Alternate Design Method- Design Procedure of Two-way Slabs using ACI Moment Coefficients and Approved by BNBC 2013

Scope and Limitations (BNBC)

6.5.8.2.1 The provisions of this section may be used as alternative to those of 6.5.1 through 6.5.7 for two way slabs supported on all four edges by walls, steel beams or monolithic concrete beams having a total depth not less than 3 times the slab thickness.

6.5.8.2.2 Panels shall be rectangular with a ratio of longer to shorter span centre to centre of supports not greater than 2.

Step 01: Determination of thickness of the slab panel.
Determine the thickness of the slab panel using previous article.

Step 02: Calculation of factored load.
W_u= 1.2*DL+1.6*LL
where DL= Total dead load (i.e.: Slab self weight, Floor finish, Partition wall, Plaster etc.)
LL= Live load.

Step 03: Determination of moment coefficients.

$m=\frac{A}{B}$

where A= Shorter length of the slab.
B= Longer length of the slab.

Case type is identified from end condition. Using the value of 'm' corresponding moment coefficients are obtained for respective 'case type' from corresponding tables. The co-efficients are:

- $C_{A\ neg}$ and $C_{B\ neg}$
- $C_{A\ DL\ pos}$ and $C_{B\ DL\ pos}$
- $C_{A\ LL\ pos}$ and $C_{B\ LL\ pos}$

C_a , C_b = Moment coefficients
l_a = Length of clear span in short direction
l_b = Length of clear span in long direction
M_a = Moment in the short direction
M_b = Moment in the long direction
w = Uniform load

Table 6.5.8.1 Coefficients for Negative Moments in Slabs †

$M_{a,neg} = C_{a,neg} w l_a^2$

$M_{b,neg} = C_{b,neg} w l_b^2$ where w = total uniform dead plus live load per unit area

Ratio $m = \frac{l_a}{l_b}$		Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9
1.00	$C_{a,neg}$		0.045		0.050	0.075	0.071		0.033	0.061
	$C_{b,neg}$		0.045	0.076	0.050			0.071	0.061	0.033
0.95	$C_{a,neg}$		0.050		0.055	0.079	0.075		0.038	0.065
	$C_{b,neg}$		0.041	0.072	0.045			0.067	0.056	0.029
0.90	$C_{a,neg}$		0.055		0.060	0.080	0.079		0.043	0.068
	$C_{b,neg}$		0.037	0.070	0.040			0.062	0.052	0.025
0.85	$C_{a,neg}$		0.060		0.066	0.082	0.083		0.049	0.072
	$C_{b,neg}$		0.031	0.065	0.034			0.057	0.046	0.021
0.80	$C_{a,neg}$		0.065		0.071	0.083	0.086		0.055	0.075
	$C_{b,neg}$		0.027	0.061	0.029			0.051	0.041	0.017
0.75	$C_{a,neg}$		0.069		0.076	0.085	0.088		0.061	0.078
	$C_{b,neg}$		0.022	0.056	0.024			0.044	0.036	0.014
0.70	$C_{a,neg}$		0.074		0.081	0.086	0.091		0.068	0.081
	$C_{b,neg}$		0.017	0.050	0.019			0.038	0.029	0.011
0.65	$C_{a,neg}$		0.077		0.085	0.087	0.093		0.074	0.083
	$C_{b,neg}$		0.014	0.043	0.015			0.031	0.024	0.008
0.60	$C_{a,neg}$		0.081		0.089	0.088	0.095		0.080	0.085
	$C_{b,neg}$		0.010	0.035	0.011			0.024	0.018	0.006
0.55	$C_{a,neg}$		0.084		0.092	0.089	0.096		0.085	0.086
	$C_{b,neg}$		0.007	0.028	0.008			0.019	0.014	0.005
0.50	$C_{a,neg}$		0.086		0.094	0.090	0.097		0.089	0.088
	$C_{b,neg}$		0.006	0.022	0.006			0.014	0.010	0.003

