capacity of 50 tons and an f’c of 4000 psi, including (4) #6 vertical bars for the top 20’ of the piles and #3 ties spaced at 16” on center. The vertical reinforcement from each pile is to extend 18” into its corresponding pile cap or grade beam with a 90° hook of 2’-0” in length. Several of the column piers will be constructed on existing footings, subsequent reinforcement bars are to be drilled and grouted into the existing footing with Hilti epoxy adhesives, providing a minimum embedment of 8”.

Floor System

The floor system of the St. Elizabeth Hospital Inpatient Facility is a two-way slab system comprised of a 4” light weight concrete slab on 2” – 20 gage galvanized composite decking with 5” long ¾” diameter shear studs and a 6x6-W2.1xW2.1 welded wire fabric reinforcement system. The majority of the beams for the floor framing are 21” in depth with a typical span of 34’. On the first two floors, the new addition’s floor systems are connected to the existing floor slabs as well as the masonry walls by ½” diameter Hilti adhesive anchors spaced at 24” on center, with a minimum embedment of 4½”.

Superstructure

The framing for the structural system consists by in large of wide flange structural steel members. The typical column size for the building is within the range of W12x40 to W12x136, while there are a minimal number of W10 and W14 columns throughout the atypical areas of the new addition. The girders for the building are on average W30x90 where the façade is brick and W18x40 where the outer façade is the aluminum panel curtain wall system. The floor to floor height of each story two through seven is 14’-8” tall while the floor to floor height for the first floor is 15’-4” in height.

Lateral System

The bracing system for the lateral load resistance consists of several types of bracings on each story comprised of HSS members, including chevron braces, knee braces, and cross braces.

Roof System

The roofing system is a flat roof which consists of structural steel members similar to that of the floor system. The area where the HVAC units rest has a slab of 4½” light weight concrete on 2”- 20 gage galvanized composite decking with 6x6-W2.1xW2.1 welded wire fabric reinforcement. While the remainder of the roof area, including the penthouse roof, is constructed of 1½”-20 gage galvanized wide ribbed steel roof deck.

Design Loads

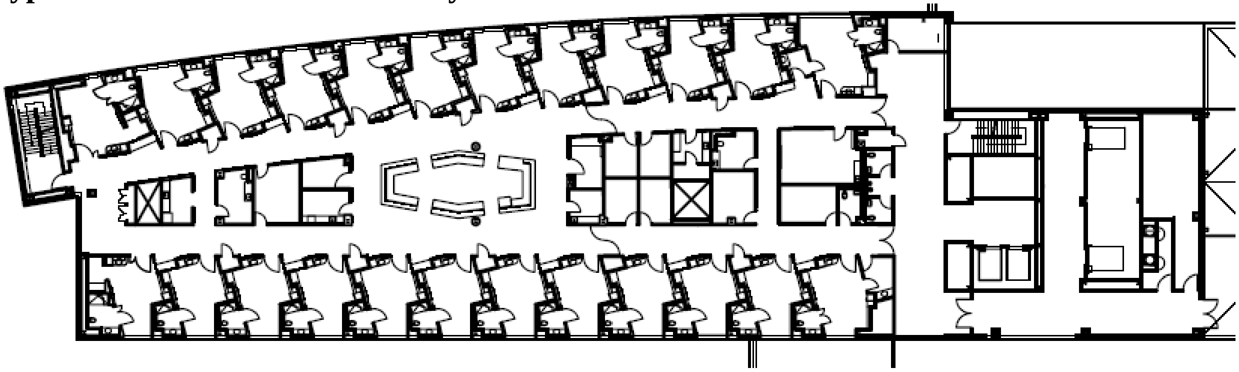
Dead Loads

	First Floor	Second Floor	Typical Floors Above	Roof
Concrete Slab	46 psf	46 psf	46 psf	52.5 psf
Metal Decking	2 psf	2psf	2 psf	2 psf
Steel Members	70 psf	70 psf	70 psf	62 psf
Partitions	20 psf	20 psf	20 psf	----
Collateral	20 psf	20 psf	20 psf	----
Total Area				
Total Weight				

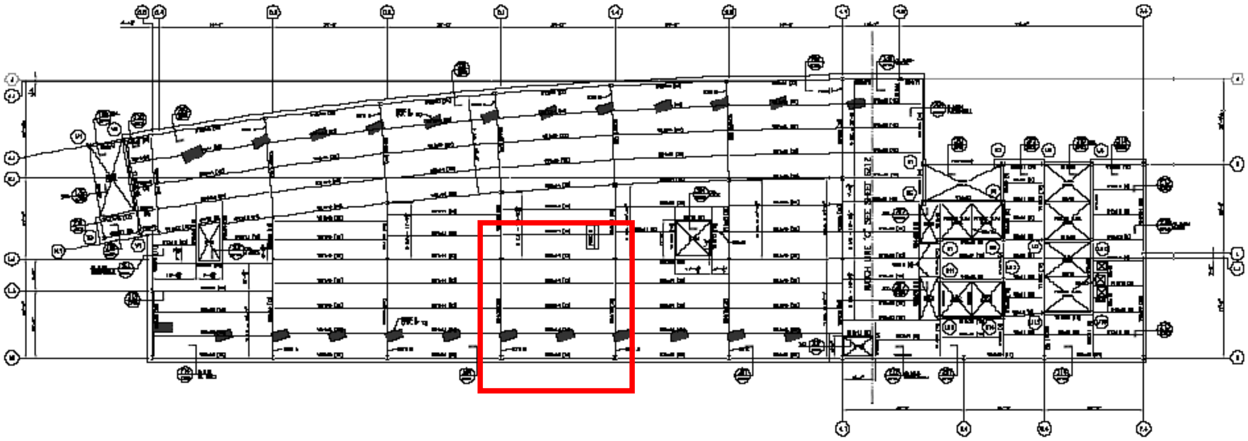
Live Loads

Roof	30 psf
Public Areas	100 psf
Lobbies	100 psf
First Floor Corridors	100 psf
Corridors Above First Floor	80 psf
Patient Rooms	60 psf
Light Storage	125 psf
Catwalks	25 psf
Mechanical	175 psf
Stairs	100 psf

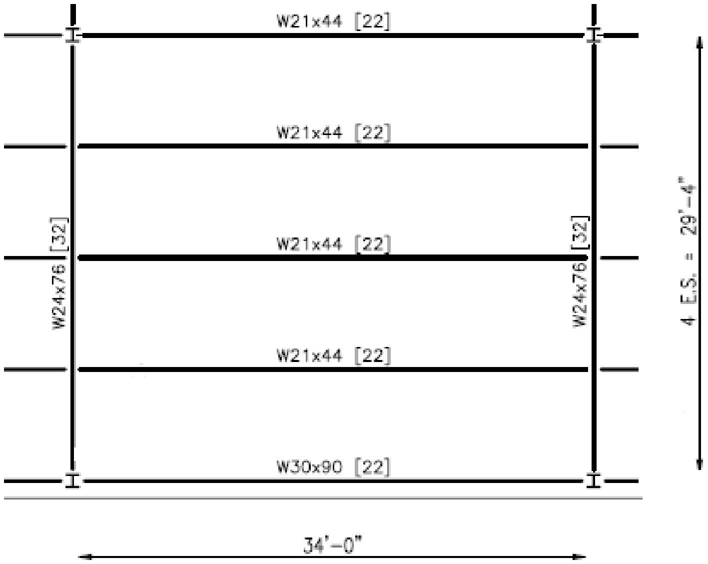
Typical Floor Plan for Seven Story Addition



Typical Framing Plan for Seven Story Addition



Typical Bay Along Exterior Wall Featuring Brick Façade

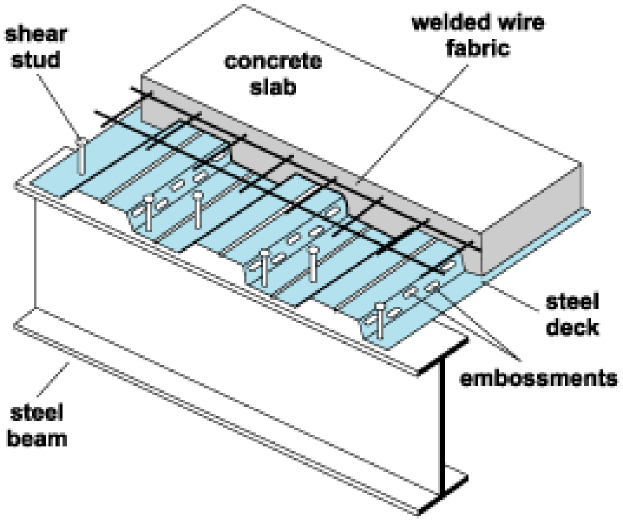


Non-Composite Lightweight Slab on Steel Framing

The first alternative system analyzed is one quite similar to the system currently in place at the hospital. This non-composite slab system is a concrete slab that is placed directly onto 2"-20 gage steel decking spanning across simply supported steel joists which then transfer respective loads into girders and so on. The one main difference between this system and the one currently in use within the hospital is the component that creates the composite action in the original design, the shear studs used in the flooring system.

Advantages

The main advantage to using a non-composite slab system is the lack of shear studs being used in the floor system. First of all, not having shear studs causes the construction process to be simpler, lowering construction costs for both material and labor. Also, the lack of studs lowers the dead load of the floor system, making a lessening of the beam and girder sizes possible. In general, with the exception of any amount of lead time, steel erection can be a very quick process



Disadvantages

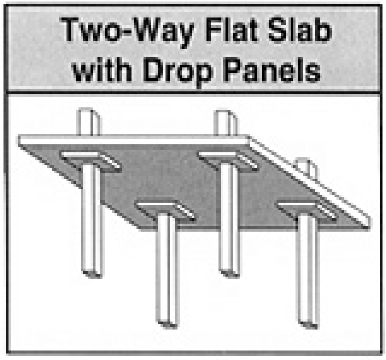
One main disadvantage with steel is that there is a greater possibility for vibration issues to arise in a steel framing system, especially when the steel and concrete slabs aren't used in composite action as in this redesign. Also, as in the original design, the steel beams will require some amount of additional fireproofing to ensure that they can resist any deflection that would occur due to extreme heat during a fire.

Two-Way Slab with Drop Panels

This alternative flooring system is an entirely concrete structural system with steel reinforcing bars spanning in both the latitudinal and longitudinal directions. For analysis purposes the column grid is laid out in a three bay system spanning the short (North-South) direction, with columns in the long (East-West) direction spaced at every 34' on center. The two end bays in the short direction span a length of 29'-4" and have a slab thickness of 10¼", while the interior bay spans 24'-0" and can support a floor system with a slab thickness of 7½". Each column in the system is sized at 14"x14" and has a drop panel of 10'x10' at either 6" or 8.5" in thickness respectively, making the maximum floor depth of the system a total of 16.5".

Advantages

Floor systems consisting of a completely structural concrete design system for the most part can allow for the use of a thinner floor in comparison to a slab on steel framing system. This design certainly does just that, cutting off nearly 20 inches of depth from the current floor system, leaving room for the ceiling system to hide mechanical or electrical equipment.



Disadvantages

In comparison, the drop panel system seems to be a much heavier flooring method than the systems that utilize steel framing components. In addition, the construction of slabs with drop panels requires a more complicated construction process due to complex framing situations and a lengthier schedule for setting and curing. Also, a change in the column size and or layout may be required to successfully attain the maximum efficiency of the drop panel system. Furthermore, the drop panels can potentially be an obstruction to mechanical and electrical operations running through the ceilings or architectural features within the hospital.

Once all of the initial design parameters were established, this design was prepared using two different methods. The initial technique used for designing the floor system was the equivalent frame method, done by hand, to determine the necessary reinforcing for the short direction of the slab. Following that a computer program known as PCAslab, which also produces the equvalent frame method, was run to determine the reinforcing requirements for the long direction.

A second design of this system was analyzed using a third deisgn method; the tables in the CRSI Design Handbook, which yield a slightly different design approach to the floor system, including slab and panel thicknesses as well as bar sizes and quantity and column sizes. This third design method considers the bays being analyzed to be perfectly square, which is not the assumption followed in the initial design for this dissertation.

Each design method used is based upon different assumptions, and thus may bear differing design dimensions, but there are many methods used to solve similar situations, showing that each system could possibly work as a viable solution.

Hollowcore Planks

The next possible alternative proposed is pre-cast hollowcore planks. The design specifications for the hollowcore flooring planks used in this report come from Nitterhouse Concrete Products, Inc. All design tables are made available on their website at www.nitterhouse.com. The planks produced at Nitterhouse are pre-cast/pre-stressed planks constructed with normal weight, high strength concrete utilizing a minimum f'c of 5000 psi. The planks are leveled and prepared for a floor finish using a 2" cast in place slab topping, which varies in thickness across the plank due to the amount of camber but also provides a two hour fire-resistance rating.

Advantages

The main advantage of using the hollowcore floor system is the lack of a need for interior beams within the floor framing system, because the planks are capable of crossing long spans, joist-like intermittent beams are not necessary, thus using much less steel throughout the floor system. Another benefit of the hollowcore planks is the ease of constructability, through all seasons. The planks are pre-cast concrete that simply need to be hoisted and set into place, quickening the erection time and reducing on-site labor requirements. Also, hence the name, the planks have large continuous voids spanning through their centers, reducing concrete weight and cost, while leaving room for mechanical or electrical equipment runs. Lastly, the plank system works with the current framing plan in place, so no addition design would be required to support the plank system.

Disadvantages

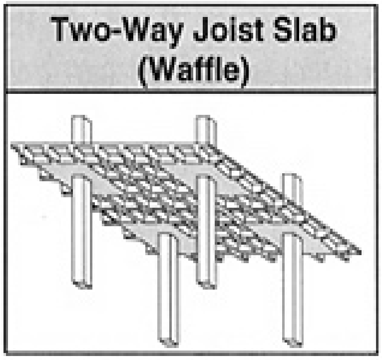
The disadvantages to using the hollowcore floor system begin with the fact that they require a substantial amount of lead time to acquire. Also, the slab thickness is considerably large, in this case the largest of all the systems analyzed, though a reduction in girder size throughout the floor framing would be a feasible solution to lessen this factor.

Waffle Slab

The final alternative system analyzed is the waffle slab, another floor system comprised entirely of structural concrete. The design for this floor system was created using an adaptation from the tables in the CRSI Design Handbook. This floor is basically a two-way joist system. In order to decrease the dead weight of a solid slab system, the formwork for the floor creates 30”x30” voids in the bottom of the slab in a rectilinear pattern, which creates a two-way grid of ribs that resembles a waffle. The voids are not used in the direct vicinity of the columns so as to more effectively resist the shear and moment forces that occur at the columns. Columns were re-sized as concrete columns at 19”x19” and normal weight concrete was used throughout the design.

Advantages

As with any purely concrete flooring system the total depth of the floor structure is much thinner than that of a steel framing system. The waffle system actually has the least depth of any of the systems evaluated at 15”. If there is no need for a suspended ceiling, the void layout of the underneath of the slab system provides an interesting architectural feature for a ceiling that does requires no additional design or maintenance



Disadvantages

The construction process for the waffle slab flooring system can become quite complicated. The formwork for the slab is complex and installation can turn out to be rather labor intensive, especially if shoring becomes involved. Plus, since it is an entirely concrete structure the loading of the waffle system is fairly high. Also, as with the slab with drop panels, a variation in the column size and layout may be necessary for achieving maximum efficiency of this design, which has potential to make considerable changes to the architecture and or floor plan of the hospital.

