Appendix B
Post-Tensioning Design

1	First Floor	Two-Way P-T Design	Main Tower

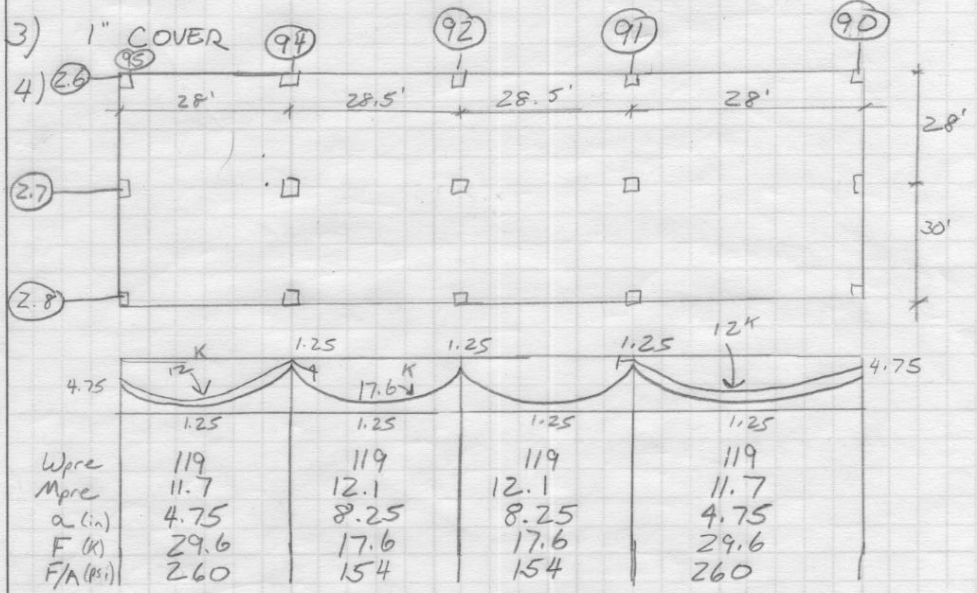
1) SLAB THICKNESS : 9.5"
LIVE LOAD = 100 psf DL = 15 psf
COLUMN SIZE = 24" SQUARE
f'_c = 5000 psi
½" Φ - 270 Ksi STRAND (ASTM A416) A_{ps} = 0.153 in²

2) LOAD TO BE BALANCED
9½" SLAB = 119 psf
DL = 15 psf
LL = 100 psf
234 psf ↓

W_{pre} = 1.0 × 119 = 119 psf ↑
NET LOAD = W_{net} = 234 - 119 = 115 psf

3) 1" COVER

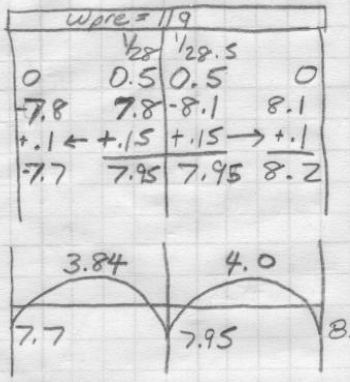
4)



W_{pre}	119	119	119	119
M_{pre}	11.7	12.1	12.1	11.7
a (in)	4.75	8.25	8.25	4.75
F (K)	29.6	17.6	17.6	29.6
F/A (psi)	260	154	154	260

30 : x = ½ : 12

FLEXURAL ANALYSIS



AVG. STRESS $A = 12 \times 9.5 = 114 in^2$ $S = \frac{bh^2}{6} = \frac{12(9.5)^2}{6} = 180.5 in^3$

- NEG. MOMENT

INT SPAN

$f = -154 \pm \frac{12 \times 8.2 \times 1000}{180.5} = -154 \pm 545 = 391.2 < 6\sqrt{5000} = 424$
$-699 < .6(5000) = 3000$

EXT. SPAN

$f = -260 \pm \frac{12 \times 7.95 \times 1000}{180.5} = -260 \pm 528.5 = 268.5 < 424$
$= -788.5 < 3000$

- POS. MOMENT

INT SPAN

$f = -154 \pm \frac{12 \times 3.84 \times 1000}{180.5} = -154 \pm 255.3 = 101.3 < 3\sqrt{5000} = 212$
$= -409.3 < 3000$

EXT SPAN

$f = -260 \pm \frac{12 \times 4 \times 1000}{180.5} = -260 \pm 266 = 6 < 212$
$= 526 < 3000$