Table 6.5.8.2 Coefficients for Dead Load Positive Moments in Slabs †

$M_{a,pos,dl} = C_{a,dl} w l_a^2$

$M_{b,pos,dl} = C_{b,dl} w l_b^2$

where w = uniform dead load per unit area

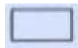
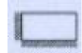
Ratio $m = \frac{l_a}{l_b}$		Case 1 	Case 2 	Case 3 	Case 4 	Case 5 	Case 6 	Case 7 	Case 8 	Case 9 
1.00	$C_{a,dl}$	0.036	0.018	0.018	0.027	0.027	0.033	0.027	0.020	0.023
	$C_{b,dl}$	0.036	0.018	0.027	0.027	0.018	0.027	0.033	0.023	0.020
0.95	$C_{a,dl}$	0.040	0.020	0.021	0.030	0.028	0.036	0.031	0.022	0.024
	$C_{b,dl}$	0.033	0.016	0.025	0.024	0.015	0.024	0.031	0.021	0.017
0.90	$C_{a,dl}$	0.045	0.022	0.025	0.033	0.029	0.039	0.035	0.025	0.026
	$C_{b,dl}$	0.029	0.014	0.024	0.022	0.013	0.021	0.028	0.019	0.015
0.85	$C_{a,dl}$	0.050	0.024	0.029	0.036	0.031	0.042	0.040	0.029	0.028
	$C_{b,dl}$	0.026	0.012	0.022	0.019	0.011	0.017	0.025	0.017	0.013
0.80	$C_{a,dl}$	0.056	0.026	0.034	0.039	0.032	0.045	0.045	0.032	0.029
	$C_{b,dl}$	0.023	0.011	0.020	0.016	0.009	0.015	0.022	0.015	0.010
0.75	$C_{a,dl}$	0.061	0.028	0.040	0.043	0.033	0.048	0.051	0.036	0.031
	$C_{b,dl}$	0.019	0.009	0.018	0.013	0.007	0.012	0.020	0.013	0.007
0.70	$C_{a,dl}$	0.068	0.030	0.046	0.046	0.035	0.051	0.058	0.040	0.033
	$C_{b,dl}$	0.016	0.007	0.016	0.011	0.005	0.009	0.017	0.011	0.006
0.65	$C_{a,dl}$	0.074	0.032	0.054	0.050	0.036	0.054	0.065	0.044	0.034
	$C_{b,dl}$	0.013	0.006	0.014	0.009	0.004	0.007	0.014	0.009	0.005
0.60	$C_{a,dl}$	0.081	0.034	0.062	0.053	0.037	0.056	0.073	0.048	0.036
	$C_{b,dl}$	0.010	0.004	0.011	0.007	0.003	0.006	0.012	0.007	0.004
0.55	$C_{a,dl}$	0.088	0.035	0.071	0.056	0.038	0.058	0.081	0.052	0.037
	$C_{b,dl}$	0.008	0.003	0.009	0.005	0.002	0.004	0.009	0.005	0.003
0.50	$C_{a,dl}$	0.095	0.037	0.080	0.059	0.039	0.061	0.089	0.056	0.038
	$C_{b,dl}$	0.006	0.002	0.007	0.004	0.001	0.003	0.007	0.004	0.002

Table 6.5.8.3 Coefficients for Live Load Positive Moments in Slabs †

$M_{a,pos,ll} = C_{a,ll} w l_a^2$

$M_{b,pos,ll} = C_{b,ll} w l_b^2$ where w = uniform live load per unit area

Ratio $m = \frac{l_a}{l_b}$		Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9
1.00	$C_{a,ll}$	0.036	0.027	0.027	0.032	0.032	0.035	0.032	0.028	0.030
	$C_{b,ll}$	0.036	0.027	0.032	0.032	0.027	0.032	0.035	0.030	0.028
0.95	$C_{a,ll}$	0.040	0.030	0.031	0.035	0.034	0.038	0.036	0.031	0.032
	$C_{b,ll}$	0.033	0.025	0.029	0.029	0.024	0.029	0.032	0.027	0.025
0.90	$C_{a,ll}$	0.045	0.034	0.035	0.039	0.037	0.042	0.040	0.035	0.036
	$C_{b,ll}$	0.029	0.022	0.027	0.026	0.021	0.025	0.029	0.024	0.022
0.85	$C_{a,ll}$	0.050	0.037	0.040	0.043	0.041	0.046	0.045	0.040	0.039
	$C_{b,ll}$	0.026	0.019	0.024	0.023	0.019	0.022	0.026	0.022	0.020
0.80	$C_{a,ll}$	0.056	0.041	0.045	0.048	0.044	0.051	0.051	0.044	0.042
	$C_{b,ll}$	0.023	0.017	0.022	0.020	0.016	0.019	0.023	0.019	0.017
0.75	$C_{a,ll}$	0.061	0.045	0.051	0.052	0.047	0.055	0.056	0.049	0.046
	$C_{b,ll}$	0.019	0.014	0.019	0.016	0.013	0.016	0.020	0.016	0.013
0.70	$C_{a,ll}$	0.068	0.049	0.057	0.057	0.051	0.060	0.063	0.054	0.050
	$C_{b,ll}$	0.016	0.012	0.016	0.014	0.011	0.013	0.017	0.014	0.011
0.65	$C_{a,ll}$	0.074	0.053	0.064	0.062	0.055	0.064	0.070	0.059	0.054
	$C_{b,ll}$	0.013	0.010	0.014	0.011	0.009	0.010	0.014	0.011	0.009
0.60	$C_{a,ll}$	0.081	0.058	0.071	0.067	0.059	0.068	0.077	0.065	0.059
	$C_{b,ll}$	0.010	0.007	0.011	0.009	0.007	0.008	0.011	0.009	0.007
0.55	$C_{a,ll}$	0.088	0.062	0.080	0.072	0.063	0.073	0.085	0.070	00.063
	$C_{b,ll}$	0.008	0.006	0.009	0.007	0.005	0.006	0.009	0.007	0.006
0.50	$C_{a,ll}$	0.095	0.066	0.088	0.077	0.067	0.078	0.092	0.076	0.067
	$C_{b,ll}$	0.006	0.004	0.007	0.005	0.004	0.005	0.007	0.005	0.004