Alternative Systems Comparison

	Composite LWC Slab on Steel Framing (Existing)	Non-Composite LWC Slab on Steel Framing	Two-way Slab with Drop Panels	Hollowcore Planks on Steel Frame	Waffle Slab
Slab Depth	6" w/ deck	6.5" w/ deck	10.25"	12"	3"
Total Floor Depth	36"	36"	16.25"	42"	15"
Concrete Weight	46 psf	50 psf	100 psf	93 psf	140 psf
Total Weight	116 psf	121 psf	100 psf	153 psf	140 psf
Cost per sqft	$26.30	$24.10	$17	$10.50	$24.60
Lead Time	Medium	Medium	Short	Long	Short
Constructability	Average	Average	Hard	Fast - Easy	Hard
Fireproofing Required	Yes	Yes	No	No	No
Vibration Issues	Yes	Yes	No	No	No
Architectural Issues	No	No	Yes	No	Yes
Plausible Alternative Worth Further Study	Existing	Yes	No	Yes	No

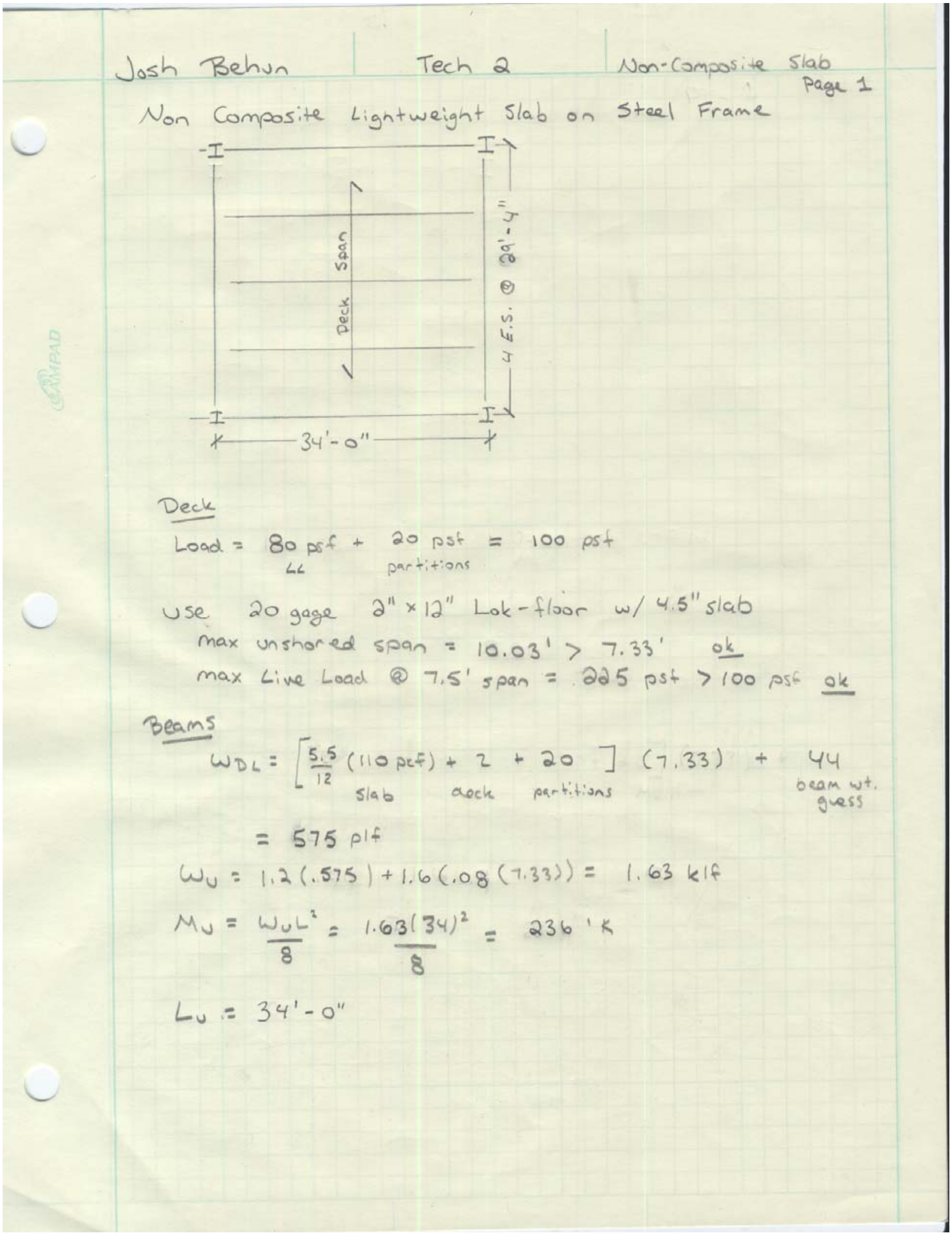
Conclusion

Due to the shape of the building and the current column grid used, it seems that a completely concrete structural system is not the best choice for alternative flooring solutions. With a few modifications, if it is reasonably possible to make minor adjustments without adversely affecting the functionality of the spaces, a concrete system would be a viable structural possibility for the building, if not for the entire building at least for isolated areas. A prefab structural system, however, does seem be a feasible construction method to pursue further investigation for. Though, due to its flexible building methods and constructability, any conversion to a concrete structural system would certainly require alternative methods of lateral bracing as well, most likely involving the use of shear walls.

As it is, with the layout of the building, a steel framing system seems to be the most functional option. Steel has fairly simple constructability, is rather light in weight, and can be built to suit most conditions. A steel system would mostly likely require a check for vibration issues as well as additional fireproofing

Appendix

Appendix A – Non Composite Lightweight Slab on Steel Frame



Josh Behun | Tech 2 | Non-Composite Slab
Page 1

Non Composite Lightweight Slab on Steel Frame

Deck

Load = 80 psf (LL) + 20 psf (partitions) = 100 psf

Use 20 gage 2" × 12" Lok-floor w/ 4.5" slab
max unshored span = 10.03' > 7.33' ok
max Live Load @ 7.5' span = 225 psf > 100 psf ok

Beams

$w_{DL} = \left[\underbrace{\frac{5.5}{12}(110\text{ pcf})}_{\text{slab}} + \underbrace{2}_{\text{deck}} + \underbrace{20}_{\text{partitions}}\right](7.33) + \underbrace{44}_{\text{beam wt. guess}}$

$= 575\text{ plf}$

$w_u = 1.2(.575) + 1.6(.08(7.33)) = 1.63\text{ klf}$

$M_u = \frac{w_u L^2}{8} = \frac{1.63(34)^2}{8} = 236\text{ 'k}$

$L_u = 34'\text{-}0"$

Josh Behun Tech 2 Non Composite Slab
page 2

$\Delta L \leq L/360 = \frac{34(12)}{360} = 1.13$

$1.13 \geq \frac{5(.08(7.33))\,34^4(1728)}{384(29000)I}$

$I = 608 \text{ in}^4$

$\Delta T \leq L/240 = \frac{34(12)}{240} = 1.7$

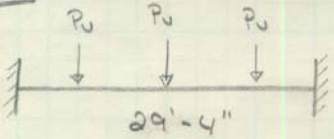
$1.7 = \frac{5(1.162)\,34^4(1728)}{384(29000)I}$

$I = 710 \text{ in}^4$ ← governs

Use W21 x44 @ 7.33" o.c. (current beam)

$I = 843 \text{ in}^4 > 704$

Girder



$P_u = 17'(1.2(.575) + 1.6(.586)) = 27.7^K(2) = 55.5^K$

$M_u^- = bPL = 0.313(55.5)(29.33) = 510\ 'K$

$M_u^+ = aPL = 0.188(55.5)(29.33) = 306\ 'K$

from table 3-22a AISC-13

$L_u = 7.33'$ unbraced length

Josh Behun Tech 2 Non-Composite Slab
page 3

$$\Delta L \le \frac{\ell}{360} = \frac{29.33(12)}{360} = 0.978$$

$$\frac{Px^2}{48EI}(3L-4x) + (2)\frac{Pb^2x^2}{6EIL^3}(3aL-3ax-bx)$$

$$\frac{20(14.67)^2}{48(29000)I}\left(3(29.33)-4(14.67)\right)(1728)$$

$$+\frac{20(7.33)^2(14.67)^2}{6(29000)I(29.33)^3}\left(3(22)(29.33)-3(22)(14.67)-(7.33)14.67\right)(1728)$$

$$= \frac{157}{I} + \frac{226}{I} = 383 = 0.978I$$

$$I = 392$$

$$\Delta T \le \frac{\ell}{240} = \frac{29.33(12)}{240} = 1.47$$

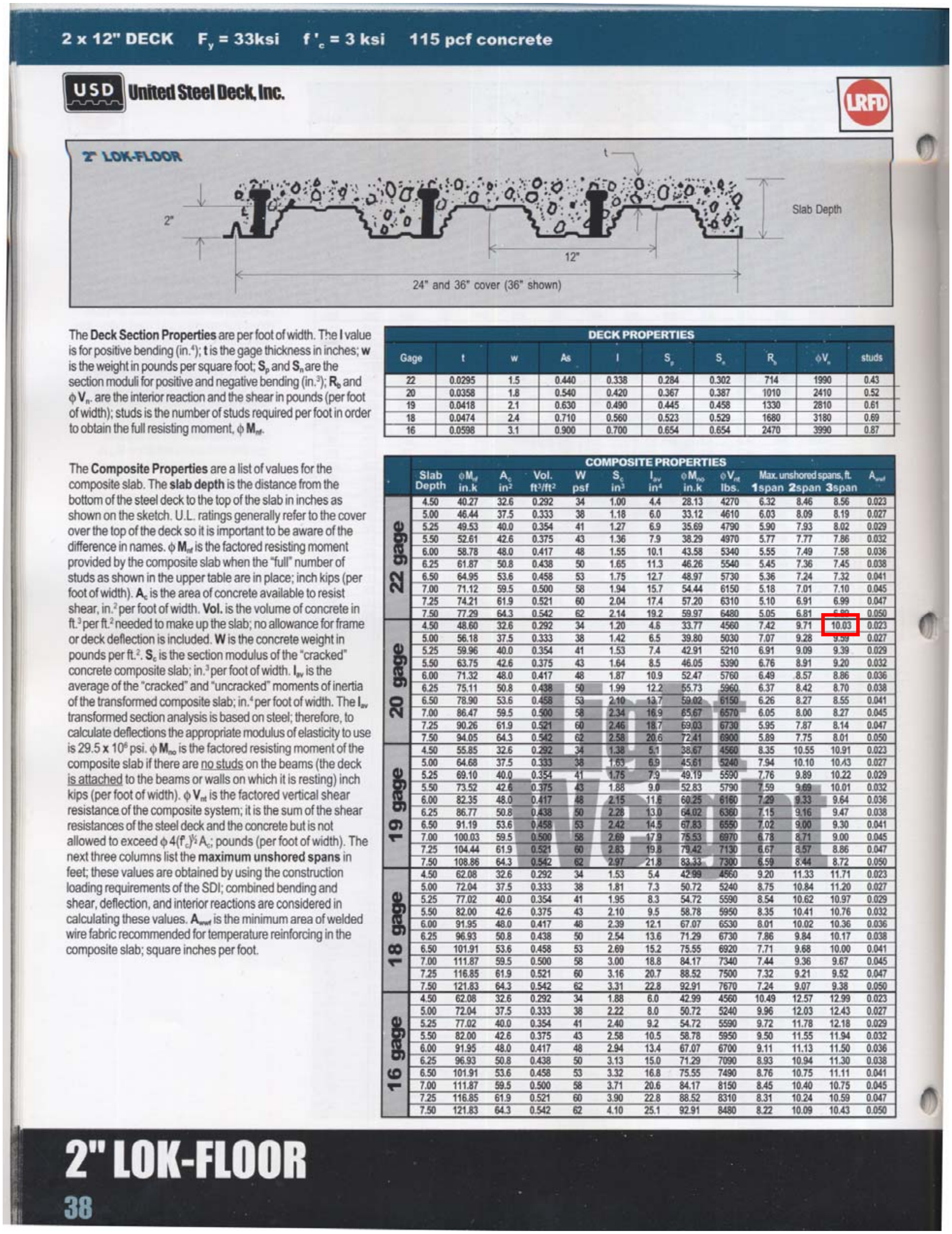
$$\frac{55.5(14.67)^2}{48(29000)I}\left(3(29.33)-4(14.67)\right)(1728)$$

$$+\frac{55.5(7.33)^2(14.67)^2}{6(29000)I(29.33)^3}\left(3(22)(29.33)-3(22)(14.67)-(7.33)14.67\right)(1728)$$

$$= \frac{435}{I} + \frac{435}{I} = 870 = 1.47I$$

$$I = 592$$

use W18×40



2 x 12" DECK F_y = 33ksi f'_c = 3 ksi 115 pcf concrete

USD United Steel Deck, Inc.

LRFD

The **Deck Section Properties** are per foot of width. The **I** value is for positive bending (in.^{4}); **t** is the gage thickness in inches; **w** is the weight in pounds per square foot; **S_p** and **S_n** are the section moduli for positive and negative bending (in.^{3}); **R_b** and ϕ **V_n**. are the interior reaction and the shear in pounds (per foot of width); studs is the number of studs required per foot in order to obtain the full resisting moment, ϕ **M_{nf}**.

The **Composite Properties** are a list of values for the composite slab. The **slab depth** is the distance from the bottom of the steel deck to the top of the slab in inches as shown on the sketch. U.L. ratings generally refer to the cover over the top of the deck so it is important to be aware of the difference in names. ϕ **M_{nf}** is the factored resisting moment provided by the composite slab when the "full" number of studs as shown in the upper table are in place; inch kips (per foot of width). **A_c** is the area of concrete available to resist shear, in.^{2} per foot of width. **Vol.** is the volume of concrete in ft.^{3} per ft.^{2} needed to make up the slab; no allowance for frame or deck deflection is included. **W** is the concrete weight in pounds per ft.^{2}. **S_c** is the section modulus of the "cracked" concrete composite slab; in.^{3} per foot of width. **I_{av}** is the average of the "cracked" and "uncracked" moments of inertia of the transformed composite slab; in.^{4} per foot of width. The **I_{av}** transformed section analysis is based on steel; therefore, to calculate deflections the appropriate modulus of elasticity to use is 29.5 x 10^6 psi. ϕ **M_{no}** is the factored resisting moment of the composite slab if there are no studs on the beams (the deck is attached to the beams or walls on which it is resting) inch kips (per foot of width). ϕ **V_{nt}** is the factored vertical shear resistance of the composite system; it is the sum of the shear resistances of the steel deck and the concrete but is not allowed to exceed $\phi 4(f'_c)^{1/2} A_c$; pounds (per foot of width). The next three columns list the **maximum unshored spans** in feet; these values are obtained by using the construction loading requirements of the SDI; combined bending and shear, deflection, and interior reactions are considered in calculating these values. **A_{wwf}** is the minimum area of welded wire fabric recommended for temperature reinforcing in the composite slab; square inches per foot.

DECK PROPERTIES

Gage	t	w	As	I	S_p	S_n	R_b	ϕV_n	studs
22	0.0295	1.5	0.440	0.338	0.284	0.302	714	1990	0.43
20	0.0358	1.8	0.540	0.420	0.367	0.387	1010	2410	0.52
19	0.0418	2.1	0.630	0.490	0.445	0.458	1330	2810	0.61
18	0.0474	2.4	0.710	0.560	0.523	0.529	1680	3180	0.69
16	0.0598	3.1	0.900	0.700	0.654	0.654	2470	3990	0.87