5) ULTIMATE STRENGTH CHECK

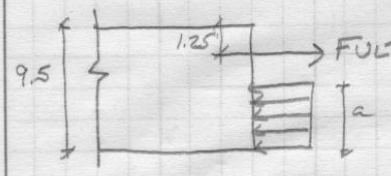
$w_u = 7.2(134) = 160.8$
$1.6(100) = 160$
320.8

$d = 9.5 - 1.25 = 8.25$

$17.6^K \times \frac{1\,in^2}{175^K} \times \frac{1}{.153} = 0.66 \frac{STRANDS}{ft} \times \frac{28+30}{2} = 19.14 \approx 20$

(ACI) $\rho_p = \frac{A_{ps}}{bd} = \frac{0.66(.153)}{12(8.25)} = 0.00102$

(ACI 18-5) $f_{su} = 175 + \frac{1.0(5)}{100(.00102)} + 10 = 224\ ksi$



$F_{ULT} = \frac{224}{175} \times 20 = 25.6$

$f_{CULT} = .85(5000) = 4250\ psi = 4.25\ ksi$

$a = \frac{25.6}{12 \times 4.25} = 0.5$

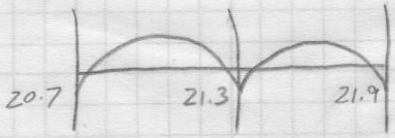
$jd = 9.5 - \frac{.5}{2} - 1.25 = 8"$

$M_u = .9 \times 25.6 \times \frac{8}{12} = 15.36^{IK}$

6) REQUIRED MOMENT

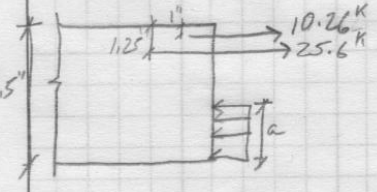
320.8

	1/28	1/28.5	
0	0.5	0.5	0
20.9	20.9	21.7	21.7
.2 ←	+.4	+.4 →	.2
20.7	21.3	21.3	21.9



$> 15.36^{IK}$ REQUIRES REINF.

$A_{smin} = .0015 \times 9.5 \times 12 \times 29 = 5\ in^2$



10.26^K
25.6^K

$\frac{5}{29} = 0.172\ in^2/ft$ $F_s = 0.172 \times 60 = 10.26^K$

$a = \frac{35.86}{12 \times 4.25} = 0.7$ $jd_P = 9.5 - 1.25 - \frac{.7}{2} = 7.9$
$jd_R = 9.5 - 1 - \frac{.7}{2} = 8.15$

$M_u = \frac{.9}{12}\left[25.6(7.9) + 10.26(8.15)\right] = 21.4^{IK} \approx 21.9$ ∴ OK

7) SHEAR DESIGN @ COLUMNS

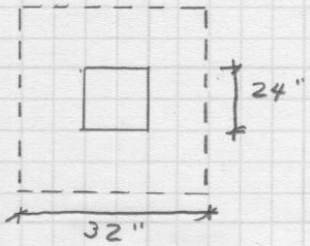
$t/2 = \frac{9.5}{2} = 4.5"$

$b' = 4.5 \times 32 = 144"$

$d = 9.5 - 1.25 = 8.25"$

$f_{pc} = \frac{260 + 154 + 154 + 154}{4}$

$= 180.5 \text{ psi}$



$V_{cw} = b'd(3.5\sqrt{f'_c} + 0.3f_{pc})$

$= \frac{144(8.25)}{1000}(3.5\sqrt{5000} + 0.3(180.5)) = 358.3^K$

REQUIRED CAPACITY

$1.2D + 1.6L$

$1.2(115 psf) + 1.6(100 psf) = 298 psf$

$\left(\frac{28}{2} + \frac{30}{2}\right) \times \left(\frac{28.5 \times 2}{2}\right) - \frac{32}{12} \times \frac{32}{12} = 570.5^{\#}$

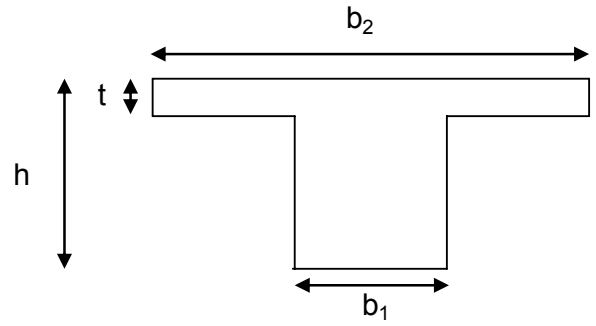
$\frac{298_{psf} \times 570.5_{sf}}{1000} = 170^K < 358.3^K \therefore OK$