Step 04: Calculation of moments.

Positive moments:

$+M_A = C_{A\,DL} \times W_{DL} \times L_A^2 + C_{A\,LL} \times W_{LL} \times L_A^2$;

$+M_B = C_{B\,DL} \times W_{DL} \times L_B^2 + C_{B\,LL} \times W_{LL} \times L_B^2$.

Negative Moments:

$-M_A = C_{A\,,\,neg} \times W_T \times L_A^2$;

$-M_B = C_{A\,,\,neg} \times W_T \times L_B^2$;

W_{LL} = Uniform Live load per unit area= 1.6 LL, (Factored since USD will be used)

W_{DL} = Uniform Dead load per unit area = 1.2 DL (Factored since USD will be used)

$W_u = W_T$ = Total Uniform load per unit area = 1.2*DL+1.6*LL (Factored since USD will be used)

Start with Max moment, M then,

$A_s = \frac{M}{.9 * fy * (d - \frac{a}{2})}$

Now, find a $= \frac{As * fy}{0.85 * f'c * b}$

Then, do at least another trial, with new a, and find area of steel.

Last Updated: May 13, 2017

The following Example was done by Md. Mahmudun Nobe, ID - 12.01.03.078, AUST Batch no. 28

Design of two-way edge supported slab by using moment coefficients.

Beam-column supported floor slab of a 93'-6"×75'-6" (center to center distance of extreme columns) "cyclone shelter" is to carry service live load of 100 psf in addition to its own weight, 1/2" thick plaster and 3/2" thick floor finish. Supporting columns of 14 in square are spaced orthogonally at an interval at 31'-2" and 25'-2" on centers along longitudinal and transverse directions respectively. Width of each beam is 14 in. Using BNBC/ACI code of moment coefficients design the slab by USD method, if f'_c= 3000 psi and f_y= 60000 psi.

Solution:

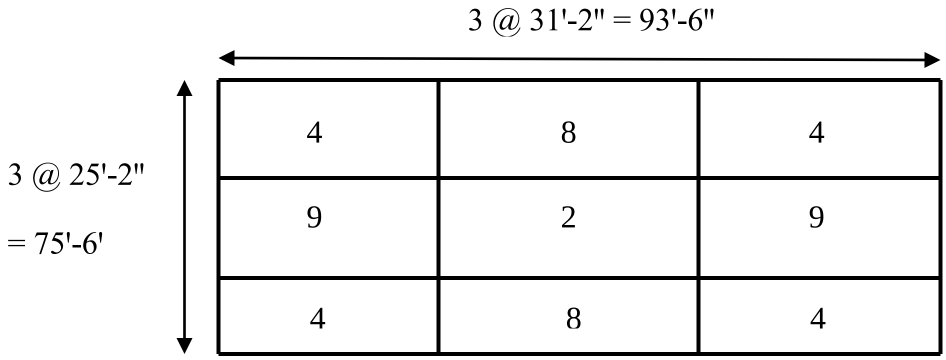


Figure 03: Slab panel orientation and case type, e.g., case 9 is typical exterior, 4 is corner slab etc.

Here A= 25'2"-1'2"= 24' and B= 31'2"-1'2"= 30'= l_n.

t= $\frac{l_n(0.8+(\frac{fy}{200000}))}{36+9\beta} = \frac{30*(0.8+(\frac{60000}{200000}))}{36+9*\frac{30}{24}}$= 8.38"≈ 8.5" say.