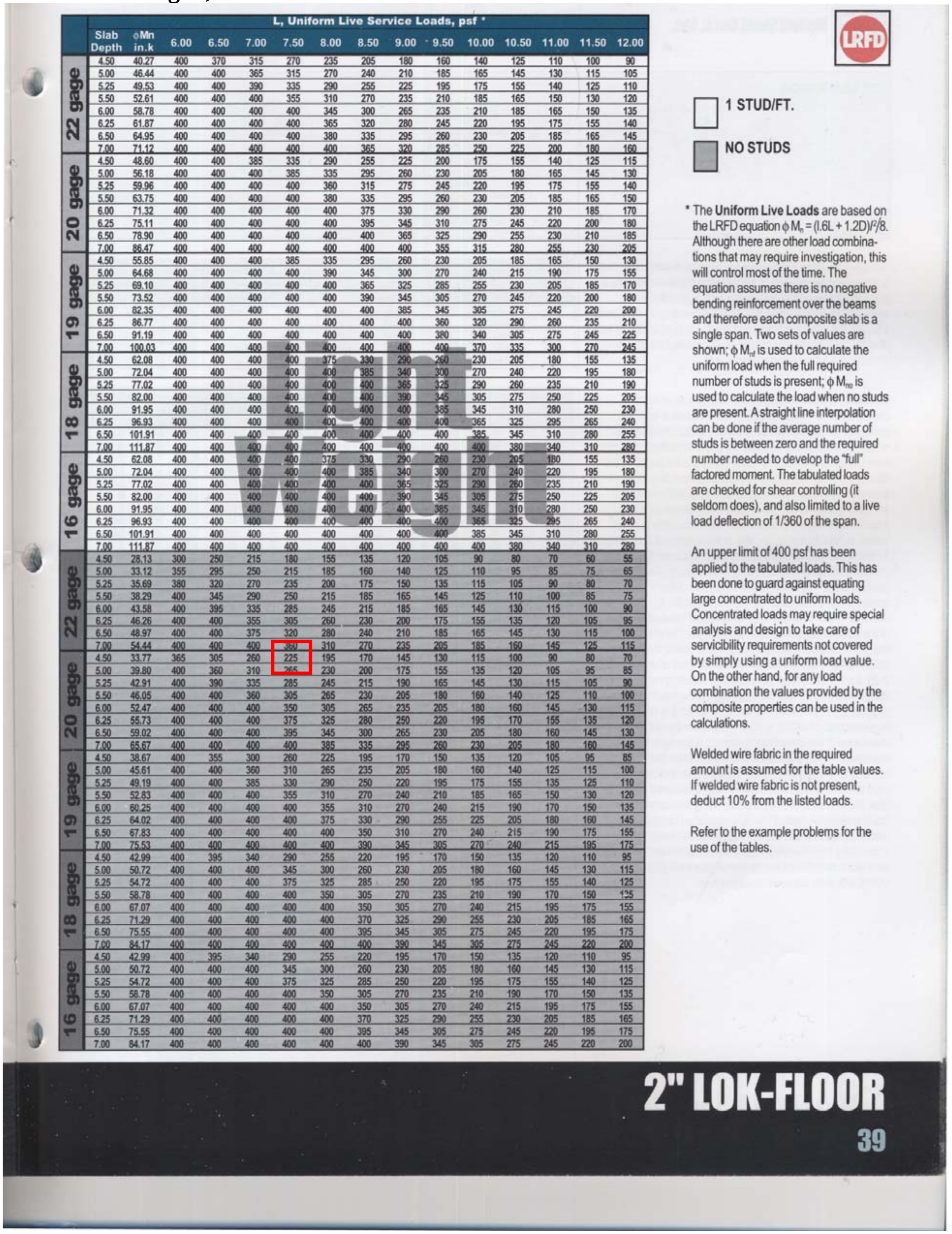
COMPOSITE PROPERTIES

	Slab Depth	ϕM_{nf} in.k	A_c in^2	Vol. ft^3/ft^2	W psf	S_c in^3	I_{av} in^4	ϕM_{no} in.k	ϕV_{nt} lbs.	Max. unshored spans, ft. 1span	2span	3span	A_{wwf}
22 gage	4.50	40.27	32.6	0.292	34	1.00	4.4	28.13	4270	6.32	8.46	8.56	0.023
	5.00	46.44	37.5	0.333	38	1.18	6.0	33.12	4610	6.03	8.09	8.19	0.027
	5.25	49.53	40.0	0.354	41	1.27	6.9	35.69	4790	5.90	7.93	8.02	0.029
	5.50	52.61	42.6	0.375	43	1.36	7.9	38.29	4970	5.77	7.77	7.86	0.032
	6.00	58.78	48.0	0.417	48	1.55	10.1	43.58	5340	5.55	7.49	7.58	0.036
	6.25	61.87	50.8	0.438	50	1.65	11.3	46.26	5540	5.45	7.36	7.45	0.038
	6.50	64.95	53.6	0.458	53	1.75	12.7	48.97	5730	5.36	7.24	7.32	0.041
	7.00	71.12	59.5	0.500	58	1.94	15.7	54.44	6150	5.18	7.01	7.10	0.045
	7.25	74.21	61.9	0.521	60	2.04	17.4	57.20	6310	5.10	6.91	6.99	0.047
	7.50	77.29	64.3	0.542	62	2.14	19.2	59.97	6480	5.05	6.81	6.89	0.050
20 gage	4.50	48.60	32.6	0.292	34	1.20	4.6	33.77	4560	7.42	9.71	10.03	0.023
	5.00	56.18	37.5	0.333	38	1.42	6.5	39.80	5030	7.07	9.28	9.59	0.027
	5.25	59.96	40.0	0.354	41	1.53	7.4	42.91	5210	6.91	9.09	9.39	0.029
	5.50	63.75	42.6	0.375	43	1.64	8.5	46.05	5390	6.76	8.91	9.20	0.032
	6.00	71.32	48.0	0.417	48	1.87	10.9	52.47	5760	6.49	8.57	8.86	0.036
	6.25	75.11	50.8	0.438	50	1.99	12.2	55.73	5960	6.37	8.42	8.70	0.038
	6.50	78.90	53.6	0.458	53	2.10	13.7	59.02	6150	6.26	8.27	8.55	0.041
	7.00	86.47	59.5	0.500	58	2.34	16.9	65.67	6570	6.05	8.00	8.27	0.045
	7.25	90.26	61.9	0.521	60	2.46	18.7	69.03	6730	5.95	7.87	8.14	0.047
	7.50	94.05	64.3	0.542	62	2.58	20.6	72.41	6900	5.89	7.75	8.01	0.050
19 gage	4.50	55.85	32.6	0.292	34	1.38	5.1	38.67	4560	8.35	10.55	10.91	0.023
	5.00	64.68	37.5	0.333	38	1.63	6.9	45.61	5240	7.94	10.10	10.43	0.027
	5.25	69.10	40.0	0.354	41	1.75	7.9	49.19	5590	7.76	9.89	10.22	0.029
	5.50	73.52	42.6	0.375	43	1.88	9.0	52.83	5790	7.59	9.69	10.01	0.032
	6.00	82.35	48.0	0.417	48	2.15	11.6	60.25	6160	7.29	9.33	9.64	0.036
	6.25	86.77	50.8	0.438	50	2.28	13.0	64.02	6360	7.15	9.16	9.47	0.038
	6.50	91.19	53.6	0.458	53	2.42	14.5	67.83	6550	7.02	9.00	9.30	0.041
	7.00	100.03	59.5	0.500	58	2.69	17.9	75.53	6970	6.78	8.71	9.00	0.045
	7.25	104.44	61.9	0.521	60	2.83	19.8	79.42	7130	6.67	8.57	8.86	0.047
	7.50	108.86	64.3	0.542	62	2.97	21.8	83.33	7300	6.59	8.44	8.72	0.050
18 gage	4.50	62.08	32.6	0.292	34	1.53	5.4	42.99	4560	9.20	11.33	11.71	0.023
	5.00	72.04	37.5	0.333	38	1.81	7.3	50.72	5240	8.75	10.84	11.20	0.027
	5.25	77.02	40.0	0.354	41	1.95	8.3	54.72	5590	8.54	10.62	10.97	0.029
	5.50	82.00	42.6	0.375	43	2.10	9.5	58.78	5950	8.35	10.41	10.76	0.032
	6.00	91.95	48.0	0.417	48	2.39	12.1	67.07	6530	8.01	10.02	10.36	0.036
	6.25	96.93	50.8	0.438	50	2.54	13.6	71.29	6730	7.86	9.84	10.17	0.038
	6.50	101.91	53.6	0.458	53	2.69	15.2	75.55	6920	7.71	9.68	10.00	0.041
	7.00	111.87	59.5	0.500	58	3.00	18.8	84.17	7340	7.44	9.36	9.67	0.045
	7.25	116.85	61.9	0.521	60	3.16	20.7	88.52	7500	7.32	9.21	9.52	0.047
	7.50	121.83	64.3	0.542	62	3.31	22.8	92.91	7670	7.24	9.07	9.38	0.050
16 gage	4.50	62.08	32.6	0.292	34	1.88	6.0	42.99	4560	10.49	12.57	12.99	0.023
	5.00	72.04	37.5	0.333	38	2.22	8.0	50.72	5240	9.96	12.03	12.43	0.027
	5.25	77.02	40.0	0.354	41	2.40	9.2	54.72	5590	9.72	11.78	12.18	0.029
	5.50	82.00	42.6	0.375	43	2.58	10.5	58.78	5950	9.50	11.55	11.94	0.032
	6.00	91.95	48.0	0.417	48	2.94	13.4	67.07	6700	9.11	11.13	11.50	0.036
	6.25	96.93	50.8	0.438	50	3.13	15.0	71.29	7090	8.93	10.94	11.30	0.038
	6.50	101.91	53.6	0.458	53	3.32	16.8	75.55	7490	8.76	10.75	11.11	0.041
	7.00	111.87	59.5	0.500	58	3.71	20.6	84.17	8150	8.45	10.40	10.75	0.045
	7.25	116.85	61.9	0.521	60	3.90	22.8	88.52	8310	8.31	10.24	10.59	0.047
	7.50	121.83	64.3	0.542	62	4.10	25.1	92.91	8480	8.22	10.09	10.43	0.050

Light Weight

2" LOK-FLOOR

38



	Slab Depth	φMn in.k	L, Uniform Live Service Loads, psf *												
			6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	12.00
22 gage	4.50	40.27	400	370	315	270	235	205	180	160	140	125	110	100	90
	5.00	46.44	400	400	365	315	270	240	210	185	165	145	130	115	105
	5.25	49.53	400	400	390	335	290	255	225	195	175	155	140	125	110
	5.50	52.61	400	400	400	355	310	270	235	210	185	165	150	130	120
	6.00	58.78	400	400	400	400	345	300	265	235	210	185	165	150	135
	6.25	61.87	400	400	400	400	365	320	280	245	220	195	175	155	140
	6.50	64.95	400	400	400	400	380	335	295	260	230	205	185	165	145
	7.00	71.12	400	400	400	400	400	365	320	285	250	225	200	180	160
20 gage	4.50	48.60	400	400	385	335	290	255	225	200	175	155	140	125	115
	5.00	56.18	400	400	400	385	335	295	260	230	205	180	165	145	130
	5.25	59.96	400	400	400	400	360	315	275	245	220	195	175	155	140
	5.50	63.75	400	400	400	400	380	335	295	260	230	205	185	165	150
	6.00	71.32	400	400	400	400	400	375	330	290	260	230	210	185	170
	6.25	75.11	400	400	400	400	400	395	345	310	275	245	220	200	180
	6.50	78.90	400	400	400	400	400	400	365	325	290	255	230	210	185
	7.00	86.47	400	400	400	400	400	400	400	355	315	280	255	230	205
19 gage	4.50	55.85	400	400	400	385	335	295	260	230	205	185	165	150	130
	5.00	64.68	400	400	400	400	390	345	300	270	240	215	190	175	155
	5.25	69.10	400	400	400	400	400	365	325	285	255	230	205	185	170
	5.50	73.52	400	400	400	400	400	390	345	305	270	245	220	200	180
	6.00	82.35	400	400	400	400	400	400	385	345	305	275	245	220	200
	6.25	86.77	400	400	400	400	400	400	400	360	320	290	260	235	210
	6.50	91.19	400	400	400	400	400	400	400	380	340	305	275	245	225
	7.00	100.03	400	400	400	400	400	400	400	400	370	335	300	270	245
18 gage	4.50	62.08	400	400	400	400	375	330	290	260	230	205	180	155	135
	5.00	72.04	400	400	400	400	400	385	340	300	270	240	220	195	180
	5.25	77.02	400	400	400	400	400	400	365	325	290	260	235	210	190
	5.50	82.00	400	400	400	400	400	400	390	345	305	275	250	225	205
	6.00	91.95	400	400	400	400	400	400	400	385	345	310	280	250	230
	6.25	96.93	400	400	400	400	400	400	400	400	365	325	295	265	240
	6.50	101.91	400	400	400	400	400	400	400	400	385	345	310	280	255
	7.00	111.87	400	400	400	400	400	400	400	400	400	380	340	310	280
16 gage	4.50	62.08	400	400	400	400	375	330	290	260	230	205	180	155	135
	5.00	72.04	400	400	400	400	400	385	340	300	270	240	220	195	180
	5.25	77.02	400	400	400	400	400	400	365	325	290	260	235	210	190
	5.50	82.00	400	400	400	400	400	400	390	345	305	275	250	225	205
	6.00	91.95	400	400	400	400	400	400	400	385	345	310	280	250	230
	6.25	96.93	400	400	400	400	400	400	400	400	365	325	295	265	240
	6.50	101.91	400	400	400	400	400	400	400	400	385	345	310	280	255
	7.00	111.87	400	400	400	400	400	400	400	400	400	380	340	310	280
22 gage	4.50	28.13	300	250	215	180	155	135	120	105	90	80	70	60	55
	5.00	33.12	355	295	250	215	185	160	140	125	110	95	85	75	65
	5.25	35.69	380	320	270	235	200	175	150	135	115	105	90	80	70
	5.50	38.29	400	345	290	250	215	185	165	145	125	110	100	85	75
	6.00	43.58	400	395	335	285	245	215	185	165	145	130	115	100	90
	6.25	46.26	400	400	355	305	260	230	200	175	155	135	120	105	95
	6.50	48.97	400	400	375	320	280	240	210	185	165	145	130	115	100
	7.00	54.44	400	400	400	360	310	270	235	205	185	160	145	125	115
20 gage	4.50	33.77	365	305	260	225	195	170	145	130	115	100	90	80	70
	5.00	39.80	400	360	310	265	230	200	175	155	135	120	105	95	85
	5.25	42.91	400	390	335	285	245	215	190	165	145	130	115	105	90
	5.50	46.05	400	400	360	305	265	230	205	180	160	140	125	110	100
	6.00	52.47	400	400	400	350	305	265	235	205	180	160	145	130	115
	6.25	55.73	400	400	400	375	325	280	250	220	195	170	155	135	120
	6.50	59.02	400	400	400	395	345	300	265	230	205	180	160	145	130
	7.00	65.67	400	400	400	400	385	335	295	260	230	205	180	160	145
19 gage	4.50	38.67	400	355	300	260	225	195	170	150	135	120	105	95	85
	5.00	45.61	400	400	360	310	265	235	205	180	160	140	125	115	100
	5.25	49.19	400	400	385	330	290	250	220	195	175	155	135	125	110
	5.50	52.83	400	400	400	355	310	270	240	210	185	165	150	130	120
	6.00	60.25	400	400	400	400	355	310	270	240	215	190	170	150	135
	6.25	64.02	400	400	400	400	375	330	290	255	225	205	180	160	145
	6.50	67.83	400	400	400	400	400	350	310	270	240	215	190	175	155
	7.00	75.53	400	400	400	400	400	390	345	305	270	240	215	195	175
18 gage	4.50	42.99	400	395	340	290	255	220	195	170	150	135	120	110	95
	5.00	50.72	400	400	400	345	300	260	230	205	180	160	145	130	115
	5.25	54.72	400	400	400	375	325	285	250	220	195	175	155	140	125
	5.50	58.78	400	400	400	400	350	305	270	235	210	190	170	150	135
	6.00	67.07	400	400	400	400	400	350	305	270	240	215	195	175	155
	6.25	71.29	400	400	400	400	400	370	325	290	255	230	205	185	165
	6.50	75.55	400	400	400	400	400	395	345	305	275	245	220	195	175
	7.00	84.17	400	400	400	400	400	400	390	345	305	275	245	220	200
16 gage	4.50	42.99	400	395	340	290	255	220	195	170	150	135	120	110	95
	5.00	50.72	400	400	400	345	300	260	230	205	180	160	145	130	115
	5.25	54.72	400	400	400	375	325	285	250	220	195	175	155	140	125
	5.50	58.78	400	400	400	400	350	305	270	235	210	190	170	150	135
	6.00	67.07	400	400	400	400	400	350	305	270	240	215	195	175	155
	6.25	71.29	400	400	400	400	400	370	325	290	255	230	205	185	165
	6.50	75.55	400	400	400	400	400	395	345	305	275	245	220	195	175
	7.00	84.17	400	400	400	400	400	400	390	345	305	275	245	220	200

Light Weight

LRFD

☐ 1 STUD/FT.

▨ NO STUDS

* The **Uniform Live Loads** are based on the LRFD equation $\phi M_n = (1.6L + 1.2D)l^2/8$. Although there are other load combinations that may require investigation, this will control most of the time. The equation assumes there is no negative bending reinforcement over the beams and therefore each composite slab is a single span. Two sets of values are shown; ϕM_{nf} is used to calculate the uniform load when the full required number of studs is present; ϕM_{no} is used to calculate the load when no studs are present. A straight line interpolation can be done if the average number of studs is between zero and the required number needed to develop the "full" factored moment. The tabulated loads are checked for shear controlling (it seldom does), and also limited to a live load deflection of 1/360 of the span.

An upper limit of 400 psf has been applied to the tabulated loads. This has been done to guard against equating large concentrated to uniform loads. Concentrated loads may require special analysis and design to take care of servicibility requirements not covered by simply using a uniform load value. On the other hand, for any load combination the values provided by the composite properties can be used in the calculations.

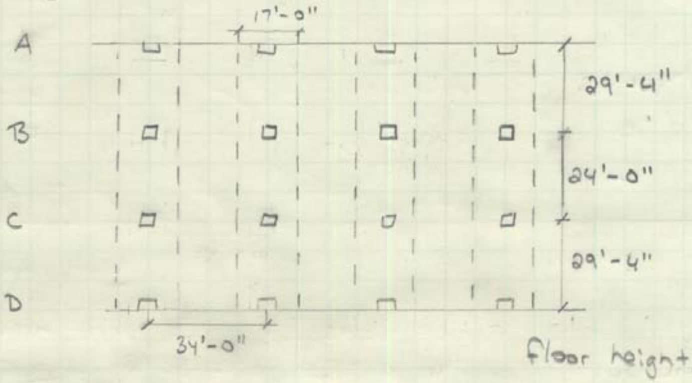
Welded wire fabric in the required amount is assumed for the table values. If welded wire fabric is not present, deduct 10% from the listed loads.

Refer to the example problems for the use of the tables.

Appendix B – Two-way slab with drop panels

Josh Behun | Tech 2 | Two-way slab
page 1

Two-way slab with drop panels



floor height = 14'-8"

assume column sizes 14" x 14"

$f'_c = 4000$ psi

$f_y = 60\,000$ psi

Live Load = 80 psi + $\underset{\text{partitions}}{20}$ = 100 psf

Dead Load = 20 psi collateral

min slab thickness

For exterior panels using drop panels without edge beams

$$t = \frac{L_n}{33} = \frac{29.33(12) - 14}{33} = 10.25'' \leftarrow \text{governs}$$

For interior panels

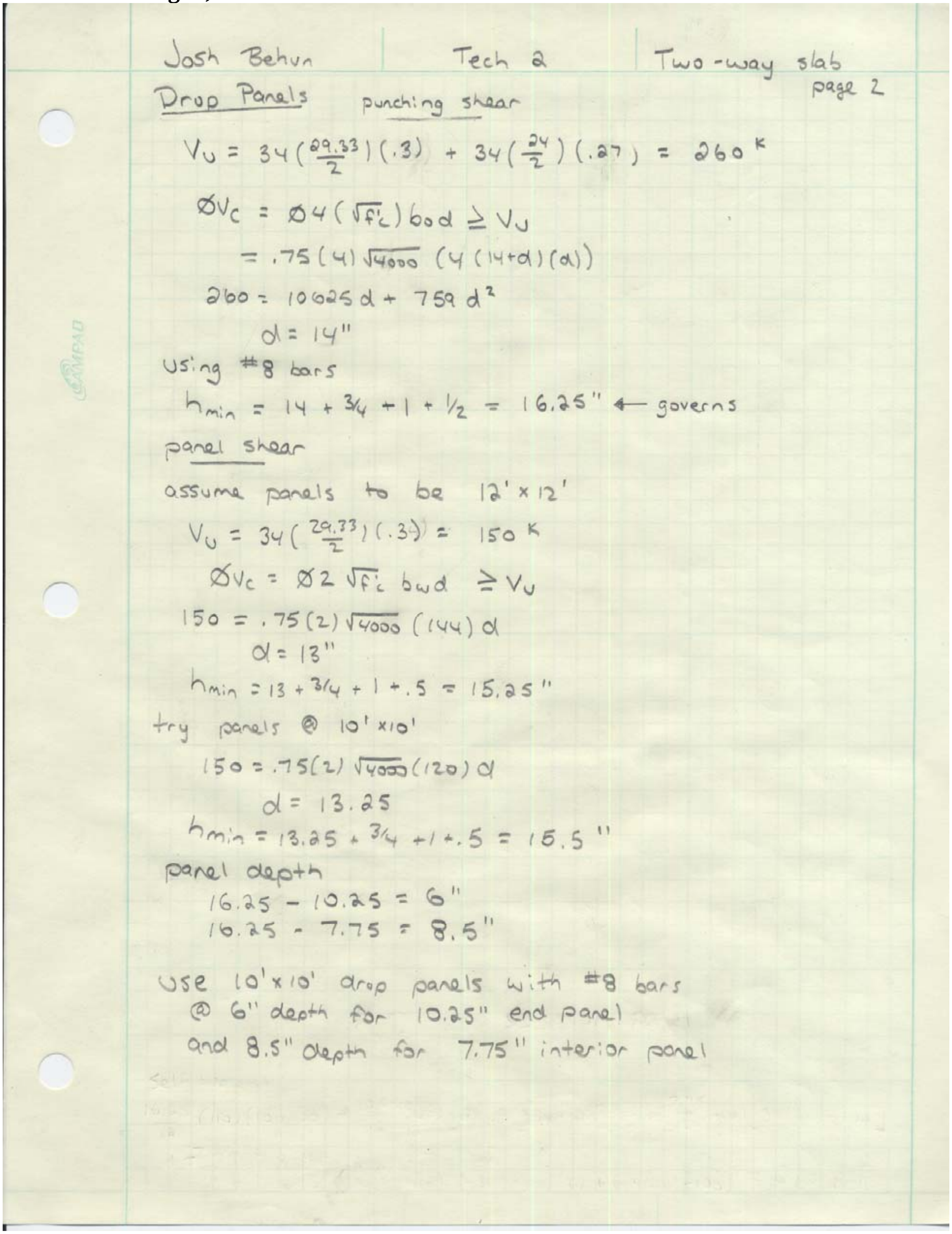
$$t = \frac{L_n}{36} = \frac{24(12) - 14}{36} = 7.6 \rightarrow 7.75''$$

