OMAR SHEMY PORTFOLIO

SUBJECT: Unbalanced moment, critical section study

DATE	PROJECT NO.	PROJECT NAME	ENGINEER	PAGE
2024 JAN 18	**202402**	**DEMO PORTFOLIO**	**O.S.**	**1**

1. **Study the method of solution of the software in use in the investigation**

density concrete and 1.0 for normal density concrete. Refer to Table 2-1 for determination of concrete type.

$\sqrt{f_c'}$ $\leq$ 8 MPa.

When the value of d is greater than 300mm, allowable stress v_c obtained from the above three equations shall be multiplied by **1300/(1000+*d*)** as required by CSA A23.3-14/04 code[90].

The allowable shear stress around drops when waffle slabs are used is computed as

$$v_c = \begin{cases} 2\lambda\sqrt{f_c'} & \text{for ACI,} \\ 0.20\,\phi_c\lambda\sqrt{f_c'} & \text{for CSA A23.3-94,} \\ 0.19\,\phi_c\lambda\sqrt{f_c'} & \text{for CSA A23.3-04.} \end{cases} \qquad \text{Eq. 2-46}$$

For waffle slab systems with valid ribs defined earlier in this chapter, the allowable shear stress is increased by 10% for ACI designs.[91]

2.11.6 Computation of Factored Shear Force at Critical Section

The factored shear force V_u in the critical section, is computed as the reaction at the centroid of the critical section (e.g., column centerline for interior columns) minus the self-weight and any superimposed surface dead and live load acting within the critical section. If the section is considered open, two 45 degree lines are drawn from the column corners to the nearest slab edge (lines AF and DE in Figure 2-19) and the self-weight and superimposed surface dead and live loads acting on the area ADEF are omitted from V_u.

2.11.7 Computation of Unbalanced Moment at Critical Section

The factored unbalanced moment used for shear transfer, M_{unbal}, is computed as the sum of the joint moments to the left and right. Moment of the vertical reaction with respect to the centroid of the critical section is also taken into account by

$$M_{unbal} = (M_{u,left} - M_{u,right}) - V_u e_g \qquad \text{Eq. 2-47}$$

90. CSA A23.3-14, 13.3.4.3; CSA A23.3-04, 13.3.4.3
91. ACI 318-14, 8.8.1.5, 9.8.1.5; ACI 318-11, 8.13.8; ACI 318-08, 8.13.8; ACI 318-05, 8.11.8; ACI 318-02, 8.11.8; ACI 318-99, 8.11.8

where

$M_{u,left}$	=	factored bending moment at the joint on the left hand side of the joint,
$M_{u,right}$	=	factored bending moment at the joint on the right hand side of the joint,
V_u	=	factored shear force in the critical section described above,
c_g	=	location of the centroid of the critical section with respect to the column centerline (positive if the centroid is to the right in longitudinal direction with respect to the column centerline).

2.11.8 Computation of Shear Stresses at Critical Section

The punching shear stress computed by the program is based on the following[92]

$$v_u = \frac{V_u}{A_c} \qquad \text{Eq. 2-48}$$

where

V_u	=	factored shear force in the critical section described above,
A_c	=	area of concrete, including beam if any, resisting shear transfer.

Under conditions of combined shear, V_u, and unbalanced moment, M_{unbal}, $\gamma_v M_{unbal}$ is assumed to be transferred by eccentricity of shear about the centroidal axis of the critical section. The shear stresses computed by the program for this condition correspond to[93]

$$v_{AB} = \frac{V_u}{A_c} + \frac{\gamma_v M_{unbal} c_{AB}}{J_c} \qquad \text{Eq. 2-49}$$

$$v_{CD} = \frac{V_u}{A_c} - \frac{\gamma_v M_{unbal} c_{CD}}{J_c} \qquad \text{Eq. 2-50}$$

92. ACI 318-14, 8.4.4.2.3; ACI 318-11, 11.11.7.2; ACI 318-08; 11.11.7.2; ACI 318-05, 11.12.6.2; ACI 318-02, 11.12.6.2; ACI 318-99, 11.12.6.2; CSA A23.3-14, 13.3.5; CSA A23.3-04, 13.3.5; CSA A23.3-94, 13.4.5