PT Beam-and-Slab Design (Conference Wing)	
Engineer:	Joe Sharkey
Date:	3/14/2007
Job:	Christiana Hospital Project
Beam #:	PB-1

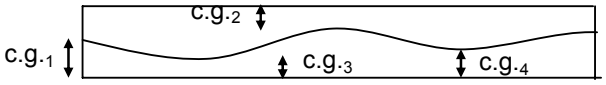
Load			
Live Load (psf) =	100		
Superimposed Dead Load (psf) =	15		
Slab Weight (psf) =	187.5		
Prestressing - w_{pslab} (psf) =	-187.5		
Net Load - w_{nslab} (psf) =	100		
Slab Weight (plf) =	5250	x 1.2	6300
Beam Weight (plf) =	675	x 1.2	810
Live Load (plf) =	2800	x 1.6	4480
Prestressing - w_{pbeam} (plf) =	-4740		
Net Load - w_{nbeam} (plf) =	3985		

Concrete Properties	
Concrete Weight (pcf) =	150
Concrete Strength - f'c (psi) =	5000

Beam/Slab Dimensions	
Slab Thickness - t (in) =	15
Beam Height - h (in) =	42
Beam Width - b_1 (in) =	24
Span (ft) =	62
Beam Spacing (ft) =	28
Effective Flange Width - b_2 (in) =	264
Total Beam Area (in^2) =	4608
Y_{top} (in) =	10.453125
Y_{bottom} (in) =	31.546875
I (in^4) =	359197.875
S_{top} (in^3) =	34362.72646
S_{bottom} (in^3) =	11386.16345
S_{slab} (in^3) =	450



Prestressing	
Slab % Prestress =	100
Beam % Prestress =	80
Unbonded Strand Type =	1/2" Φ - 270ksi (ASTM A461)
Prestressing - w_{pslab} (psf) =	-187.5
Prestressing - w_{pbeam} (plf) =	-4740
$c.g._{slab\ 1}$ (in) =	7.5
$c.g._{slab\ 2}$ (in) =	1.25
$c.g._{slab\ 3}$ (in) =	1.25



$c.g._{beam\ 1}$ (in) =	10.453125
$c.g._{beam\ 2}$ (in) =	4
$c.g._{beam\ 3}$ (in) =	4
$c.g._{beam\ 4}$ (in) =	7.2265625

Design Stresses

Slab

Interior Spans

M_p (ft-kip) =	18.375	
a (in) =	12.5	
F (k/ft) =	17.64	
# of Strands/ft =	0.658823529	
F/A (psi) =	98	
CL M_n (ft-kip) =	7.127272727	
Va/3 (ft-kip) =	0.466666667	
M (ft-kip) =	6.660606061	
S (in^3) =	450	
f (psi) =	79.61616162	< 6√f'c therefore OK
	-275.6161616	< .6f'c therefore OK

Exterior Spans

M_p (ft-kip) =	18.375	
a (in) =	16.875	
F (k/ft) =	13.06666667	
# of Strands/ft =	0.488017429	
F/A (psi) =	72.59259259	
CL M_n (ft-kip) =	7.84	
Va/3 (ft-kip) =	0.466666667	
M (ft-kip) =	7.373333333	
S (in^3) =	450	
f (psi) =	124.0296296	< 6√f'c therefore OK
	-269.2148148	< .6f'c therefore OK

Beam

All Spans

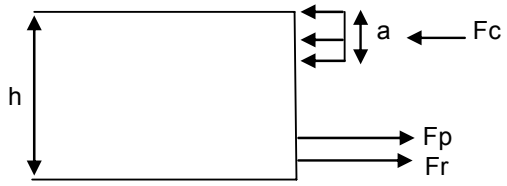
M_p (ft-kip) =	2277.57	
a (in) =	30.7734375	
F (k/ft) =	888.1308759	
F/A (psi) =	192.7367352	
# of Strands =	29	
$F_{e\ supplied}$ (kip) =	892.4296875	
S_{top} (in^3) =	34362.72646	
S_{bottom} (in^3) =	11386.16345	