Note:

Frames A and B analyzed as if columns were aligned in a straight line, as aposed to the slanted column grid that they actually follow.

$$W_u = 1.2\left(\frac{10.25}{12}(110) + 20\right) + 1.6(100) = 300 \text{ psf} \quad \text{end span}$$

$$W_u = 1.2\left(\frac{7.75}{12}(110) + 20\right) + 1.6(100) = 270 \text{ psf} \quad \text{interior}$$



Josh Behun | Tech 2 | Two-way slab

page 2

Drop Panels punching shear

$V_u = 34(\frac{29.33}{2})(.3) + 34(\frac{24}{2})(.27) = 260^K$

$\phi V_c = \phi 4(\sqrt{f'_c})b_o d \geq V_u$

$= .75(4)\sqrt{4000}\ (4(14+d)(d))$

$260 = 10625d + 759d^2$

$d = 14''$

using #8 bars

$h_{min} = 14 + 3/4 + 1 + 1/2 = 16.25''$ ← governs

panel shear

assume panels to be 12' x 12'

$V_u = 34(\frac{29.33}{2})(.3) = 150^K$

$\phi V_c = \phi 2\sqrt{f'_c}\ b_w d \geq V_u$

$150 = .75(2)\sqrt{4000}\ (144)d$

$d = 13''$

$h_{min} = 13 + 3/4 + 1 + .5 = 15.25''$

try panels @ 10' x 10'

$150 = .75(2)\sqrt{4000}(120)d$

$d = 13.25$

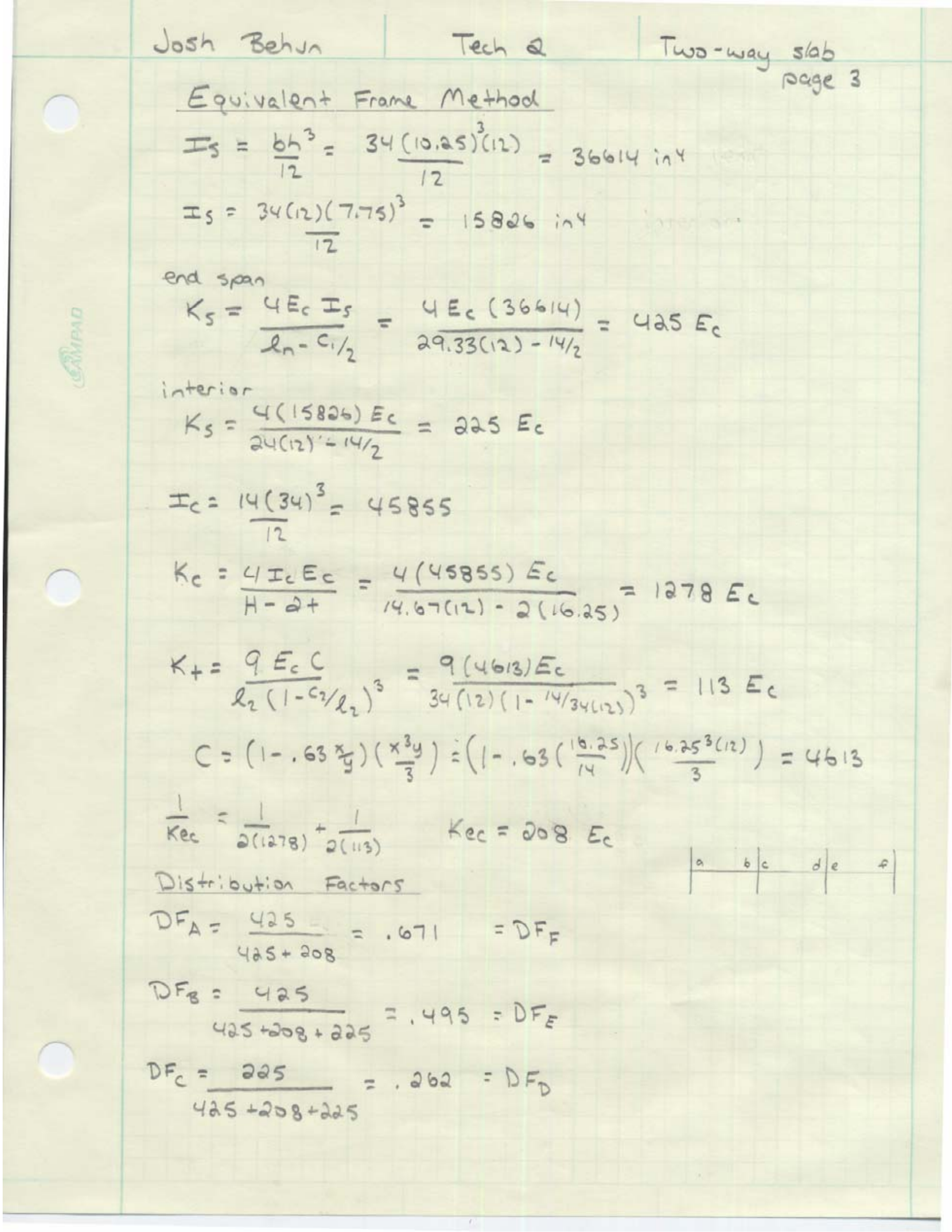
$h_{min} = 13.25 + 3/4 + 1 + .5 = 15.5''$

panel depth

$16.25 - 10.25 = 6''$

$16.25 - 7.75 = 8.5''$

use 10'x10' drop panels with #8 bars
@ 6'' depth for 10.25'' end panel
and 8.5'' depth for 7.75'' interior panel



Josh Behun | Tech 2 | Two-way slab
page 3

Equivalent Frame Method

$$I_s = \frac{bh^3}{12} = \frac{34(10.25)^3(12)}{12} = 36614 \text{ in}^4$$

$$I_s = \frac{34(12)(7.75)^3}{12} = 15826 \text{ in}^4$$

end span

$$K_s = \frac{4E_c I_s}{\ell_n - c_1/2} = \frac{4E_c(36614)}{29.33(12) - 14/2} = 425\,E_c$$

interior

$$K_s = \frac{4(15826)E_c}{24(12) - 14/2} = 225\,E_c$$

$$I_c = \frac{14(34)^3}{12} = 45855$$

$$K_c = \frac{4 I_c E_c}{H - 2t} = \frac{4(45855)E_c}{14.67(12) - 2(16.25)} = 1278\,E_c$$

$$K_t = \frac{9E_c C}{\ell_2(1 - c_2/\ell_2)^3} = \frac{9(4613)E_c}{34(12)(1 - 14/34(12))^3} = 113\,E_c$$

$$C = (1 - .63\tfrac{x}{y})(\tfrac{x^3y}{3}) = (1 - .63(\tfrac{16.25}{14}))(\tfrac{16.25^3(12)}{3}) = 4613$$

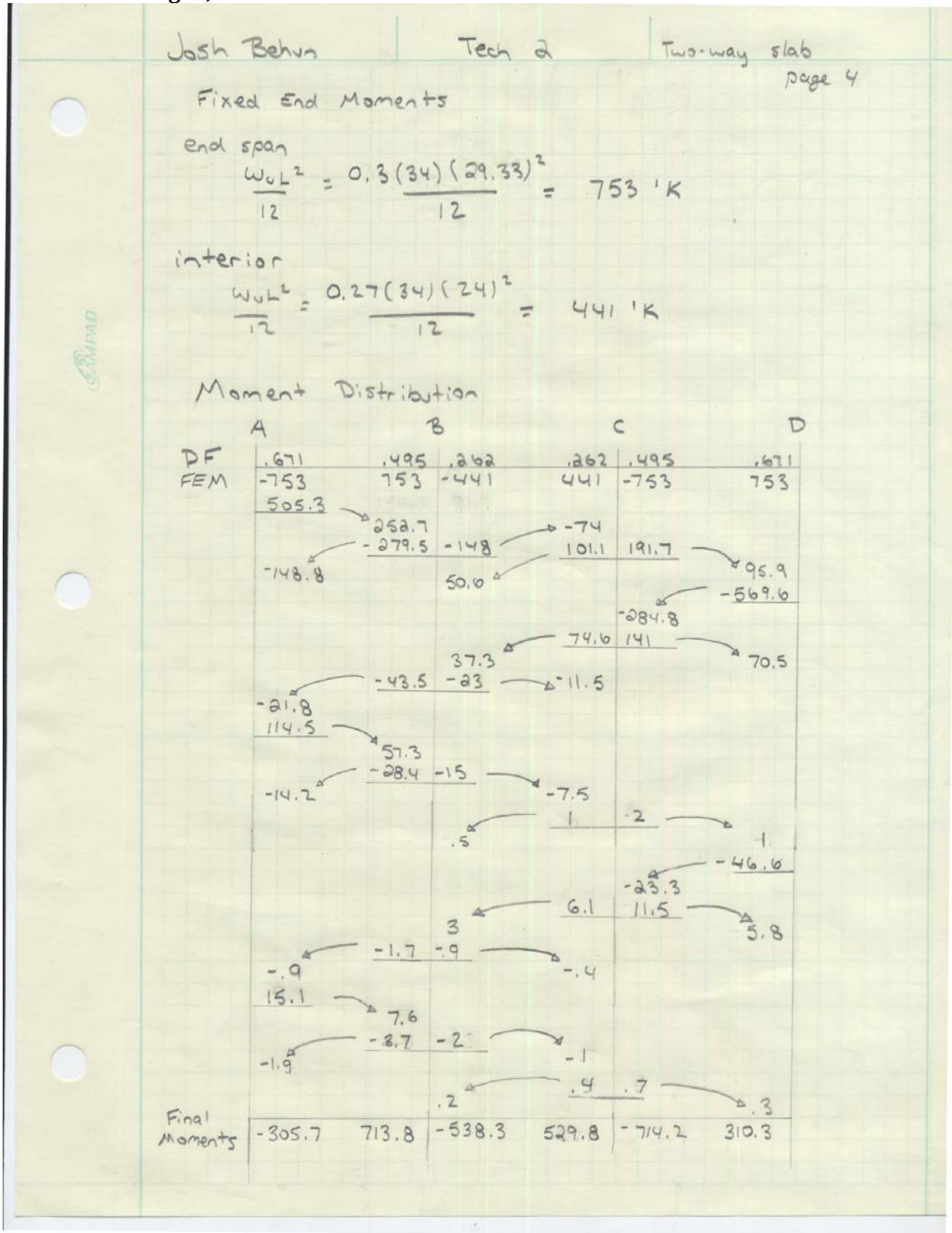
$$\frac{1}{K_{ec}} = \frac{1}{2(1278)} + \frac{1}{2(113)} \qquad K_{ec} = 208\,E_c$$

Distribution Factors

$$DF_A = \frac{425}{425+208} = .671 = DF_F$$

$$DF_B = \frac{425}{425+208+225} = .495 = DF_E$$

$$DF_C = \frac{225}{425+208+225} = .262 = DF_D$$



Josh Behun | Tech 2 | Two-way slab

page 4

Fixed End Moments

end span

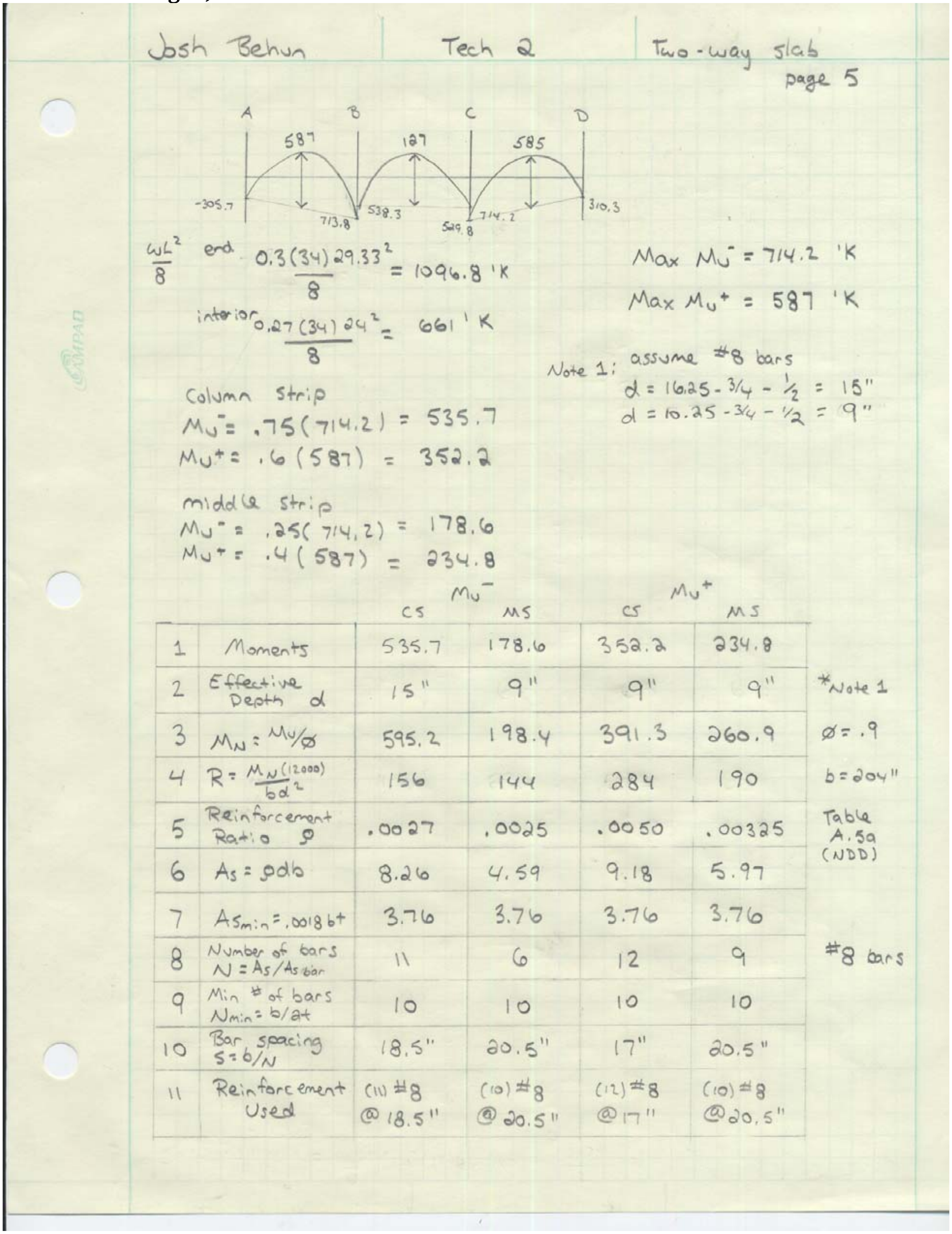
$$\frac{w_u L^2}{12} = \frac{0.3(34)(29.33)^2}{12} = 753\ 'K$$

interior

$$\frac{w_u L^2}{12} = \frac{0.27(34)(24)^2}{12} = 441\ 'K$$

Moment Distribution

	A	B		C		D
DF	.671	.495	.262	.262	.495	.671
FEM	-753	753	-441	441	-753	753
	505.3					
		252.7		-74		
		-279.5	-148	101.1	191.7	
	-148.8		50.6			95.9
						-569.6
					-284.8	
				74.6	141	
			37.3			70.5
		-43.5	-23	-11.5		
	-21.8					
	114.5					
		57.3				
		-28.4	-15			
	-14.2			-7.5		
				1	2	
			.5			1
						-46.6
					-23.3	
				6.1	11.5	
			3			5.8
		-1.7	-.9			
	-.9			-.4		
	15.1					
		7.6				
		-3.7	-2			
	-1.9			-.1		
				.4	.7	
			.2			.3
Final Moments	-305.7	713.8	-538.3	529.8	-714.2	310.3