93. ACI 318-14, R8.4.4.2.3; ACI 318-11, R11.11.7.2; ACI 318-08, R11.11.7.2; ACI 318-05, R11.12.6.2; ACI 318-02, R11.12.6.2; ACI 318-99, R11.12.6.2; CSA A23.3-14, 13.3.5.5; CSA A23.3-04, 13.3.5.5; CSA A23.3-94, 13.4.5.5; Ref. [24]

where

M_{unbal}	=	factored unbalanced moment transferred directly from slab to column, as described above,
γ_v	=	$(1 - \gamma_f)$ Eq 2-51 is a fraction of unbalanced moment considered transferred by the eccentricity of shear about the centroid of the assumed critical section,[94]
c	=	distance from centroid of critical section to the face of section where stress is being computed,
J_c	=	property of the assumed critical section analogous to polar moment of inertia.

Factor γ_f in Eq. 2-51 is calculated as[95]

$$\gamma_f = \frac{1}{1 + (2/3)\sqrt{b_1 / b_2}} \qquad \text{Eq. 2-52}$$

where

b_1	=	width of critical section in the direction of analysis,
b_2	=	width of the critical section in the transverse direction.

If an ACI 318 standard is selected then the program provides an option to use an increased value[96] of γ_f. For edge and corner columns with unbalanced moment about an axis parallel to the edge, the value can be increased to 1.0 if the factored shear force at the support doesn't exceed $0.75\phi V_c$ for edge columns and $0.5\phi V_c$ for corner columns. For ACI 318-99, ACI 318-02, and ACI 318-05, condition that reinforcement ratio in the effective slab width doesn't exceed $0.375\rho_b$ must also be satisfied to apply the increase. For interior columns and for edge columns with unbalanced moment perpendicular to the edge, γ_f can be increased 25% but the final value of γ_f cannot exceed 1.0. The increase can be applied if the shear doesn't exceed $0.4\phi V_c$. Also, the net tensile strain in the effective slab has to exceed 0.010 for the ACI 318-08, ACI 318-11, and ACI 318-14. For earlier ACI 318 editions, the condition that reinforcement ratio does not exceed $0.375\rho_b$ applies.

spSlab calculates v_u as the absolute maximum of v_{AB} and v_{CD}. Local effects of concentrated loads are not computed by spSlab and must be calculated manually.

94. ACI 318-14, 8.4.4.2.1, 8.4.4.2.2; ACI 318-11, 11.11.7.1; ACI 318-08, 11.11.7.1; ACI 318-05, 11.12.6.1; ACI 318-02, 11.12.6.1; ACI 318-99, 11.12.6.1; CSA A23.3-04, Eq. 13-8; CSA A23.3-94, Eq. 13-8
95. ACI 318-14, 8.4.2.3.2; ACI 318-11, 13.5.3.2; ACI 318-08, 13.5.3.2; ACI 318-05, 13.5.3.2; ACI 318-02, 13.5.3.2; ACI 318-99, 13.5.3.2; CSA A23.3-04, Eq. 13-8; CSA A23.3-94, Eq. 13-7
96. ACI 318-14, 8.4.2.3.4; ACI 318-11, 13.5.3.3; ACI 318-08, 13.5.3.3; ACI 318-05, 13.5.3.3; ACI 318-02, 13.5.3.3; ACI 318-99, 13.5.3.3;

2. Study the code definition of the solution being investigated (CL. 13.10.2 CSA A23.3-2019)

7.5 Slab reinforcement

13.10 Slab reinforcement

13.10.1 General

Reinforcement in each direction for two-way slab systems shall be determined from moments at critical sections but shall be not less than that required by Clause 7.8.1.

Note: *Where strict crack control is a concern, slabs with drop panels, particularly in a corrosive environment, can require additional reinforcement in the negative middle strip region to limit cracking. This additional reinforcement is not included in the calculation of moment resistance. The reinforcement required to limit cracking is generally more than that required by Clause 7.8.1.*

13.10.2 Shear and moment transfer

When gravity load, wind, earthquake, or other lateral forces cause transfer of moment between slab and column, a fraction of unbalanced moment given by

$$\gamma_f = 1 - \gamma_v \qquad \text{Equation 13.25}$$

shall be transferred by flexural reinforcement placed within a width b_b.