Positive Moment

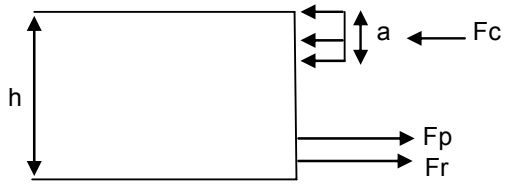
M^+ (ft-kip) =	233	
f (psi) =	52.82446834	< 6√f'c therefore OK
	-274.1039691	< .6f'c therefore OK

Negative Moment		
M^- (ft-kip) =	268	
f (psi) =	-99.14695548	< 6√f'c therefore OK
	-475.1848148	< .6f'c therefore OK

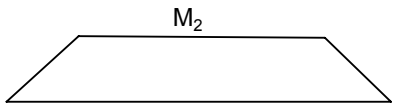
Ultimate Strength Design			
Slab			
Ultimate Strength @ Interior Span			
M^+ max (ft-kip/ft) =	18		
M^- max (ft-kip/ft) =	25		
A_{smin} (in^2/ft) =	0.27		
$A_{ssupplied}$ (in^2/ft) =	0.31	1-#5	Min Req Steel Met
Rebar Cover (in) =	1		
Fp (kips) =	17.64		
Fr (kips) =	18.6		
a (in) =	0.710588235	Compression within slab therefore OK	
Mu (ft-kips/ft) =	36.75556059	OK	



Ultimate Strength @ Exterior Span			
M^+ max (ft-kip/ft) =	18		
M^- max (ft-kip/ft) =	36		
A_{smin} (in^2/ft) =	0.27		
$A_{ssupplied}$ (in^2/ft) =	0.6	1-#7	Min Req Steel Met
Rebar Cover (in) =	1		
Fp (kips) =	13.06666667		
Fr (kips) =	36		
a (in) =	0.962091503	Compression within slab therefore OK	
Mu (ft-kips/ft) =	49.50475163	OK	

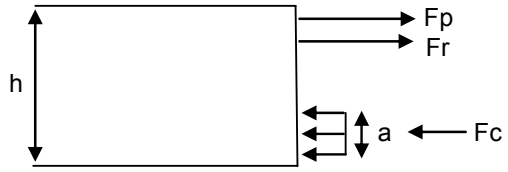


Beam		
M^+ max (ft-kip) =	2560	
M^- max (ft-kip) =	3400	
Secondary Moments		
Wp (klf) =	4.762942978	
Mp = M_1 + M_2 (ft-kip) =	1830.875281	
M_1 (ft-kip) =	479.9133606	
M_2 (ft-kip) =	1350.96192	

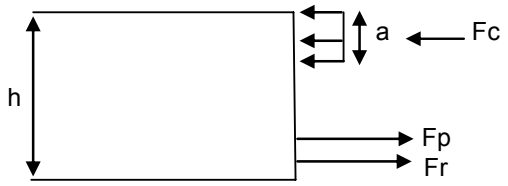


M^+ total (ft-kip) =	3235.48096		
M^- total (ft-kip) =	2049.03808		
f_{su} not to exceed f_{sy} =			235
ρ @ midspan exterior =	0.000442285	f_{su} (ksi) =	235
ρ @ support =	0.004865132	f_{su} (ksi) =	195.2772

Itimate Strength @ Interior Support			
A_{smin} (in^2) =	3.0285		
$A_{ssupplied}$ (in^2) =	3.16	4-#8	**Min Req Steel Met**
Rebar Cover (in) =	2		
Fp (kips) =	1198.40558		
Fr (kips) =	189.6		
a (in) =	1.237081622	**Compression within slab therefore OK**	
Mu (ft-kips) =	3919.865547	**OK**	



Ultimate Strength @ Midspan			
A_{smin} (in^2) =	1.0035		
$A_{ssupplied}$ (in^2) =	6	6-#9	**Min Req Steel Met**
Rebar Cover (in) =	2		
Fp (kips) =	995.8353335		
Fr (kips) =	360		
a (in) =	13.29250327	**Compression within beam therefore OK**	
Mu (ft-kips) =	3242.28899	**OK**	