Josh Behun | Tech 2 | Two-way slab

page 5

$\frac{wL^2}{8}$ end $\frac{0.3(34)29.33^2}{8} = 1096.8$ 'K

interior $\frac{0.27(34)24^2}{8} = 661$ 'K

Max $M_u^- = 714.2$ 'K

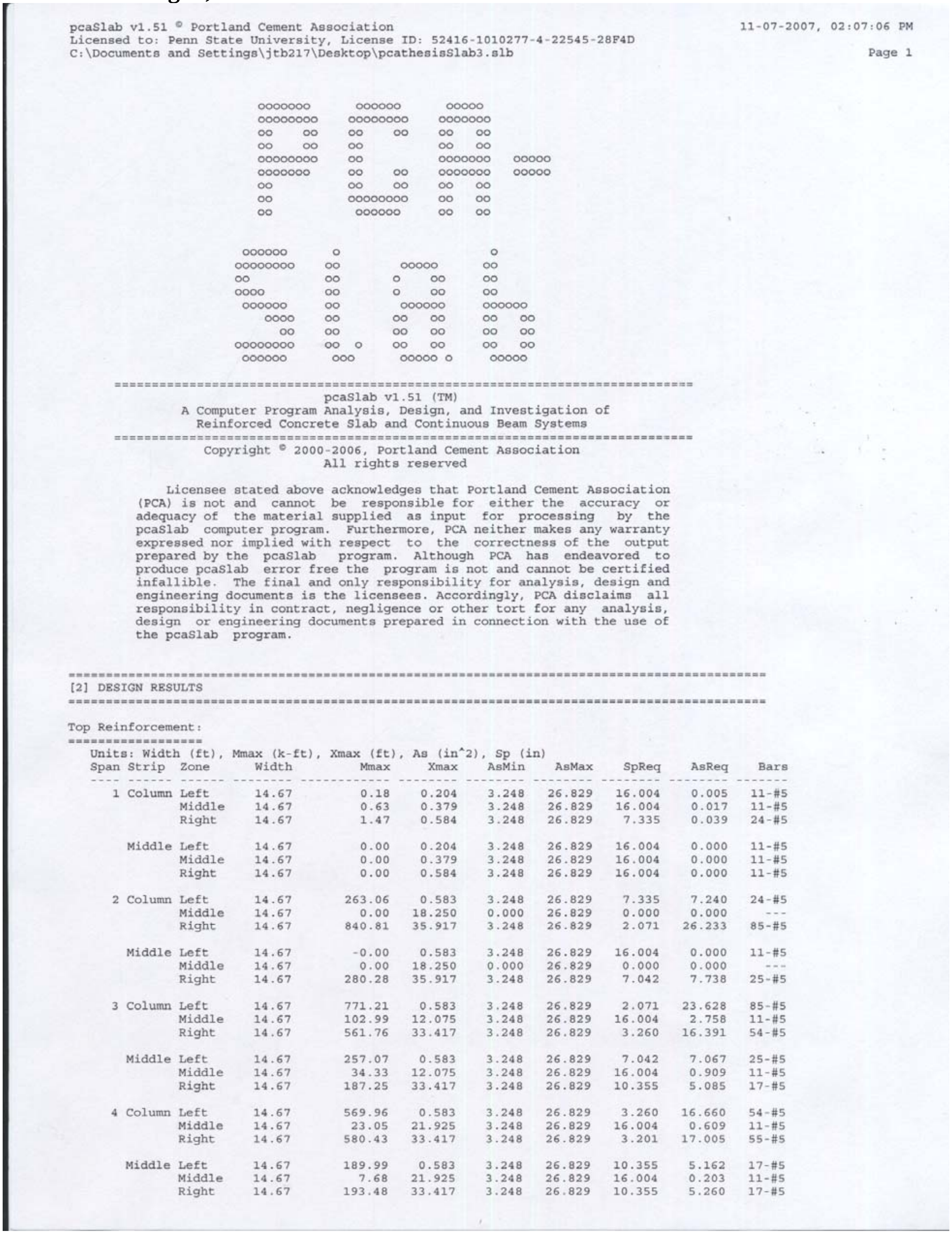
Max $M_u^+ = 587$ 'K

Note 1: assume #8 bars
$d = 16.25 - 3/4 - \frac{1}{2} = 15"$
$d = 10.25 - 3/4 - 1/2 = 9"$

Column strip
$M_u^- = .75(714.2) = 535.7$
$M_u^+ = .6(587) = 352.2$

middle strip
$M_u^- = .25(714.2) = 178.6$
$M_u^+ = .4(587) = 234.8$

		M_u^-		M_u^+		
		CS	MS	CS	MS	
1	Moments	535.7	178.6	352.2	234.8	
2	Effective Depth d	15"	9"	9"	9"	*Note 1
3	$M_N = M_u/\phi$	595.2	198.4	391.3	260.9	$\phi = .9$
4	$R = \frac{M_N(12000)}{bd^2}$	156	144	284	190	b = 204"
5	Reinforcement Ratio ρ	.0027	.0025	.0050	.00325	Table A.5a (NDD)
6	$A_s = \rho db$	8.26	4.59	9.18	5.97	
7	$A_{s_{min}} = .0018bt$	3.76	3.76	3.76	3.76	
8	Number of bars $N = A_s/A_{s\,bar}$	11	6	12	9	#8 bars
9	Min # of bars $N_{min} = b/2t$	10	10	10	10	
10	Bar spacing $s = b/N$	18.5"	20.5"	17"	20.5"	
11	Reinforcement Used	(11) #8 @ 18.5"	(10) #8 @ 20.5"	(12) #8 @ 17"	(10) #8 @ 20.5"	



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        adequacy of  the material supplied  as input  for  processing   by  the
        pcaSlab  computer program.  Furthermore, PCA neither makes any warranty
        expressed nor implied with respect  to  the  correctness of the  output
        prepared by the  pcaSlab   program.  Although  PCA  has  endeavored  to
        produce pcaSlab  error free the  program is not and cannot be certified
        infallible.  The final and only responsibility for analysis, design and
        engineering documents is the licensees. Accordingly, PCA disclaims  all
        responsibility in contract, negligence or other tort for any  analysis,
        design  or engineering documents prepared in connection with the use of
        the pcaSlab  program.


==============================================================================================
[2] DESIGN RESULTS
==============================================================================================

Top Reinforcement:
==================
   Units: Width (ft), Mmax (k-ft), Xmax (ft), As (in^2), Sp (in)
   Span Strip  Zone      Width         Mmax     Xmax    AsMin    AsMax    SpReq    AsReq    Bars
   ---- ------ ------ -------- ------------ -------- -------- -------- -------- -------- -------
      1 Column Left      14.67         0.18    0.204    3.248   26.829   16.004    0.005   11-#5
               Middle    14.67         0.63    0.379    3.248   26.829   16.004    0.017   11-#5
               Right     14.67         1.47    0.584    3.248   26.829    7.335    0.039   24-#5

        Middle Left      14.67         0.00    0.204    3.248   26.829   16.004    0.000   11-#5
               Middle    14.67         0.00    0.379    3.248   26.829   16.004    0.000   11-#5
               Right     14.67         0.00    0.584    3.248   26.829   16.004    0.000   11-#5

      2 Column Left      14.67       263.06    0.583    3.248   26.829    7.335    7.240   24-#5
               Middle    14.67         0.00   18.250    0.000   26.829    0.000    0.000     ---
               Right     14.67       840.81   35.917    3.248   26.829    2.071   26.233   85-#5

        Middle Left      14.67        -0.00    0.583    3.248   26.829   16.004    0.000   11-#5
               Middle    14.67         0.00   18.250    0.000   26.829    0.000    0.000     ---
               Right     14.67       280.28   35.917    3.248   26.829    7.042    7.738   25-#5

      3 Column Left      14.67       771.21    0.583    3.248   26.829    2.071   23.628   85-#5
               Middle    14.67       102.99   12.075    3.248   26.829   16.004    2.758   11-#5
               Right     14.67       561.76   33.417    3.248   26.829    3.260   16.391   54-#5

        Middle Left      14.67       257.07    0.583    3.248   26.829    7.042    7.067   25-#5
               Middle    14.67        34.33   12.075    3.248   26.829   16.004    0.909   11-#5
               Right     14.67       187.25   33.417    3.248   26.829   10.355    5.085   17-#5

      4 Column Left      14.67       569.96    0.583    3.248   26.829    3.260   16.660   54-#5
               Middle    14.67        23.05   21.925    3.248   26.829   16.004    0.609   11-#5
               Right     14.67       580.43   33.417    3.248   26.829    3.201   17.005   55-#5

        Middle Left      14.67       189.99    0.583    3.248   26.829   10.355    5.162   17-#5
               Middle    14.67         7.68   21.925    3.248   26.829   16.004    0.203   11-#5
               Right     14.67       193.48   33.417    3.248   26.829   10.355    5.260   17-#5
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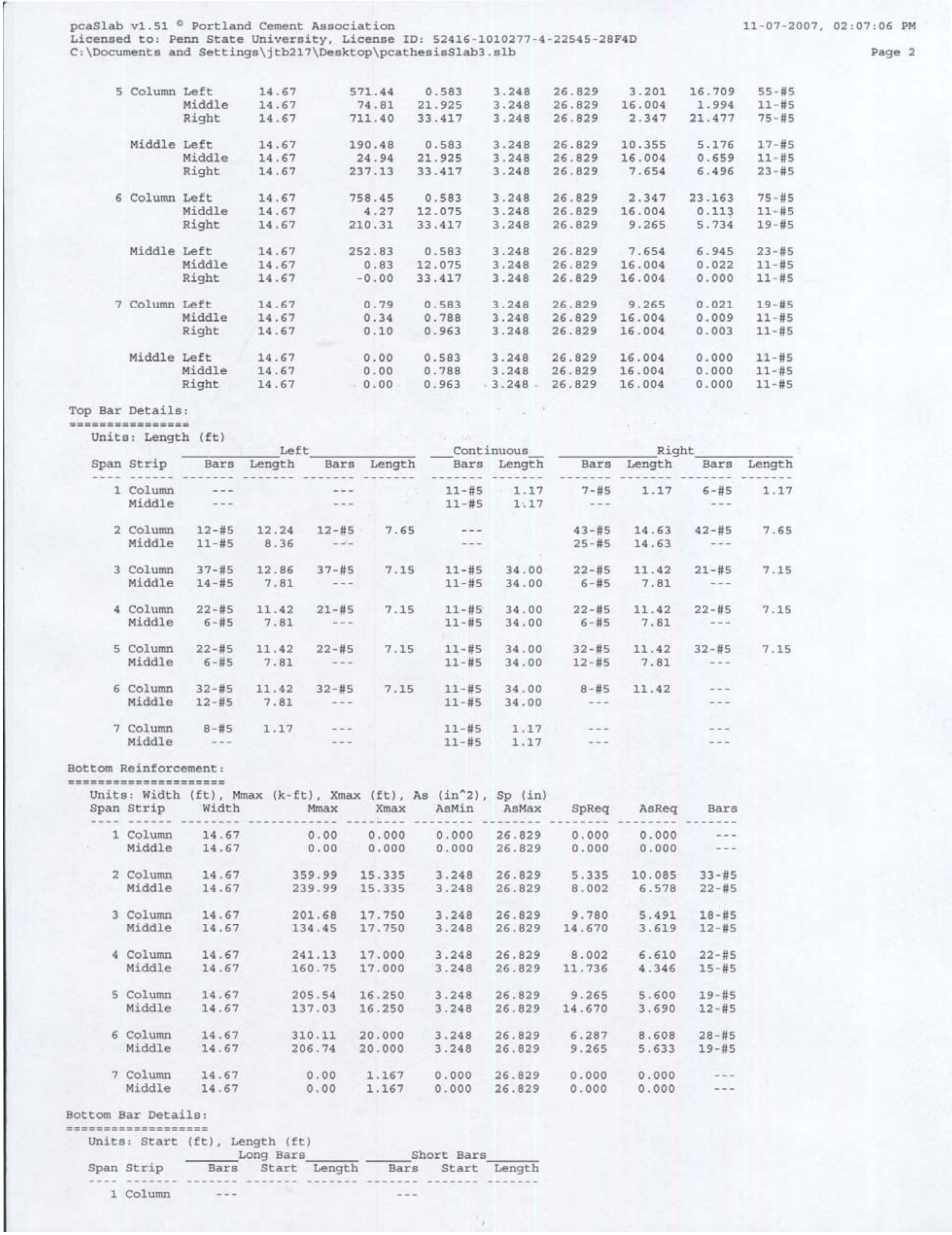

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       5 Column Left      14.67        571.44     0.583     3.248    26.829     3.201    16.709    55-#5
                Middle    14.67         74.81    21.925     3.248    26.829    16.004     1.994    11-#5
                Right     14.67        711.40    33.417     3.248    26.829     2.347    21.477    75-#5

         Middle Left      14.67        190.48     0.583     3.248    26.829    10.355     5.176    17-#5
                Middle    14.67         24.94    21.925     3.248    26.829    16.004     0.659    11-#5
                Right     14.67        237.13    33.417     3.248    26.829     7.654     6.496    23-#5

       6 Column Left      14.67        758.45     0.583     3.248    26.829     2.347    23.163    75-#5
                Middle    14.67          4.27    12.075     3.248    26.829    16.004     0.113    11-#5
                Right     14.67        210.31    33.417     3.248    26.829     9.265     5.734    19-#5

         Middle Left      14.67        252.83     0.583     3.248    26.829     7.654     6.945    23-#5
                Middle    14.67          0.83    12.075     3.248    26.829    16.004     0.022    11-#5
                Right     14.67         -0.00    33.417     3.248    26.829    16.004     0.000    11-#5

       7 Column Left      14.67          0.79     0.583     3.248    26.829     9.265     0.021    19-#5
                Middle    14.67          0.34     0.788     3.248    26.829    16.004     0.009    11-#5
                Right     14.67          0.10     0.963     3.248    26.829    16.004     0.003    11-#5

         Middle Left      14.67          0.00     0.583     3.248    26.829    16.004     0.000    11-#5
                Middle    14.67          0.00     0.788     3.248    26.829    16.004     0.000    11-#5
                Right     14.67          0.00     0.963     3.248    26.829    16.004     0.000    11-#5

Top Bar Details:
================
   Units: Length (ft)
              _____________Left______________   ___Continuous__   _____________Right_____________
   Span Strip    Bars  Length    Bars  Length      Bars  Length      Bars  Length    Bars  Length
   ---- ------ ------- ------- ------- -------   ------- -------   ------- ------- ------- -------
      1 Column    ---             ---              11-#5    1.17      7-#5    1.17    6-#5    1.17
        Middle    ---             ---              11-#5    1.17       ---             ---

      2 Column  12-#5   12.24   12-#5    7.65        ---             43-#5   14.63   42-#5    7.65
        Middle  11-#5    8.36     ---                ---             25-#5   14.63     ---

      3 Column  37-#5   12.86   37-#5    7.15      11-#5   34.00     22-#5   11.42   21-#5    7.15
        Middle  14-#5    7.81     ---              11-#5   34.00      6-#5    7.81     ---

      4 Column  22-#5   11.42   21-#5    7.15      11-#5   34.00     22-#5   11.42   22-#5    7.15
        Middle   6-#5    7.81     ---              11-#5   34.00      6-#5    7.81     ---

      5 Column  22-#5   11.42   22-#5    7.15      11-#5   34.00     32-#5   11.42   32-#5    7.15
        Middle   6-#5    7.81     ---              11-#5   34.00     12-#5    7.81     ---

      6 Column  32-#5   11.42   32-#5    7.15      11-#5   34.00      8-#5   11.42     ---
        Middle  12-#5    7.81     ---              11-#5   34.00       ---             ---

      7 Column   8-#5    1.17     ---              11-#5    1.17       ---             ---
        Middle    ---             ---              11-#5    1.17       ---             ---

Bottom Reinforcement:
=====================
   Units: Width (ft), Mmax (k-ft), Xmax (ft), As (in^2), Sp (in)
   Span Strip    Width          Mmax     Xmax    AsMin    AsMax   SpReq    AsReq    Bars
   ---- ------ -------- ------------ -------- -------- -------- -------- -------- -------
      1 Column    14.67         0.00    0.000    0.000   26.829    0.000    0.000     ---
        Middle    14.67         0.00    0.000    0.000   26.829    0.000    0.000     ---

      2 Column    14.67       359.99   15.335    3.248   26.829    5.335   10.085   33-#5
        Middle    14.67       239.99   15.335    3.248   26.829    8.002    6.578   22-#5

      3 Column    14.67       201.68   17.750    3.248   26.829    9.780    5.491   18-#5
        Middle    14.67       134.45   17.750    3.248   26.829   14.670    3.619   12-#5

      4 Column    14.67       241.13   17.000    3.248   26.829    8.002    6.610   22-#5
        Middle    14.67       160.75   17.000    3.248   26.829   11.736    4.346   15-#5

      5 Column    14.67       205.54   16.250    3.248   26.829    9.265    5.600   19-#5
        Middle    14.67       137.03   16.250    3.248   26.829   14.670    3.690   12-#5

      6 Column    14.67       310.11   20.000    3.248   26.829    6.287    8.608   28-#5
        Middle    14.67       206.74   20.000    3.248   26.829    9.265    5.633   19-#5

      7 Column    14.67         0.00    1.167    0.000   26.829    0.000    0.000     ---
        Middle    14.67         0.00    1.167    0.000   26.829    0.000    0.000     ---