Note: *For exterior supports, including corner columns, Clause 13.10.3 satisfies this requirement.*

13.10.3 Exterior columns

Reinforcement for the total factored negative moment transferred to the exterior columns shall be placed within a band width b_b. Temperature and shrinkage reinforcement determined as specified in Clause 7.8.1 shall be provided in that section of the slab outside of the band region defined by b_b, or as required by Clause 13.10.9.

13.10.4 Spacing

Except for portions of slab area that are of cellular or ribbed construction, spacing of reinforcement at critical sections shall not exceed the following limits:

Negative reinforcement in the band defined by b_b:	$1.5h_s$, but $s \le 250$ mm
Remaining negative moment reinforcement:	$3h_s$, but $s \le 500$ mm
Positive moment reinforcement:	$3h_s$, but $s \le 500$ mm

In the slab over cellular spaces, reinforcement shall be provided as required by Clause 7.8.

b_b = width of slab extending $1.5h_s$ past the sides of the column

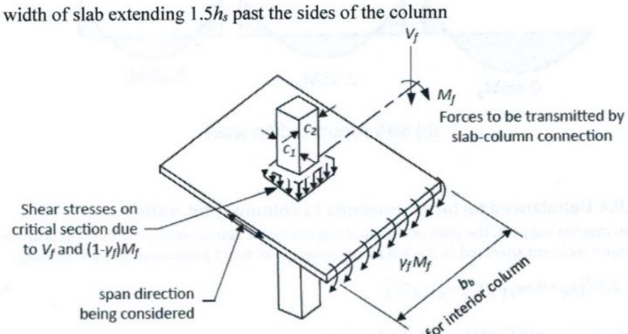

Fig. N13.10.2 Shear and moment transfer at slab-column connections

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3. **Summarize concepts and definitions:**

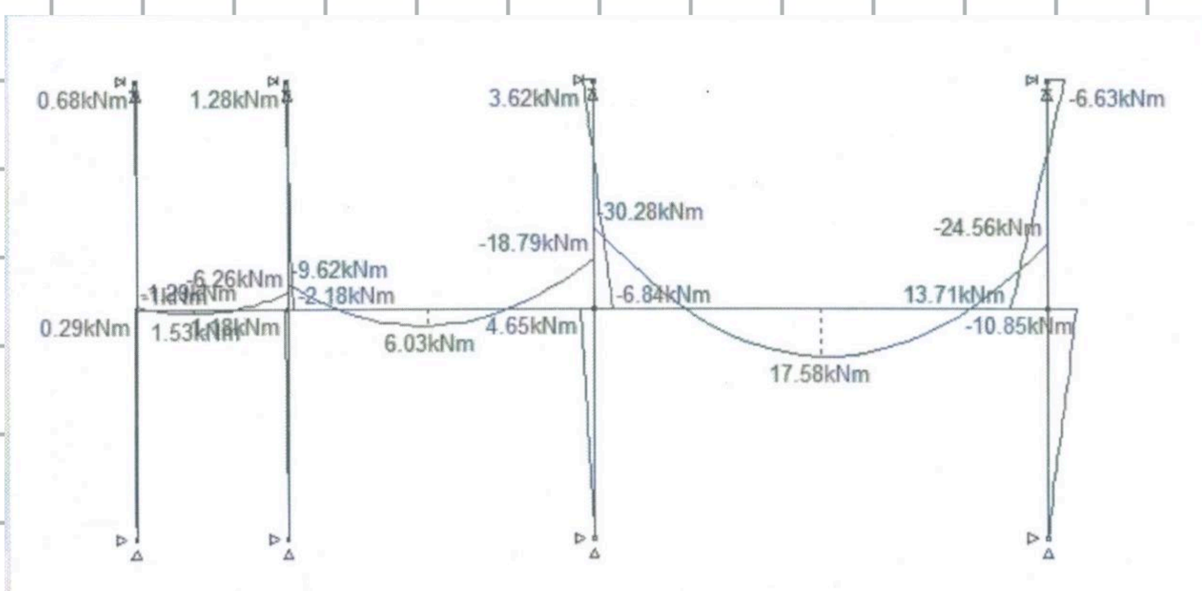
   a) **The unbalanced moment is the moment that is drawn to a column in a column slab/beam assembly.**