So d= 8.5"-1"= 7.5'

W_{DL}= (8.5+0.5+1.5)*12.5*1.2= 157.5 psf

W_{LL}= 100*1.6= 160 psf

W_u = 317.5 psf

m= A/B= 24/30= 0.8

	2	4	8	9
$-C_A$	0.065	0.071	0.055	0.075
$-C_B$	0.027.	0.029	0.041	0.017
$C_{A\ DL}$	0.026	0.039	0.032	0.029
$C_{B\ DL}$	0.011	0.016	0.015	0.010
$C_{A\ LL}$	0.041	0.048	0.044	0.042
$C_{B\ LL}$	0.017	0.020	0.019	0.017

(circled) Controlling coefficient.

[Note: In this slab, there are four different types of cases among all panels. We take the maximum value of moment coefficient from four cases.]

$+M_A= C_{A\ DL}*W_{DL}*A^2+ C_{A\ LL}*W_{LL}*A^2$

$= 0.039*157.5*24^2+ 0.048*160*24^2$

= 7961.76l lb-ft/ft

= 7.96 k-ft/ft

$-M_A= C_A*W_u*A^2$

$= 0.075*317.5*24^2$

= 13716 lb-ft/ft

= 13.6 k-ft/ft

$+M_B= C_{B\ DL}*W_{DL}*B^2+ C_{B\ LL}*W_{LL}*B^2$

$= 0.016*157.5*30^2+ 0.020*160*30^2$

= 5148 lb-ft/ft

= 5.148 k-ft/ft

$-M_B= C_B*W_u*B^2$

= 0.041*317.5*30^2
= 11716 lb-ft/ft
= 11.716 k-ft/ft

Rebar for short direction/transverse direction:

$+A_{S\ A} = \frac{M*12}{0.9*f_y*\left(d-\frac{a}{2}\right)} = \frac{M*12}{0.9*60*\left(d-\frac{a}{2}\right)} = \frac{M}{4.5*\left(d-\frac{a}{2}\right)} = \frac{7.96}{4.5*(7.5-0.24)}$ = 0.244 in^2/ft (Controlling).

and $a = \frac{A_s f_y}{0.85 f_c' b} = \frac{A_s*60}{0.85*3*12}$ = 1.96*A_S = 1.96*0.244 = 0.478 in.

A_{min}= 0.0018xbxt = 0.0018x12x8.5 = 0.1836 in^2/ft

Using φ10mm bar

$S = \frac{\text{Area of bar used} * \text{width of strip}}{\text{Requried } A_s} = \frac{0.121*12}{0.244}$ = 5.95" ≈ 5.5"c/c at bottom along short direction crank 50% bar to negative zone.

$-A_{S\ A} = \frac{M}{4.5*\left(d-\frac{a}{2}\right)} = \frac{13.61}{4.5*(7.5-0.42)}$ = 0.427 in^2/ft (Controlling).

$a = 1.96 * A_s$ = 0.838 in

A_{min}= 0.1836 in^2/ft.

Already provided $A_{s1} = \frac{0.121*12}{11}$= 0.132 in^2/ft

Extra top required, A_{s2}= (0.427-0.132) = 0.295 in^2/ft.

Using Φ10mm bar S= 4.92 ≈ 4.5" c/c extra top.

Rebar along long direction:

$+A_{S\ B} = \frac{5.148}{4.5*(7.5-0.15)}$ = 0.155 in^2/ft

A_{min}= 0.1836 in^2/ft (Controlling).

Using Φ10 mm bar @ 7.90"≈7.5" c/c at bottom along long direction crank 50% bar to negative zone.

$-A_{S\ B} = \frac{11.716}{4.5*(7.5-0.36)}$ = 0.365 in^2/ft

Already provided $A_{s1} = \frac{0.121*12}{15}$ = 0.0968in^2/ft

Extra top required, A_{s2}= (0.365-00.0968) in^2/ft = 0.2682 in^2/ft

Using Φ 10mm bar @ 5.41" ≈ 5" c/c extra top.

Corner Reinforcement (BNBC 2013)

a) Corner reinforcement shall be provided at exterior corners in both bottom and top of the slab, for a distance in each direction from the corner equal to one-fifth the longer span of the corner panel as per provisions of 6.5.3.6.

6.5.3.6.1 Corner reinforcement in both top and bottom of slab shall be sufficient to resist a moment per unit of width equal to the maximum positive moment per unit width in the slab panel.