Bottom Bar Details:
===================
   Units: Start (ft), Length (ft)
               ________Long Bars_______  _______Short Bars_______
   Span Strip      Bars   Start  Length     Bars   Start  Length
   ---- ------- ------- ------- -------  ------- ------- -------
      1 Column     ---                      ---
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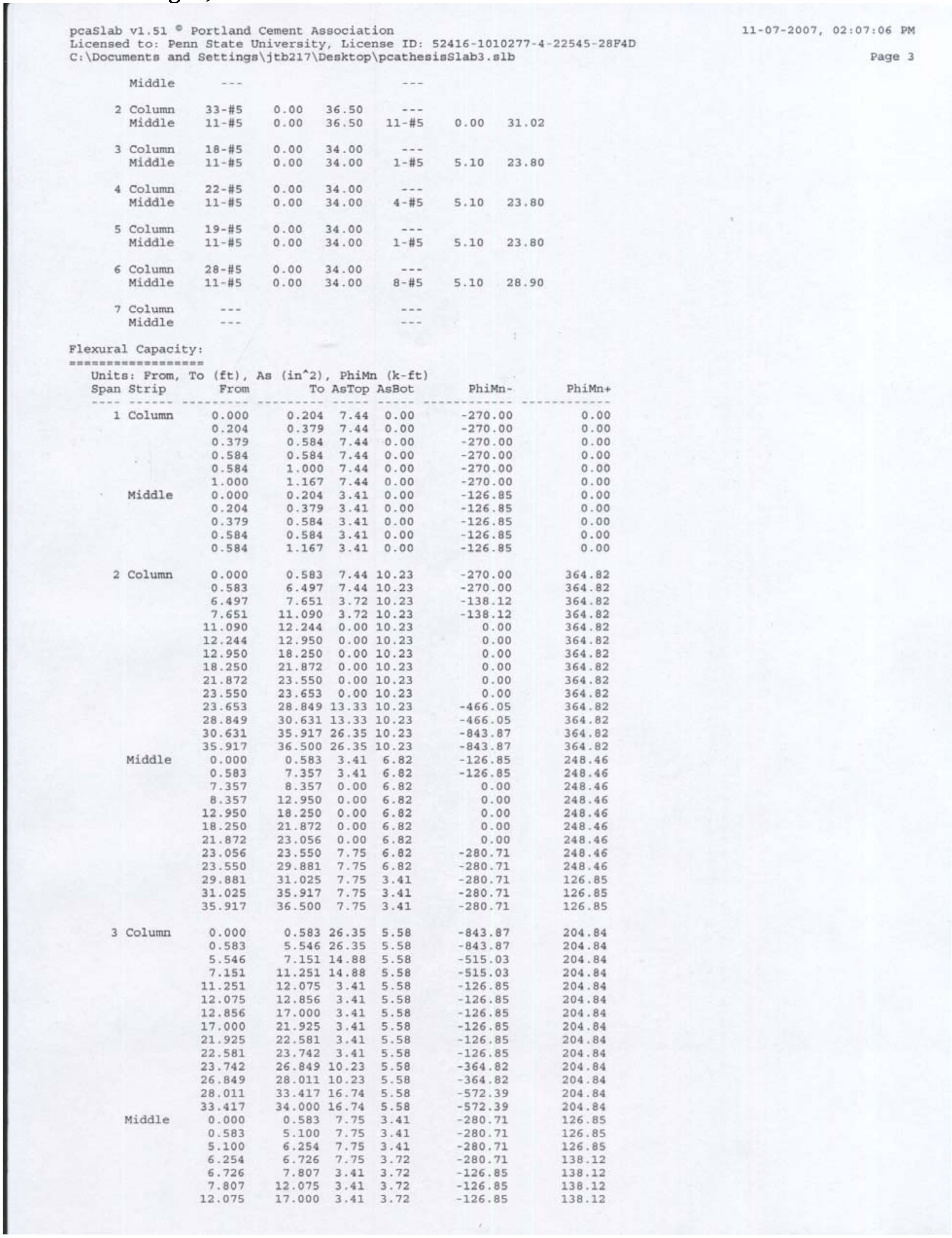

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        Middle      ---                   ---

      2 Column    33-#5    0.00   36.50   ---
        Middle    11-#5    0.00   36.50  11-#5    0.00   31.02

      3 Column    18-#5    0.00   34.00   ---
        Middle    11-#5    0.00   34.00   1-#5    5.10   23.80

      4 Column    22-#5    0.00   34.00   ---
        Middle    11-#5    0.00   34.00   4-#5    5.10   23.80

      5 Column    19-#5    0.00   34.00   ---
        Middle    11-#5    0.00   34.00   1-#5    5.10   23.80

      6 Column    28-#5    0.00   34.00   ---
        Middle    11-#5    0.00   34.00   8-#5    5.10   28.90

      7 Column      ---                   ---
        Middle      ---                   ---

Flexural Capacity:
==================
   Units: From, To (ft), As (in^2), PhiMn (k-ft)
   Span Strip       From        To AsTop AsBot      PhiMn-      PhiMn+
   ---- ------ --------- --------- ----- ----- ----------- -----------
      1 Column     0.000     0.204  7.44  0.00     -270.00        0.00
                   0.204     0.379  7.44  0.00     -270.00        0.00
                   0.379     0.584  7.44  0.00     -270.00        0.00
                   0.584     0.584  7.44  0.00     -270.00        0.00
                   0.584     1.000  7.44  0.00     -270.00        0.00
                   1.000     1.167  7.44  0.00     -270.00        0.00
        Middle     0.000     0.204  3.41  0.00     -126.85        0.00
                   0.204     0.379  3.41  0.00     -126.85        0.00
                   0.379     0.584  3.41  0.00     -126.85        0.00
                   0.584     0.584  3.41  0.00     -126.85        0.00
                   0.584     1.167  3.41  0.00     -126.85        0.00

      2 Column     0.000     0.583  7.44 10.23     -270.00      364.82
                   0.583     6.497  7.44 10.23     -270.00      364.82
                   6.497     7.651  3.72 10.23     -138.12      364.82
                   7.651    11.090  3.72 10.23     -138.12      364.82
                  11.090    12.244  0.00 10.23        0.00      364.82
                  12.244    12.950  0.00 10.23        0.00      364.82
                  12.950    18.250  0.00 10.23        0.00      364.82
                  18.250    21.872  0.00 10.23        0.00      364.82
                  21.872    23.550  0.00 10.23        0.00      364.82
                  23.550    23.653  0.00 10.23        0.00      364.82
                  23.653    28.849 13.33 10.23     -466.05      364.82
                  28.849    30.631 13.33 10.23     -466.05      364.82
                  30.631    35.917 26.35 10.23     -843.87      364.82
                  35.917    36.500 26.35 10.23     -843.87      364.82
        Middle     0.000     0.583  3.41  6.82     -126.85      248.46
                   0.583     7.357  3.41  6.82     -126.85      248.46
                   7.357     8.357  0.00  6.82        0.00      248.46
                   8.357    12.950  0.00  6.82        0.00      248.46
                  12.950    18.250  0.00  6.82        0.00      248.46
                  18.250    21.872  0.00  6.82        0.00      248.46
                  21.872    23.056  0.00  6.82        0.00      248.46
                  23.056    23.550  7.75  6.82     -280.71      248.46
                  23.550    29.881  7.75  6.82     -280.71      248.46
                  29.881    31.025  7.75  3.41     -280.71      126.85
                  31.025    35.917  7.75  3.41     -280.71      126.85
                  35.917    36.500  7.75  3.41     -280.71      126.85

      3 Column     0.000     0.583 26.35  5.58     -843.87      204.84
                   0.583     5.546 26.35  5.58     -843.87      204.84
                   5.546     7.151 14.88  5.58     -515.03      204.84
                   7.151    11.251 14.88  5.58     -515.03      204.84
                  11.251    12.075  3.41  5.58     -126.85      204.84
                  12.075    12.856  3.41  5.58     -126.85      204.84
                  12.856    17.000  3.41  5.58     -126.85      204.84
                  17.000    21.925  3.41  5.58     -126.85      204.84
                  21.925    22.581  3.41  5.58     -126.85      204.84
                  22.581    23.742  3.41  5.58     -126.85      204.84
                  23.742    26.849 10.23  5.58     -364.82      204.84
                  26.849    28.011 10.23  5.58     -364.82      204.84
                  28.011    33.417 16.74  5.58     -572.39      204.84
                  33.417    34.000 16.74  5.58     -572.39      204.84
        Middle     0.000     0.583  7.75  3.41     -280.71      126.85
                   0.583     5.100  7.75  3.41     -280.71      126.85
                   5.100     6.254  7.75  3.41     -280.71      126.85
                   6.254     6.726  7.75  3.72     -280.71      138.12
                   6.726     7.807  3.41  3.72     -126.85      138.12
                   7.807    12.075  3.41  3.72     -126.85      138.12
                  12.075    17.000  3.41  3.72     -126.85      138.12
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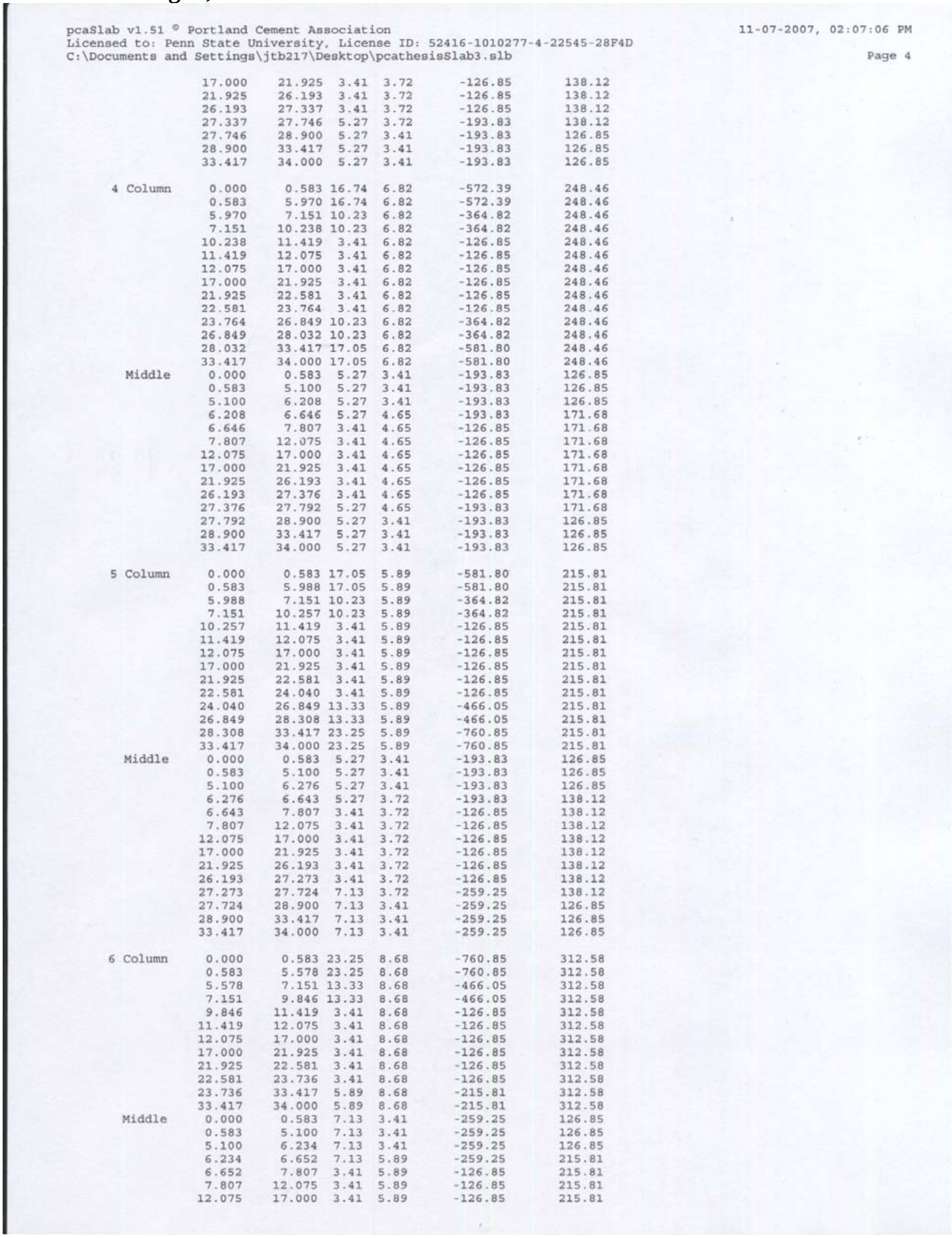

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                 17.000    21.925  3.41  3.72      -126.85      138.12
                 21.925    26.193  3.41  3.72      -126.85      138.12
                 26.193    27.337  3.41  3.72      -126.85      138.12
                 27.337    27.746  5.27  3.72      -193.83      138.12
                 27.746    28.900  5.27  3.41      -193.83      126.85
                 28.900    33.417  5.27  3.41      -193.83      126.85
                 33.417    34.000  5.27  3.41      -193.83      126.85

     4 Column     0.000     0.583 16.74  6.82      -572.39      248.46
                  0.583     5.970 16.74  6.82      -572.39      248.46
                  5.970     7.151 10.23  6.82      -364.82      248.46
                  7.151    10.238 10.23  6.82      -364.82      248.46
                 10.238    11.419  3.41  6.82      -126.85      248.46
                 11.419    12.075  3.41  6.82      -126.85      248.46
                 12.075    17.000  3.41  6.82      -126.85      248.46
                 17.000    21.925  3.41  6.82      -126.85      248.46
                 21.925    22.581  3.41  6.82      -126.85      248.46
                 22.581    23.764  3.41  6.82      -126.85      248.46
                 23.764    26.849 10.23  6.82      -364.82      248.46
                 26.849    28.032 10.23  6.82      -364.82      248.46
                 28.032    33.417 17.05  6.82      -581.80      248.46
                 33.417    34.000 17.05  6.82      -581.80      248.46
       Middle     0.000     0.583  5.27  3.41      -193.83      126.85
                  0.583     5.100  5.27  3.41      -193.83      126.85
                  5.100     6.208  5.27  3.41      -193.83      126.85
                  6.208     6.646  5.27  4.65      -193.83      171.68
                  6.646     7.807  3.41  4.65      -126.85      171.68
                  7.807    12.075  3.41  4.65      -126.85      171.68
                 12.075    17.000  3.41  4.65      -126.85      171.68
                 17.000    21.925  3.41  4.65      -126.85      171.68
                 21.925    26.193  3.41  4.65      -126.85      171.68
                 26.193    27.376  3.41  4.65      -126.85      171.68
                 27.376    27.792  5.27  4.65      -193.83      171.68
                 27.792    28.900  5.27  3.41      -193.83      126.85
                 28.900    33.417  5.27  3.41      -193.83      126.85
                 33.417    34.000  5.27  3.41      -193.83      126.85

     5 Column     0.000     0.583 17.05  5.89      -581.80      215.81
                  0.583     5.988 17.05  5.89      -581.80      215.81
                  5.988     7.151 10.23  5.89      -364.82      215.81
                  7.151    10.257 10.23  5.89      -364.82      215.81
                 10.257    11.419  3.41  5.89      -126.85      215.81
                 11.419    12.075  3.41  5.89      -126.85      215.81
                 12.075    17.000  3.41  5.89      -126.85      215.81
                 17.000    21.925  3.41  5.89      -126.85      215.81
                 21.925    22.581  3.41  5.89      -126.85      215.81
                 22.581    24.040  3.41  5.89      -126.85      215.81
                 24.040    26.849 13.33  5.89      -466.05      215.81
                 26.849    28.308 13.33  5.89      -466.05      215.81
                 28.308    33.417 23.25  5.89      -760.85      215.81
                 33.417    34.000 23.25  5.89      -760.85      215.81
       Middle     0.000     0.583  5.27  3.41      -193.83      126.85
                  0.583     5.100  5.27  3.41      -193.83      126.85
                  5.100     6.276  5.27  3.41      -193.83      126.85
                  6.276     6.643  5.27  3.72      -193.83      138.12
                  6.643     7.807  3.41  3.72      -126.85      138.12
                  7.807    12.075  3.41  3.72      -126.85      138.12
                 12.075    17.000  3.41  3.72      -126.85      138.12
                 17.000    21.925  3.41  3.72      -126.85      138.12
                 21.925    26.193  3.41  3.72      -126.85      138.12
                 26.193    27.273  3.41  3.72      -126.85      138.12
                 27.273    27.724  7.13  3.72      -259.25      138.12
                 27.724    28.900  7.13  3.41      -259.25      126.85
                 28.900    33.417  7.13  3.41      -259.25      126.85
                 33.417    34.000  7.13  3.41      -259.25      126.85

     6 Column     0.000     0.583 23.25  8.68      -760.85      312.58
                  0.583     5.578 23.25  8.68      -760.85      312.58
                  5.578     7.151 13.33  8.68      -466.05      312.58
                  7.151     9.846 13.33  8.68      -466.05      312.58
                  9.846    11.419  3.41  8.68      -126.85      312.58
                 11.419    12.075  3.41  8.68      -126.85      312.58
                 12.075    17.000  3.41  8.68      -126.85      312.58
                 17.000    21.925  3.41  8.68      -126.85      312.58
                 21.925    22.581  3.41  8.68      -126.85      312.58
                 22.581    23.736  3.41  8.68      -126.85      312.58
                 23.736    33.417  5.89  8.68      -215.81      312.58
                 33.417    34.000  5.89  8.68      -215.81      312.58
       Middle     0.000     0.583  7.13  3.41      -259.25      126.85
                  0.583     5.100  7.13  3.41      -259.25      126.85
                  5.100     6.234  7.13  3.41      -259.25      126.85
                  6.234     6.652  7.13  5.89      -259.25      215.81
                  6.652     7.807  3.41  5.89      -126.85      215.81
                  7.807    12.075  3.41  5.89      -126.85      215.81
                 12.075    17.000  3.41  5.89      -126.85      215.81
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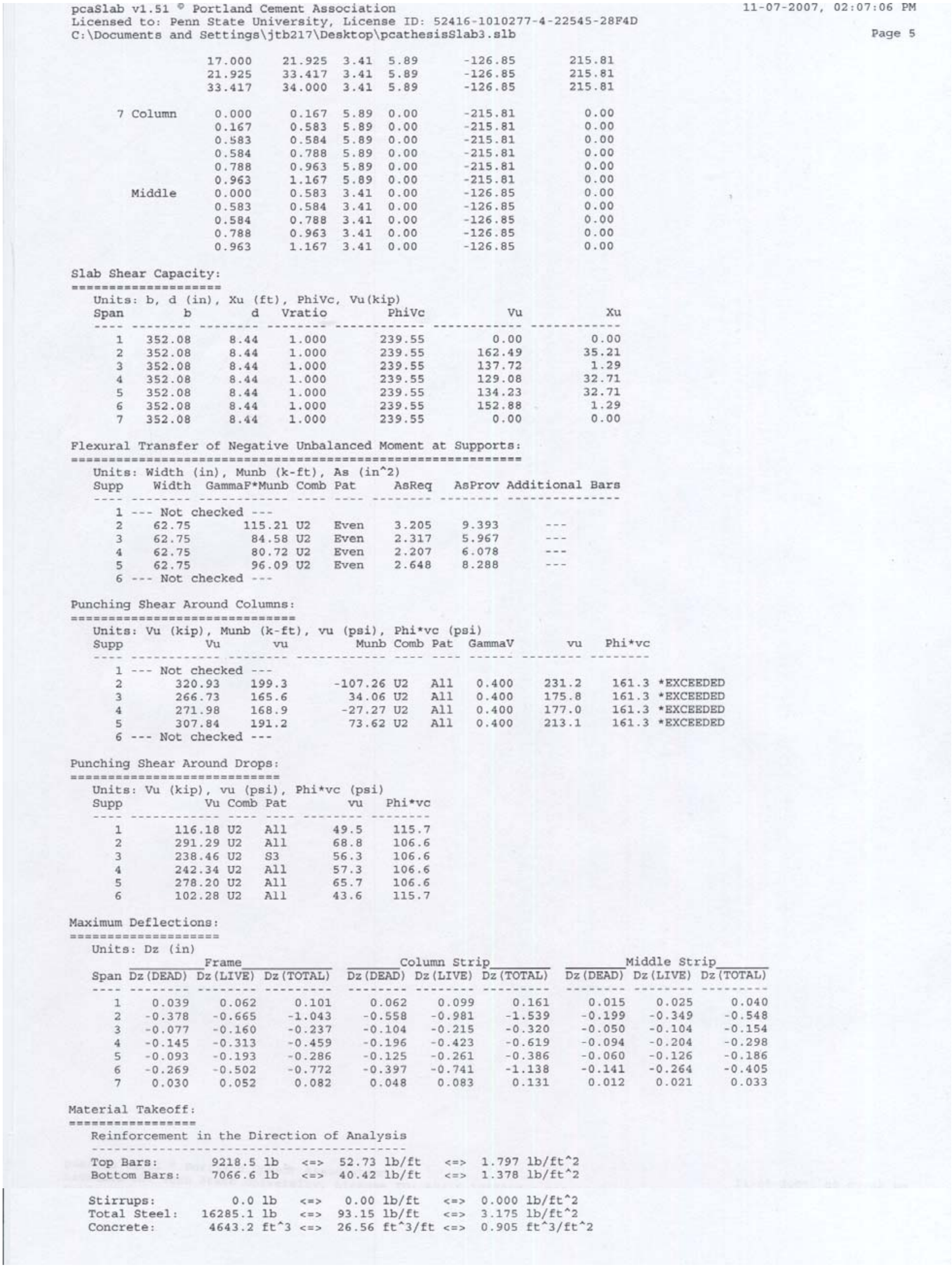