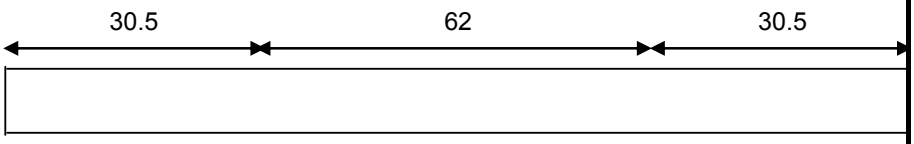


Shear			
Line Load on Beam (klf) =	12.544		
Vu (kips) =	443.7027097		
Vu (psi) =	453.6837522		
Vc (psi) =	321.0965718	**NOT OK Need Shear Reinf**	
Stirrup Spacing - s (in) =	5		
fy (psi) =	60000		
Cross-Sectional Area of Steel -Av (in^2) =	0.4	2-#4	
Max s (in) =	18.85618083		
d (in) =	38		
Vc from stirrups (psi) =	135.7142857		
Vc total with stirrups =	456.8108575	**OK**	

PB-1 Moment Distribution

		(plf)			(plf)
Beam Weight =	150	1050	x 1.2 =		1260
Slab Weight =	150	5250	x 1.2 =		6300
Dead Load =	15	420	x 1.2 =		504
Live Load =	100	2800	x 1.6 =		4480
Total =	415				12544

Beam Dim.	b (in)	h (in)		
	24	42	Slab Thickness (in) =	15
			Tributary Width (ft) =	28



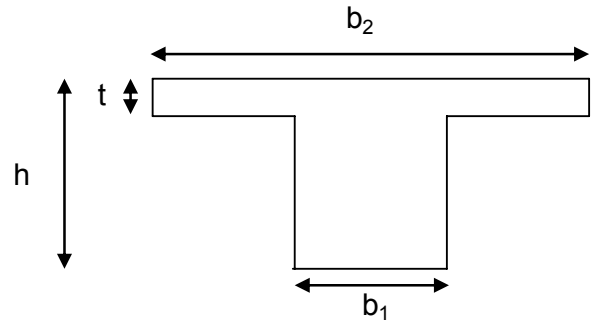
DF	0	0.67027	0.32973	0.32972973	0.67027	0
FEM	-972.4213	972.4213	-4018.261	4018.261333	-972.4213	972.4213
		2041.536	1004.304			
	1020.768			502.152		
				-1169.878443	-2378.114	
			-584.9392			-1189.057
		392.0674	192.8719			
	196.0337			96.43592573		
				-31.79779173	-64.63813	
			-15.8989			-32.31907
		10.65656	5.242339			
	5.328279			2.621169318		
				-0.864277451	-1.756892	
						-0.878446
Total (ft-kips)	249.7086	3417.352	-3416.352	3417.259646	-3416.26	-249.833
Positive Moment	-125.1895		2610.586		-124.5813	

PT Beam-and-Slab Design (Conference Wing)	
Engineer:	Joe Sharkey
Date:	3/14/2007
Job:	Christiana Hospital Project
Beam #:	PB-2

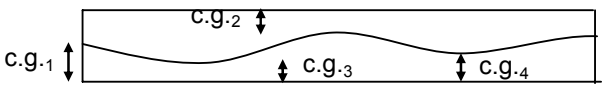
Load			
Live Load (psf) =	100		
Superimposed Dead Load (psf) =	15		
Slab Weight (psf) =	187.5		
Prestressing - w_{pslab} (psf) =	-187.5		
Net Load - w_{nslab} (psf) =	100		
Slab Weight (plf) =	6187.5	x 1.2	7425
Beam Weight (plf) =	506.25	x 1.2	607.5
Live Load (plf) =	3300	x 1.6	5280
Prestressing - w_{pbeam} (plf) =	-6024.375		
Net Load - w_{nbeam} (plf) =	3969.375		

Concrete Properties	
Concrete Weight (pcf) =	150
Concrete Strength - f'c (psi) =	5000

Beam/Slab Dimensions	
Slab Thickness - t (in) =	15
Beam Height - h (in) =	42
Beam Width - b_1 (in) =	18
Span (ft) =	41.8
Beam Spacing (ft) =	33
Effective Flange Width - b_2 (in) =	258
Total Beam Area (in^2) =	4356
Y_{top} (in) =	9.842975207
Y_{bottom} (in) =	32.15702479
I (in^4) =	292500.595
S_{top} (in^3) =	29716.68514
S_{bottom} (in^3) =	9096.009252
S_{slab} (in^3) =	450