6.5.3.6.2 The moment shall be assumed to be about an axis perpendicular to the diagonal from the corner in the top of the slab and about an axis parallel to the diagonal from the corner in the bottom of the slab.

6.5.3.6.3 Corner reinforcement shall be provided for a distance in each direction from the corner equal to one-fifth the longer span.

6.5.3.6.4 Corner reinforcement shall be placed parallel to the diagonal in the top of the slab and perpendicular to the diagonal in the bottom of the slab. Alternatively, reinforcement shall be placed in two layers parallel to the sides of the slab in both the top and bottom of the slab.

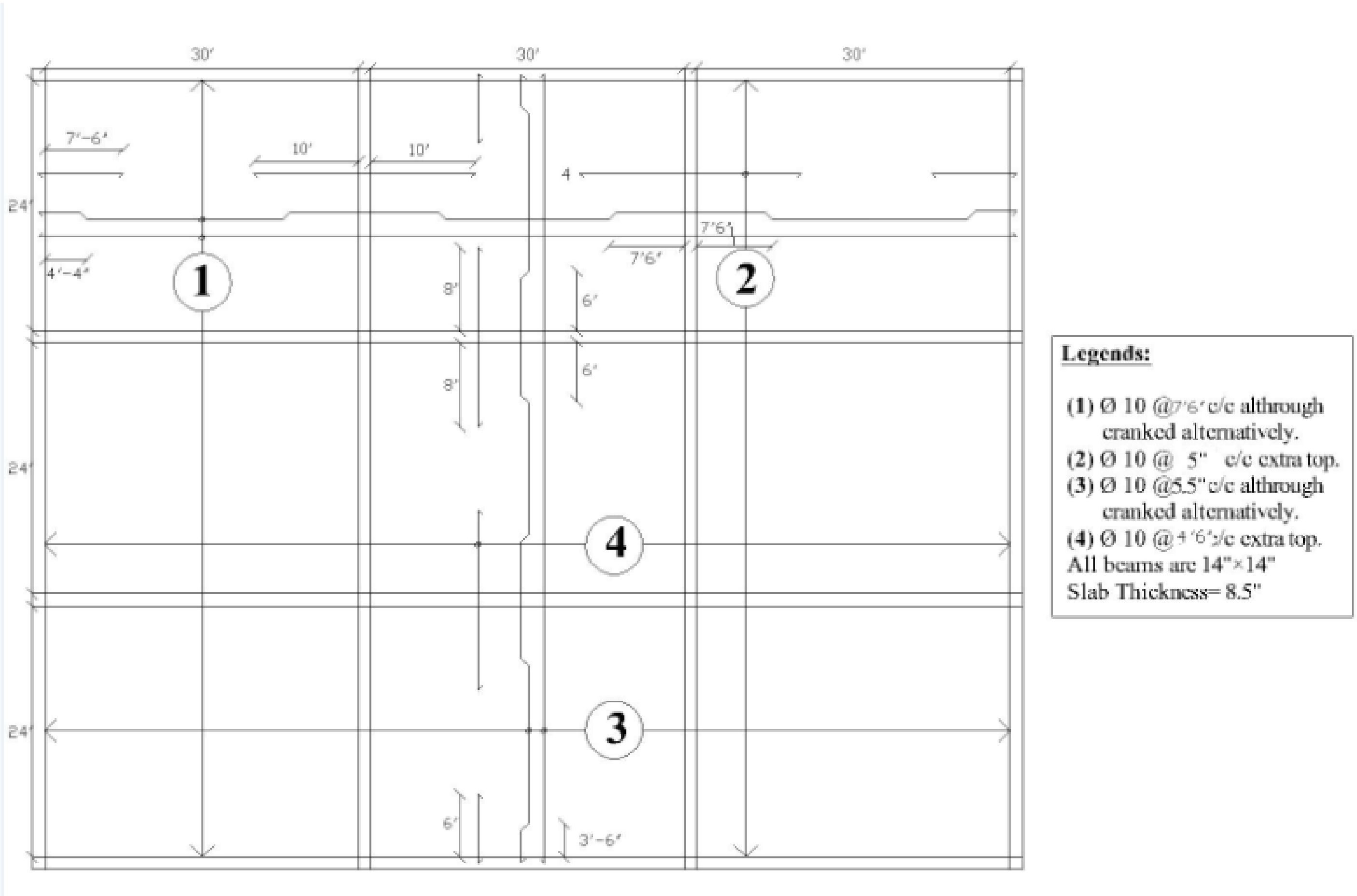


Figure: Reinforcement details of slab in plan.