   b) **If you imagine a three-column frame perfectly symmetric with respect to geometry and load, there would be no rotation at the center column joint and therefore no moment would be drawn into the column. The moments on either side of the center column joint would "balance".**

   c) **That being said, if you take that same frame and make one slab/beam span twice as long as the other, the moment on either side of the center column joints would be unbalanced and a portion (not all) of that unbalanced moment would be supported by the column through two components of force transfer namely:**

      a. **eccentric punching shear γ_v and**
      b. **flexure in the slab/column joint γ_f.**

   d) **Functionally, the unbalanced moment is represented by the vertical step in the moment diagram that manifests itself where the slab/beam system passes over the columns.**



4. Study the output of the software in use in the investigation

2.8. Bottom Bar Development Lengths

Span	Strip	Long Bars Bars	Long Bars DevLen (in)	Short Bars Bars	Short Bars DevLen (in)
1	Column	---		---	
	Middle	---		---	
2	Column	4-#15	12.00	---	
	Middle	12-#15	12.00	---	
3	Column	12-#15	12.00	---	
	Middle	9-#15	12.00	---	
4	Column	---		---	
	Middle	---		---	
5	Column	8-#15	12.00	---	
	Middle	5-#15	12.28	---	
6	Column	5-#15	12.00	---	
	Middle	9-#15	12.00	---	
7	Column	---		---	
	Middle	---		---	

2.9. Flexural Capacity

Span	Strip	Top x (ft)	Top $A_{s,top}$ (in²)	Top ΦM_n- (k-ft)	Top M_u- (k-ft)	Top Comb Pat	Top Status	Bottom $A_{s,bot}$ (in²)	Bottom ΦM_n+ (k-ft)	Bottom M_u+ (k-ft)	Bottom Comb Pat	Bottom Status
1	Column	0.000	2.48	-75.94	0.00	U1 All	OK	0.00	0.00	0.00	U1 All	OK
		1.925	2.48	-75.94	-6.66	U2 All	OK	0.00	0.00	0.00	U1 All	OK
		3.250	2.48	-75.94	-18.91	U2 All	OK	0.00	0.00	0.00	U1 All	OK
		3.575	2.48	-75.94	-22.91	U2 All	OK	0.00	0.00	0.00	U1 All	OK
		5.500	2.48	-75.94	-54.17	U2 All	OK	0.00	0.00	0.00	U1 All	OK
		6.500	2.48	-75.94	-75.65	U2 All	---	0.00	0.00	0.00	U1 All	---
	Middle	0.000	1.55	-48.75	0.00	U1 All	OK	0.00	0.00	0.00	U1 All	OK
		1.925	1.55	-48.75	0.00	U2 All	OK	0.00	0.00	0.00	U1 All	OK
		3.250	1.55	-48.75	0.00	U2 All	OK	0.00	0.00	0.00	U1 All	OK
		3.575	1.55	-48.75	0.00	U2 All	OK	0.00	0.00	0.00	U1 All	OK
		4.290	1.55	-48.75	0.00	U2 All	OK	0.00	0.00	0.00	U1 All	OK
		5.290	3.72	-112.91	0.00	U2 All	OK	0.00	0.00	0.00	U1 All	OK
		5.500	3.72	-112.91	0.00	U2 All	OK	0.00	0.00	0.00	U1 All	OK
		6.500	3.72	-112.91	0.00	U2 All	---	0.00	0.00	0.00	U1 All	---
left span 2	Column	0.000	2.48	-75.94	-31.32	U2 S1	---	1.24	38.97	0.00	U1 All	---
		1.000	2.48	-75.94	-17.55	U2 S1	OK	1.24	38.97	0.77	U3 S3	OK
		2.805	2.48	-75.94	-11.85	U2 Odd	OK	1.24	38.97	2.25	U3 Even	OK
		3.000	2.30	-70.66	-12.52	U2 Odd	OK	1.24	38.97	2.35	U3 Even	OK
		3.805	1.55	-48.40	-16.67	U2 Odd	OK	1.24	38.97	1.82	U3 Even	OK
		3.975	1.55	-48.40	-17.80	U2 Odd	OK	1.24	38.97	1.53	U3 Even	OK
		5.250	1.55	-48.40	-29.09	U2 Odd	OK	1.24	38.97	0.00	U1 All	OK
		6.140	1.55	-48.40	-39.69	U2 Odd	OK	1.24	38.97	0.00	U1 All	OK
		6.525	2.39	-73.20	-44.88	U2 Odd	OK	1.24	38.97	0.00	U1 All	OK
		7.140	3.72	-110.91	-53.94	U2 Odd	OK	1.24	38.97	0.00	U1 All	OK
		7.800	3.72	-110.91	-64.89	U2 All	OK	1.24	38.97	0.00	U1 All	OK
		8.800	5.58	-159.61	-86.36	U2 All	OK	1.24	38.97	0.00	U1 All	OK