Prestressing	
Slab % Prestress =	100
Beam % Prestress =	90
Unbonded Strand Type =	1/2" Φ - 270ksi (ASTM A461)
Prestressing - w_{pslab} (psf) =	-187.5
Prestressing - w_{pbeam} (plf) =	-6024.375
$c.g._{slab\ 1}$ (in) =	7.5
$c.g._{slab\ 2}$ (in) =	1.25
$c.g._{slab\ 3}$ (in) =	1.25



$c.g._{beam\ 1}$ (in) =	9.842975207
$c.g._{beam\ 2}$ (in) =	2.5
$c.g._{beam\ 3}$ (in) =	2.5
$c.g._{beam\ 4}$ (in) =	6.171487603

Design Stresses

Slab

Interior Spans

M_p (ft-kip) =	25.5234375	
a (in) =	12.5	
F (k/ft) =	24.5025	
# of Strands/ft =	0.91512605	
F/A (psi) =	136.125	
CL M_n (ft-kip) =	9.9	
Va/3 (ft-kip) =	0.55	
M (ft-kip) =	9.35	
S (in^3) =	450	
f (psi) =	113.2083333	**< 6√f'c therefore OK**
	-385.4583333	**< .6f'c therefore OK**

Exterior Spans

M_p (ft-kip) =	25.5234375	
a (in) =	16.875	
F (k/ft) =	18.15	
# of Strands/ft =	0.677871148	
F/A (psi) =	100.8333333	
CL M_n (ft-kip) =	10.89	
Va/3 (ft-kip) =	0.55	
M (ft-kip) =	10.34	
S (in^3) =	450	
f (psi) =	174.9	**< 6√f'c therefore OK**
	-376.5666667	**< .6f'c therefore OK**

Beam

All Spans

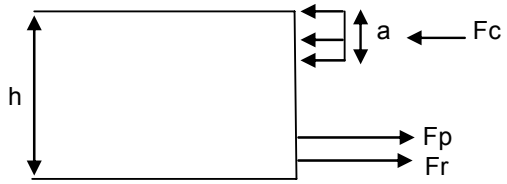
M_p (ft-kip) =	1315.753622	
a (in) =	33.3285124	
F (k/ft) =	473.73982	
F/A (psi) =	108.7556979	
# of Strands =	15	
$F_{e\ supplied}$ (kip) =	499.927686	
S_{top} (in^3) =	29716.68514	
S_{bottom} (in^3) =	9096.009252	

Positive Moment

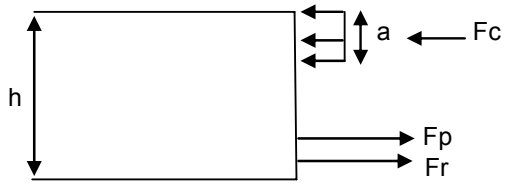
M^+ (ft-kip) =	233	
f (psi) =	198.6318523	**< 6√f'c therefore OK**
	-202.8442541	**< .6f'c therefore OK**

Negative Moment		
M^- (ft-kip) =	268	
f (psi) =	-0.533667562	< 6√f'c therefore OK
	-462.3173435	< .6f'c therefore OK

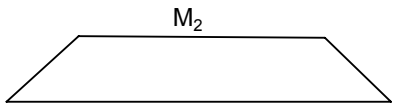
Ultimate Strength Design			
Slab			
Ultimate Strength @ Interior Span			
M^+ max (ft-kip/ft) =	18		
M^- max (ft-kip/ft) =	25		
A_{smin} (in^2/ft) =	0.27		
$A_{ssupplied}$ (in^2/ft) =	0.31	1-#5	Min Req Steel Met
Rebar Cover (in) =	1		
Fp (kips) =	24.5025		
Fr (kips) =	18.6		
a (in) =	0.845147059	Compression within slab therefore OK	
Mu (ft-kips/ft) =	43.43215496	OK	



Ultimate Strength @ Exterior Span			
M^+ max (ft-kip/ft) =	18		
M^- max (ft-kip/ft) =	36		
A_{smin} (in^2/ft) =	0.27		
$A_{ssupplied}$ (in^2/ft) =	0.6	1-#7	Min Req Steel Met
Rebar Cover (in) =	1		
Fp (kips) =	18.15		
Fr (kips) =	36		
a (in) =	1.061764706	Compression within slab therefore OK	
Mu (ft-kips/ft) =	54.36114154	OK	