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                  17.000     21.925  3.41  5.89      -126.85        215.81
                  21.925     33.417  3.41  5.89      -126.85        215.81
                  33.417     34.000  3.41  5.89      -126.85        215.81

      7 Column     0.000      0.167  5.89  0.00      -215.81          0.00
                   0.167      0.583  5.89  0.00      -215.81          0.00
                   0.583      0.584  5.89  0.00      -215.81          0.00
                   0.584      0.788  5.89  0.00      -215.81          0.00
                   0.788      0.963  5.89  0.00      -215.81          0.00
                   0.963      1.167  5.89  0.00      -215.81          0.00
        Middle     0.000      0.583  3.41  0.00      -126.85          0.00
                   0.583      0.584  3.41  0.00      -126.85          0.00
                   0.584      0.788  3.41  0.00      -126.85          0.00
                   0.788      0.963  3.41  0.00      -126.85          0.00
                   0.963      1.167  3.41  0.00      -126.85          0.00

Slab Shear Capacity:
====================
   Units: b, d (in), Xu (ft), PhiVc, Vu(kip)
   Span        b        d   Vratio        PhiVc           Vu           Xu
   ---- -------- -------- -------- ------------ ------------ ------------
      1   352.08     8.44    1.000       239.55         0.00         0.00
      2   352.08     8.44    1.000       239.55       162.49        35.21
      3   352.08     8.44    1.000       239.55       137.72         1.29
      4   352.08     8.44    1.000       239.55       129.08        32.71
      5   352.08     8.44    1.000       239.55       134.23        32.71
      6   352.08     8.44    1.000       239.55       152.88         1.29
      7   352.08     8.44    1.000       239.55         0.00         0.00

Flexural Transfer of Negative Unbalanced Moment at Supports:
============================================================
   Units: Width (in), Munb (k-ft), As (in^2)
   Supp    Width  GammaF*Munb Comb Pat     AsReq   AsProv Additional Bars
   ---- -------- ------------ ---- ---- -------- -------- ---------------
      1 --- Not checked ---
      2    62.75       115.21 U2   Even    3.205    9.393       ---
      3    62.75        84.58 U2   Even    2.317    5.967       ---
      4    62.75        80.72 U2   Even    2.207    6.078       ---
      5    62.75        96.09 U2   Even    2.648    8.288       ---
      6 --- Not checked ---

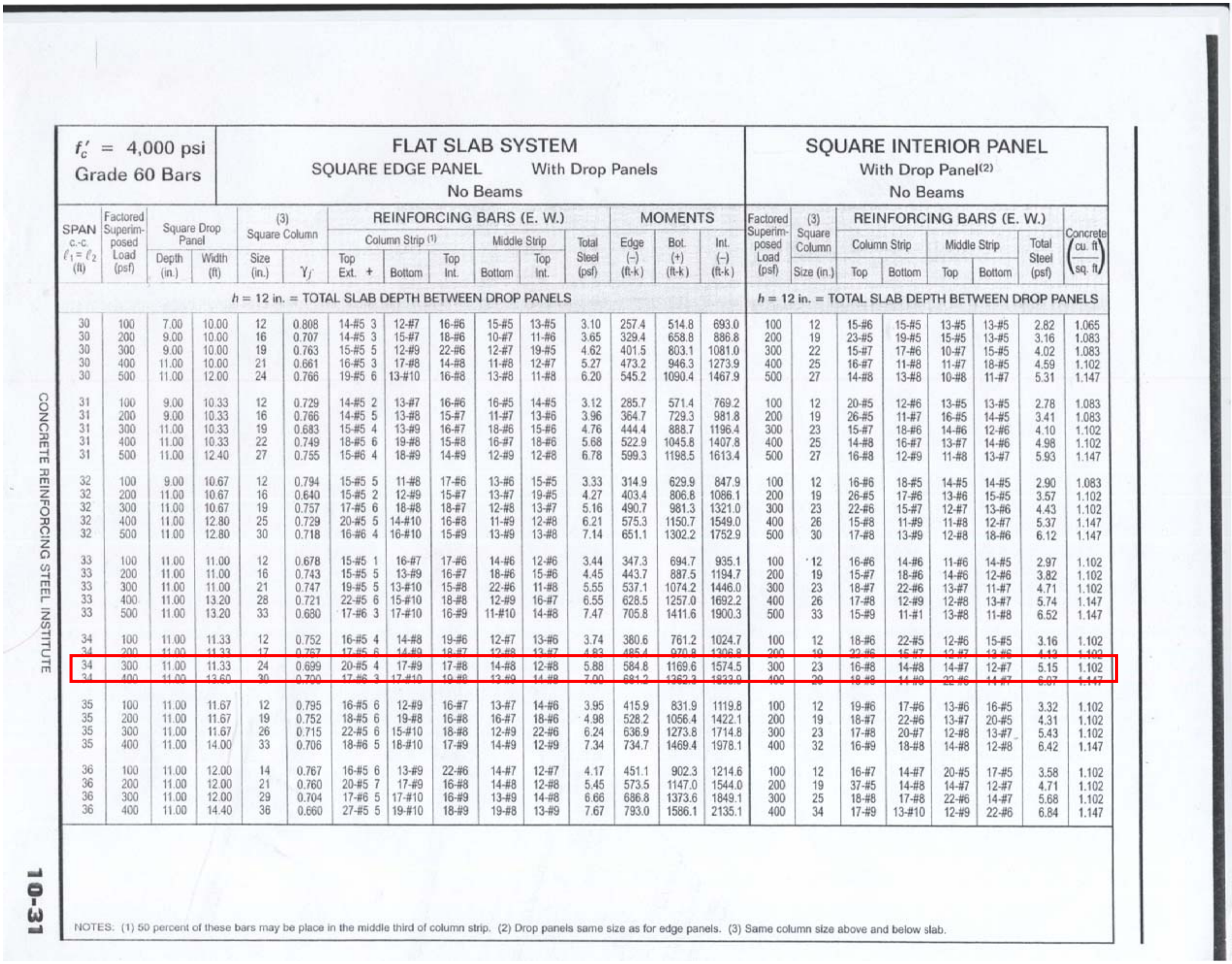
Punching Shear Around Columns:
==============================
   Units: Vu (kip), Munb (k-ft), vu (psi), Phi*vc (psi)
   Supp           Vu       vu         Munb Comb Pat  GammaV       vu   Phi*vc
   ---- ------------ -------- ------------ ---- ---- ------ -------- --------
      1 --- Not checked ---
      2       320.93    199.3      -107.26 U2   All   0.400    231.2    161.3 *EXCEEDED
      3       266.73    165.6        34.06 U2   All   0.400    175.8    161.3 *EXCEEDED
      4       271.98    168.9       -27.27 U2   All   0.400    177.0    161.3 *EXCEEDED
      5       307.84    191.2        73.62 U2   All   0.400    213.1    161.3 *EXCEEDED
      6 --- Not checked ---

Punching Shear Around Drops:
============================
   Units: Vu (kip), vu (psi), Phi*vc (psi)
   Supp           Vu Comb Pat        vu   Phi*vc
   ---- ------------ ---- ---- -------- --------
      1       116.18 U2   All      49.5    115.7
      2       291.29 U2   All      68.8    106.6
      3       238.46 U2   S3       56.3    106.6
      4       242.34 U2   All      57.3    106.6
      5       278.20 U2   All      65.7    106.6
      6       102.28 U2   All      43.6    115.7

Maximum Deflections:
====================
   Units: Dz (in)
        __________Frame____________  _______Column Strip________  _______Middle Strip_______
   Span Dz(DEAD) Dz(LIVE) Dz(TOTAL)  Dz(DEAD) Dz(LIVE) Dz(TOTAL)  Dz(DEAD) Dz(LIVE) Dz(TOTAL)
   ---- -------- -------- ---------  -------- -------- ---------  -------- -------- ---------
      1    0.039    0.062     0.101     0.062    0.099     0.161     0.015    0.025     0.040
      2   -0.378   -0.665    -1.043    -0.558   -0.981    -1.539    -0.199   -0.349    -0.548
      3   -0.077   -0.160    -0.237    -0.104   -0.215    -0.320    -0.050   -0.104    -0.154
      4   -0.145   -0.313    -0.459    -0.196   -0.423    -0.619    -0.094   -0.204    -0.298
      5   -0.093   -0.193    -0.286    -0.125   -0.261    -0.386    -0.060   -0.126    -0.186
      6   -0.269   -0.502    -0.772    -0.397   -0.741    -1.138    -0.141   -0.264    -0.405
      7    0.030    0.052     0.082     0.048    0.083     0.131     0.012    0.021     0.033

Material Takeoff:
=================
   Reinforcement in the Direction of Analysis
   ------------------------------------------
   Top Bars:        9218.5 lb   <=>  52.73 lb/ft    <=>  1.797 lb/ft^2
   Bottom Bars:     7066.6 lb   <=>  40.42 lb/ft    <=>  1.378 lb/ft^2