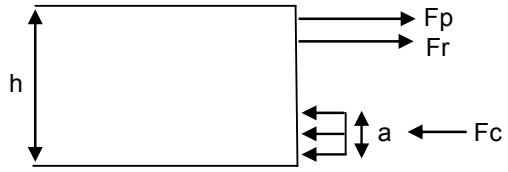


Beam	
M^+ max (ft-kip) =	1957
M^- max (ft-kip) =	2243
Secondary Moments	
Wp (klf) =	6.357396457
Mp = M_1 + M_2 (ft-kip) =	1110.789739
M_1 (ft-kip) =	305.9130503
M_2 (ft-kip) =	804.8766883

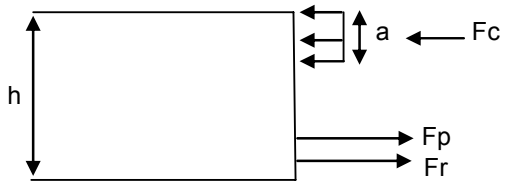


M^+ total (ft-kip) =	2359.438344		
M^- total (ft-kip) =	1438.123312		
f_{su} not to exceed f_{sy} =			235
ρ @ midspan exterior =	0.000225199	f_{su} (ksi) =	235
ρ @ support =	0.003227848	f_{su} (ksi) =	200.4902

timate Strength @ Exterior Support			
A_{smin} (in^2) =	2.315305785		
$A_{ssupplied}$ (in^2) =	3	3-#9	**Min Req Steel Met**
Rebar Cover (in) =	2		
Fp (kips) =	671.331464		
Fr (kips) =	180		
a (in) =	0.776408084	**Compression within slab therefore OK**	
Mu (ft-kips) =	2504.032688	**OK**	



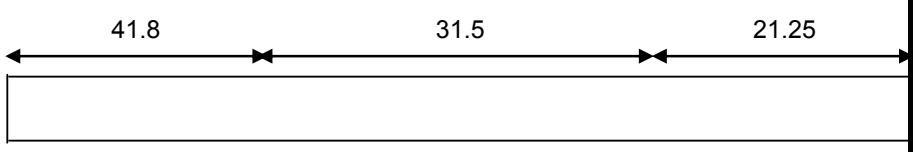
Ultimate Strength @ Midspan			
A_{smin} (in^2) =	0.708694215		
$A_{ssupplied}$ (in^2) =	6.08	6-#9	**Min Req Steel Met**
Rebar Cover (in) =	2		
Fp (kips) =	572.7462845		
Fr (kips) =	364.8		
a (in) =	12.25550699	**Compression within beam therefore OK**	
Mu (ft-kips) =	2360.281929	**OK**	



Shear			
Line Load on Beam (klf) =	14.244		
Vu (kips) =	351.3598871		
Vu (psi) =	479.018251		
Vc (psi) =	392.7612852	**NOT OK Need Shear Reinf**	
Stirrup Spacing - s (in) =	10		
fy (psi) =	60000		
Cross-Sectional Area of Steel -Av (in^2) =	0.4	2-#4	
Max s (in) =	25.14157444		
d (in) =	39.5		
Vc from stirrups (psi) =	94.04761905		
Vc total with stirrups =	486.8089043	**OK**	

PB-2 Moment Distribution

				(plf)		(plf)
		Beam Weight =	150	666.6666667	x 1.2 =	800
		Slab Weight =	150	6187.5	x 1.2 =	7425
		Dead Load =	15	495	x 1.2 =	594
		Live Load =	100	3300	x 1.6 =	5280
		Total =	415			14099
Beam Dim.	b (in)	h (in)				
	16	40		Slab Thickness (in) =	15	
				Tributary Width (ft) =	33	



DF	1	0.429741	0.570259	0.402843602	0.597156	1
FEM	-2052.861	2052.861	-1165.811	1165.811063	-530.5483	530.5483
	2052.861					
		1026.431				
		-822.3009	-1091.18			
	-411.1504			-545.5900898		
				-36.12405954	-53.54861	
			-18.06203			-26.7743
		7.761991	10.30004			-503.774
	3.880995			5.150019403	-251.887	
				99.39641486	147.3406	
			49.69821			73.67028
		-21.35735	-28.34086			
	-10.67867			-14.17043022		
	417.9481			5.708467151	8.461963	
						4.230982
						-77.90127
Total (ft-kips)	0	2243.396	-2243.396	680.1813844	-680.1814	0
Positive Moment	1957.594		286.928		455.7318	