   Stirrups:           0.0 lb   <=>   0.00 lb/ft    <=>  0.000 lb/ft^2
   Total Steel:    16285.1 lb   <=>  93.15 lb/ft    <=>  3.175 lb/ft^2
   Concrete:        4643.2 ft^3 <=>  26.56 ft^3/ft  <=>  0.905 ft^3/ft^2
```



f'_c = 4,000 psi
Grade 60 Bars

FLAT SLAB SYSTEM

SQUARE EDGE PANEL With Drop Panels
No Beams

SQUARE INTERIOR PANEL

With Drop Panel(2)
No Beams

SPAN c.-c. $\ell_1 = \ell_2$ (ft)	Factored Superimposed Load (psf)	Square Drop Panel		(3) Square Column		REINFORCING BARS (E. W.)							MOMENTS			Factored Superimposed Load (psf)	(3) Square Column	REINFORCING BARS (E. W.)					Concrete (cu. ft / sq. ft)
						Column Strip (1)				Middle Strip		Total Steel (psf)	Edge (−) (ft-k)	Bot. (+) (ft-k)	Int. (−) (ft-k)			Column Strip		Middle Strip		Total Steel (psf)	
		Depth (in.)	Width (ft)	Size (in.)	γ_f	Top Ext.	+	Bottom	Top Int.	Bottom	Top Int.						Size (in.)	Top	Bottom	Top	Bottom		
h = 12 in. = TOTAL SLAB DEPTH BETWEEN DROP PANELS																h = 12 in. = TOTAL SLAB DEPTH BETWEEN DROP PANELS							
30	100	7.00	10.00	12	0.808	14-#5	3	12-#7	16-#6	15-#5	13-#5	3.10	257.4	514.8	693.0	100	12	15-#6	15-#5	13-#5	13-#5	2.82	1.065
30	200	9.00	10.00	16	0.707	14-#5	3	15-#7	18-#6	10-#7	11-#6	3.65	329.4	658.8	886.8	200	19	23-#5	19-#5	15-#5	13-#5	3.16	1.083
30	300	9.00	10.00	19	0.763	15-#5	5	12-#9	22-#6	12-#7	19-#5	4.62	401.5	803.1	1081.0	300	22	15-#7	17-#6	10-#7	15-#5	4.02	1.083
30	400	11.00	10.00	21	0.661	16-#5	3	17-#8	14-#8	11-#8	12-#7	5.27	473.2	946.3	1273.9	400	25	16-#7	11-#8	11-#7	18-#5	4.59	1.102
30	500	11.00	12.00	24	0.766	19-#5	6	13-#10	16-#8	13-#8	11-#8	6.20	545.2	1090.4	1467.9	500	27	14-#8	13-#8	10-#8	11-#7	5.31	1.147
31	100	9.00	10.33	12	0.729	14-#5	2	13-#7	16-#6	16-#5	14-#5	3.12	285.7	571.4	769.2	100	12	20-#5	12-#6	13-#5	13-#5	2.78	1.083
31	200	9.00	10.33	16	0.766	14-#5	5	13-#8	15-#7	11-#7	13-#6	3.96	364.7	729.3	981.8	200	19	26-#5	11-#7	16-#5	14-#5	3.41	1.083
31	300	11.00	10.33	19	0.683	15-#5	4	13-#9	16-#7	18-#6	15-#6	4.76	444.4	888.7	1196.4	300	23	15-#7	18-#6	14-#6	12-#6	4.10	1.102
31	400	11.00	10.33	22	0.749	18-#5	6	19-#8	15-#8	16-#7	18-#6	5.68	522.9	1045.8	1407.8	400	25	14-#8	16-#7	13-#7	14-#6	4.98	1.102
31	500	11.00	12.40	27	0.755	15-#6	4	18-#9	14-#9	12-#9	12-#8	6.78	599.3	1198.5	1613.4	500	27	16-#8	12-#9	11-#8	13-#7	5.93	1.147
32	100	9.00	10.67	12	0.794	15-#5	5	11-#8	17-#6	13-#6	15-#5	3.33	314.9	629.9	847.9	100	12	16-#6	18-#5	14-#5	14-#5	2.90	1.083
32	200	11.00	10.67	16	0.640	15-#5	2	12-#9	15-#7	13-#7	19-#5	4.27	403.4	806.8	1086.1	200	19	26-#5	17-#6	13-#6	15-#5	3.57	1.102
32	300	11.00	10.67	19	0.757	17-#5	6	18-#8	18-#7	12-#8	13-#7	5.16	490.7	981.3	1321.0	300	23	22-#6	15-#7	12-#7	13-#6	4.43	1.102
32	400	11.00	12.80	25	0.729	20-#5	5	14-#10	16-#8	11-#9	12-#8	6.21	575.3	1150.7	1549.0	400	26	15-#8	11-#9	11-#8	12-#7	5.37	1.147
32	500	11.00	12.80	30	0.718	16-#6	4	16-#10	15-#9	13-#9	13-#8	7.14	651.1	1302.2	1752.9	500	30	17-#8	13-#9	12-#8	18-#6	6.12	1.147
33	100	11.00	11.00	12	0.678	15-#5	1	16-#7	17-#6	14-#6	12-#6	3.44	347.3	694.7	935.1	100	12	16-#6	14-#6	11-#6	14-#5	2.97	1.102
33	200	11.00	11.00	16	0.743	15-#5	5	13-#9	16-#7	18-#6	15-#6	4.45	443.7	887.5	1194.7	200	19	15-#7	18-#6	14-#6	12-#6	3.82	1.102
33	300	11.00	11.00	21	0.747	19-#5	5	13-#10	15-#8	22-#6	11-#8	5.55	537.1	1074.2	1446.0	300	23	18-#7	22-#6	13-#7	11-#7	4.71	1.102
33	400	11.00	13.20	28	0.721	22-#5	6	15-#10	18-#8	12-#9	16-#7	6.55	628.5	1257.0	1692.2	400	26	17-#8	12-#9	12-#8	13-#7	5.74	1.147
33	500	11.00	13.20	33	0.680	17-#6	3	17-#10	16-#9	11-#10	14-#8	7.47	705.8	1411.6	1900.3	500	33	15-#9	11-#1	13-#8	11-#8	6.52	1.147
34	100	11.00	11.33	12	0.752	16-#5	4	14-#8	19-#6	12-#7	13-#6	3.74	380.6	761.2	1024.7	100	12	18-#6	22-#5	12-#6	15-#5	3.16	1.102
34	200	11.00	11.33	17	0.767	17-#5	6	14-#9	18-#7	12-#8	13-#7	4.83	485.4	970.8	1306.8	200	19	22-#6	15-#7	12-#7	13-#6	4.13	1.102
34	300	11.00	11.33	24	0.699	20-#5	4	17-#9	17-#8	14-#8	12-#8	5.88	584.8	1169.6	1574.5	300	23	16-#8	14-#8	14-#7	12-#7	5.15	1.102
34	400	11.00	13.60	30	0.700	17-#6	3	17-#10	19-#8	13-#9	14-#8	7.00	681.2	1362.3	1833.9	400	29	18-#8	14-#9	22-#6	14-#7	6.07	1.147
35	100	11.00	11.67	12	0.795	16-#5	6	12-#9	16-#7	13-#7	14-#6	3.95	415.9	831.9	1119.8	100	12	19-#6	17-#6	13-#6	16-#5	3.32	1.102
35	200	11.00	11.67	19	0.752	18-#5	6	19-#8	16-#8	16-#7	18-#6	4.98	528.2	1056.4	1422.1	200	19	18-#7	22-#6	13-#7	20-#5	4.31	1.102
35	300	11.00	11.67	26	0.715	22-#5	6	15-#10	18-#8	12-#9	22-#6	6.24	636.9	1273.8	1714.8	300	23	17-#8	20-#7	12-#8	13-#7	5.43	1.102
35	400	11.00	14.00	33	0.706	18-#6	5	18-#10	17-#9	14-#9	12-#9	7.34	734.7	1469.4	1978.1	400	32	16-#9	18-#8	14-#8	12-#8	6.42	1.147
36	100	11.00	12.00	14	0.767	16-#5	6	13-#9	22-#6	14-#7	12-#7	4.17	451.1	902.3	1214.6	100	12	16-#7	14-#7	20-#5	17-#5	3.58	1.102
36	200	11.00	12.00	21	0.760	20-#5	7	17-#9	16-#8	14-#8	12-#8	5.45	573.5	1147.0	1544.0	200	19	37-#5	14-#8	14-#7	12-#7	4.71	1.102
36	300	11.00	12.00	29	0.704	17-#6	5	17-#10	16-#9	13-#9	14-#8	6.66	686.8	1373.6	1849.1	300	25	18-#8	17-#8	22-#6	14-#7	5.68	1.102
36	400	11.00	14.40	36	0.660	27-#5	5	19-#10	18-#9	19-#8	13-#9	7.67	793.0	1586.1	2135.1	400	34	17-#9	13-#10	12-#9	22-#6	6.84	1.147

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

Appendix C – Hollowcore planks on steel girders

Josh Behun | Tech 2 | Hollowcore page 1

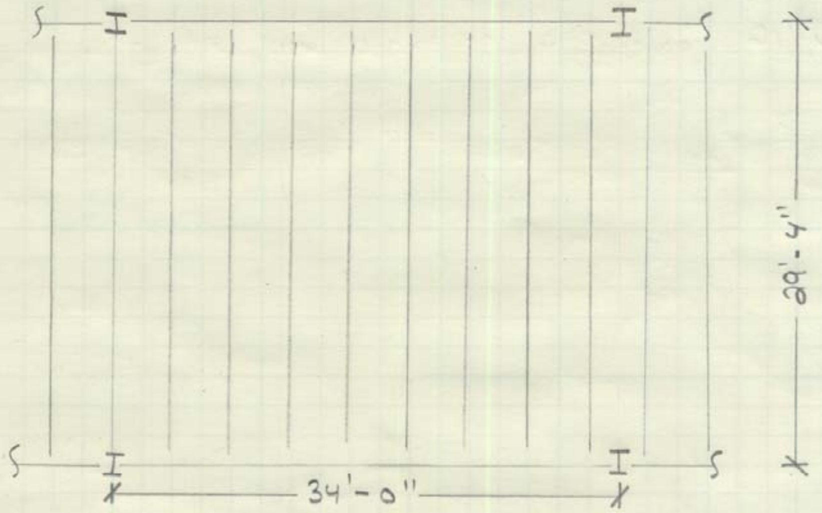
Hollowcore planks on steel girders

Typical Bay

w_{LL} = 100 psf
w_{DL} = 20 psf partition allowance
20 psf superimposed / collateral (assumed)
140 psf total service load

From Nitterhouse Concrete Products load tables using 10" x 4'-0" hollow core plank @ 29'-4" span with (7) 1/2" Ø, 270^k Lo-Relaxation planks and 2 hr fire rating with 2" topping

w_{allow} = 153 psf > 140 psf <u>ok</u>



8.5 planks to span bay

Josh Behun | Tech 2 | Hollowcore page 2

Girder Check

$w_{LL} = 100 \text{ psf} \left[\frac{30'}{2} + \frac{34'}{2} \right] = 3.2 \text{ klf}$

$w_{DL} = \left[\underset{\text{plank}}{68 \text{ psf}} + \underset{\text{topping}}{25 \text{ psf}} + \underset{\text{partition}}{20 \text{ psf}} + \underset{\text{collateral}}{20 \text{ psf}} \right] \left[\frac{30'}{2} + \frac{34'}{2} \right]$

$= 3.59 \text{ klf}$

$w_u = 1.2(3.59) + 1.6(3.2) = 9.5 \text{ klf}$

$M_u^- = \frac{w_u L^2}{12} = \frac{9.5(34)^2}{12} = 915 \text{ 'k}$

assuming - beam fully braced by hollowcore grout making $L_b = 0'$ so that M^+ will not control
- fixed end connections

Try W30x90 (current girder)

$\Delta L = \ell/360 = \frac{34'(12)}{360} \geq \frac{wL^4}{384EI} = \frac{3.2(34)^4(1728)}{384(29000)(3610)}$

$1.13'' \geq .18''$ ok

$\Delta T = \frac{\ell}{240} = \frac{34'(12)}{240} \geq \frac{9.5(34)^4(1728)}{384(29000)(3610)}$

$1.7 \geq .55$ ok

Try W27x84

$\Delta L = \frac{\ell}{360} = \frac{34(12)}{360} \geq \frac{3.2(34)^4(1728)}{384(29000)(2850)}$

$1.13'' \geq .23''$ ok

$\Delta T = \frac{\ell}{240} = \frac{34(12)}{240} \geq \frac{9.5(34)^4(1728)}{384(29000)(2850)}$

$1.7 \geq .69$ ok

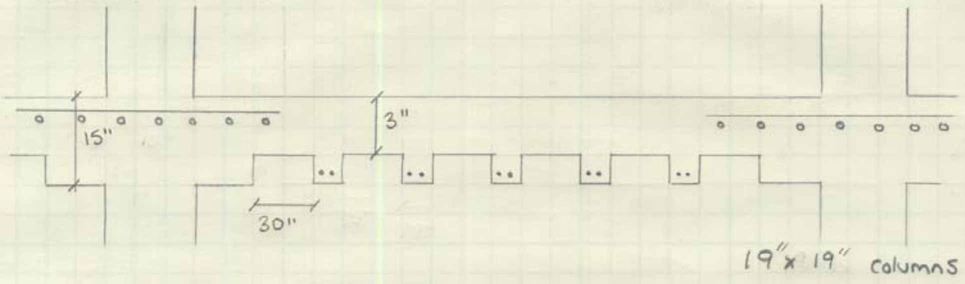
* based on deflection could easily use smaller girders

Appendix D – Waffle Slab

Josh Behun | Tech 2 | Waffle Slab

page 1

Waffle Slab



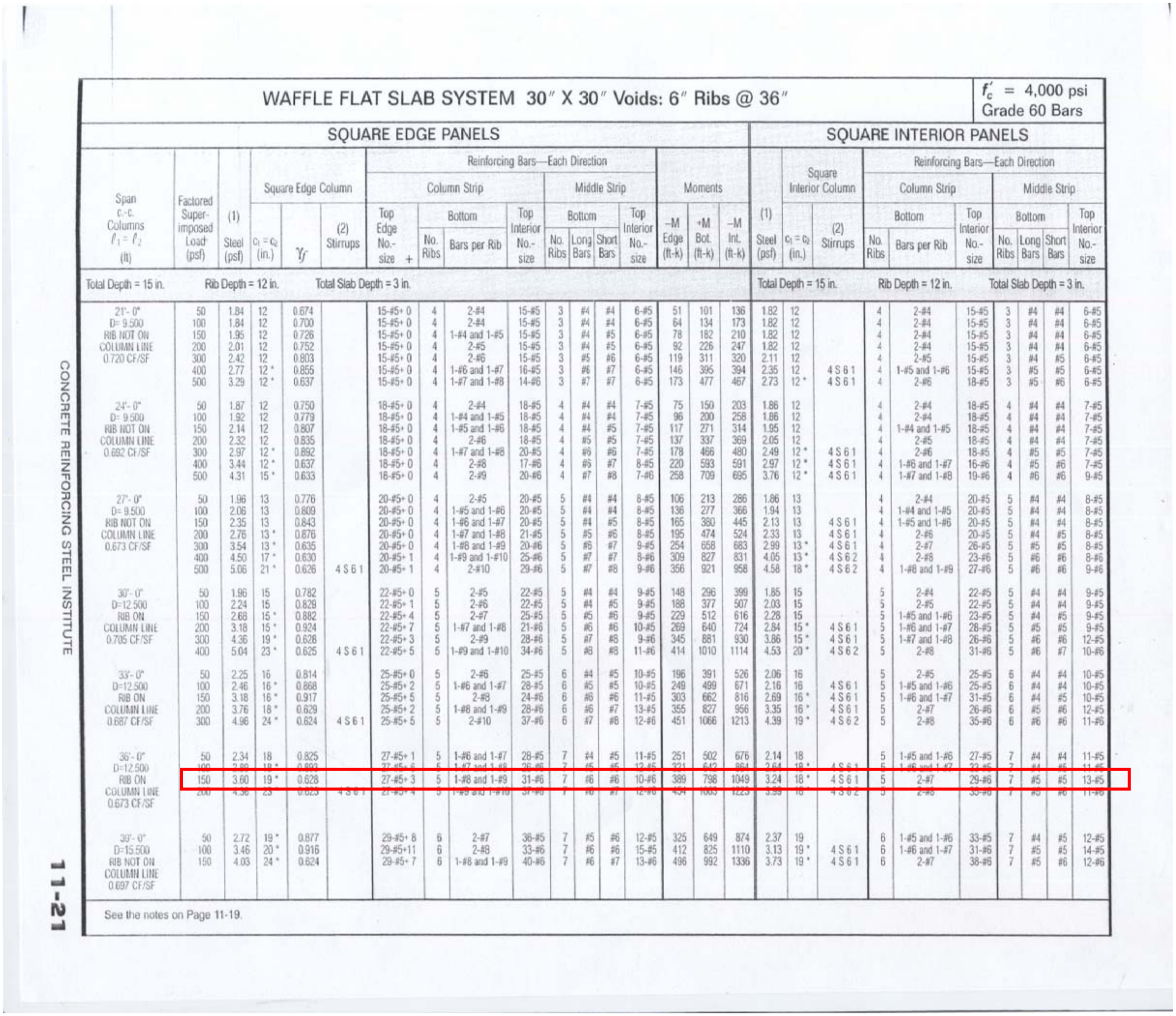
Live Load = 80 psf

Dead Load = 20 psf

$W_u = 1.2(20) + 1.6(80) = 153$ psf

Self Weight = $\frac{3}{12}(150) + \left[\frac{12}{12}(150)(.673)\right] = 140$ psf

using Normal weight concrete



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

f'_c = 4,000 psi
Grade 60 Bars

Span c.-c. Columns $\ell_1 = \ell_2$ (ft)	Factored Super-imposed Load (psf)	SQUARE EDGE PANELS															SQUARE INTERIOR PANELS									
		(1)	Square Edge Column			Reinforcing Bars—Each Direction								Moments			(1)	Square Interior Column		Reinforcing Bars—Each Direction						
						Column Strip				Middle Strip										Column Strip			Middle Strip			
						Top Edge	Bottom		Top Interior	Bottom			Top Interior	−M Edge	+M Bot.	−M Int.				Bottom		Top Interior	Bottom			Top Interior
		Steel (psf)	$c_1 = c_2$ (in.)	γ_f	(2) Stirrups	No.-size +	No. Ribs	Bars per Rib	No.-size	No. Ribs	Long Bars	Short Bars	No.-size	(ft-k)	(ft-k)	(ft-k)	Steel (psf)	$c_1 = c_2$ (in.)	(2) Stirrups	No. Ribs	Bars per Rib	No.-size	No. Ribs	Long Bars	Short Bars	No.-size
Total Depth = 15 in.		Rib Depth = 12 in.			Total Slab Depth = 3 in.												Total Depth = 15 in.			Rib Depth = 12 in.			Total Slab Depth = 3 in.			
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	1.82	12		4	2-#4	15-#5	3	#4	#4	6-#5
	100	1.84	12	0.700		15-#5+ 0	4	2-#4	15-#5	3	#4	#4	6-#5	64	134	173	1.82	12		4	2-#4	15-#5	3	#4	#4	6-#5
	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	1.82	12		4	2-#4	15-#5	3	#4	#4	6-#5
	200	2.01	12	0.752		15-#5+ 0	4	2-#5	15-#5	3	#4	#5	6-#5	92	226	247	1.82	12		4	2-#4	15-#5	3	#4	#4	6-#5
	300	2.42	12	0.803		15-#5+ 0	4	2-#6	15-#5	3	#5	#6	6-#5	119	311	320	2.11	12		4	2-#5	15-#5	3	#4	#5	6-#5
	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	2.35	12	4 S 6 1	4	1-#5 and 1-#6	15-#5	3	#5	#5	6-#5
	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	2.73	12 *	4 S 6 1	4	2-#6	18-#5	3	#5	#6	6-#5
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	1.86	12		4	2-#4	18-#5	4	#4	#4	7-#5
	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	1.86	12		4	2-#4	18-#5	4	#4	#4	7-#5
	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	1.95	12		4	1-#4 and 1-#5	18-#5	4	#4	#4	7-#5
	200	2.32	12	0.835		18-#5+ 0	4	2-#6	18-#5	4	#5	#5	7-#5	137	337	369	2.05	12		4	2-#5	18-#5	4	#4	#4	7-#5
	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	2.49	12 *	4 S 6 1	4	2-#6	18-#5	4	#5	#5	7-#5
	400	3.44	12 *	0.637		18-#5+ 0	4	2-#8	17-#6	4	#6	#7	8-#5	220	593	591	2.97	12 *	4 S 6 1	4	1-#6 and 1-#7	16-#6	4	#5	#6	7-#5
	500	4.31	15 *	0.633		18-#5+ 0	4	2-#9	20-#6	4	#7	#8	7-#6	258	709	695	3.76	12 *	4 S 6 1	4	1-#7 and 1-#8	19-#6	4	#6	#6	9-#5
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	1.86	13		4	2-#4	20-#5	5	#4	#4	8-#5
	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	1.94	13		4	1-#4 and 1-#5	20-#5	5	#4	#4	8-#5
	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	2.13	13	4 S 6 1	4	1-#5 and 1-#6	20-#5	5	#4	#4	8-#5
	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	2.33	13	4 S 6 1	4	2-#6	20-#5	5	#4	#5	8-#5
	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	2.99	13 *	4 S 6 1	4	2-#7	26-#5	5	#5	#5	8-#5
	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	4.05	13 *	4 S 6 2	4	2-#8	23-#6	5	#6	#6	8-#6
	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	4.58	18 *	4 S 6 2	4	1-#8 and 1-#9	27-#6	5	#6	#6	9-#6
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	1.85	15		5	2-#4	22-#5	5	#4	#4	9-#5
	100	2.24	15	0.829		22-#5+ 1	5	2-#6	22-#5	5	#4	#5	9-#5	188	377	507	2.03	15		5	2-#5	22-#5	5	#4	#4	9-#5
	150	2.68	15 *	0.882		22-#5+ 4	5	2-#7	25-#5	5	#5	#6	9-#5	229	512	616	2.28	15		5	1-#5 and 1-#6	23-#5	5	#4	#5	9-#5
	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	2.84	15 *	4 S 6 1	5	1-#6 and 1-#7	28-#5	5	#5	#5	9-#5
	300	4.36	19 *	0.628		22-#5+ 3	5	2-#9	28-#6	5	#7	#8	9-#6	345	881	930	3.86	15 *	4 S 6 1	5	1-#7 and 1-#8	26-#6	5	#6	#6	12-#5
	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	4.53	20 *	4 S 6 2	5	2-#8	31-#6	5	#6	#7	10-#6
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	2.06	16		5	2-#5	25-#5	6	#4	#4	10-#5
	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	2.16	16	4 S 6 1	5	1-#5 and 1-#6	25-#5	6	#4	#4	10-#5
	150	3.18	16 *	0.917		25-#5+ 5	5	2-#8	24-#6	6	#6	#6	11-#5	303	662	816	2.69	16 *	4 S 6 1	5	1-#6 and 1-#7	31-#5	6	#4	#5	10-#5
	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	3.35	16 *	4 S 6 1	5	2-#7	26-#6	6	#5	#6	12-#5
	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	4.39	19 *	4 S 6 2	5	2-#8	35-#6	6	#6	#6	11-#6
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	2.14	18		5	1-#5 and 1-#6	27-#5	7	#4	#4	11-#5
	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	2.64	18 *	4 S 6 1	5	1-#6 and 1-#7	33-#5	7	#4	#5	11-#5
	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	3.24	18 *	4 S 6 1	5	2-#7	29-#6	7	#5	#5	13-#5
	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	1063	1223	3.99	18 *	4 S 6 2	5	2-#8	35-#6	7	#5	#6	11-#6
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	2.37	19		6	1-#5 and 1-#6	33-#5	7	#4	#5	12-#5
	100	3.46	20 *	0.916		29-#5+11	6	2-#8	33-#6	7	#6	#6	15-#5	412	825	1110	3.13	19 *	4 S 6 1	6	1-#6 and 1-#7	31-#6	7	#5	#5	14-#5
	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	3.73	19 *	4 S 6 1	6	2-#7	38-#6	7	#5	#6	12-#6

See the notes on Page 11-19.

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11-21