left span

-128.74 - 37.06 = -165.8

- 165.8

right span

Moment left of the support is the end of the span on the left

Moment right of the support is the start of the span on the right

-204.69 - 51.17 = -255.86

right span

Span Strip	Top x (ft)	$A_{s,top}$ (in²)	ΦM_n- (k-ft)	M_u- (k-ft)	Comb Pat	Status	Bottom $A_{s,bot}$ (in²)	ΦM_n+ (k-ft)	M_u+ (k-ft)	Comb Pat	Status
	9.500	5.58	-159.61	-102.99	U2 All	OK	1.24	38.97	0.00	U1 All	OK
	10.500	5.58	-159.61	-128.74	U2 All	---	1.24	38.97	0.00	U1 All	---
Middle	0.000	3.72	-117.01	0.72	U2 S1	---	3.72	117.01	0.00	U1 All	---
	1.000	3.72	-117.01	0.00	U2 S1	OK	3.72	117.01	0.52	U3 S3	OK
	3.000	3.72	-117.01	-0.62	U2 Odd	OK	3.72	117.01	1.57	U3 Even	OK
	3.975	3.72	-117.01	-1.34	U2 Odd	OK	3.72	117.01	1.02	U3 Even	OK
	5.250	3.72	-117.01	-3.23	U2 Odd	OK	3.72	117.01	0.00	U1 All	OK
	6.525	3.72	-117.01	-6.71	U2 Odd	OK	3.72	117.01	0.00	U1 All	OK
	9.500	3.72	-117.01	-25.75	U2 All	OK	3.72	117.01	0.00	U1 All	OK
	10.500	3.72	-117.01	-37.06	U2 All	---	3.72	117.01	0.00	U1 All	---
3 Column	0.000	5.58	-159.61	-204.69	U2 All	---	3.72	115.25	0.00	U1 All	---
	0.750	5.58	-159.61	-166.24	U2 All	---	3.72	115.25	0.00	U1 All	---
	1.000	5.58	-159.61	-153.92	U2 All	OK	3.72	115.25	0.00	U1 All	OK
	4.401	5.58	-159.61	-11.45	U2 S2	OK	3.72	115.25	0.00	U1 All	OK
	5.417	2.79	-84.87	0.00	U1 All	OK	3.72	115.25	16.72	U2 All	OK
	7.272	2.79	-84.87	0.00	U1 All	OK	3.72	115.25	54.72	U2 All	OK
	8.287	0.00	0.00	0.00	U1 All	OK	3.72	115.25	71.13	U2 All	OK
	8.729	0.00	0.00	0.00	U1 All	OK	3.72	115.25	77.31	U2 All	OK
	11.750	0.00	0.00	0.00	U1 All	OK	3.72	115.25	103.74	U2 All	OK
	13.158	0.00	0.00	0.00	U1 All	OK	3.72	115.25	106.69	U2 All	OK
	15.354	0.00	0.00	0.00	U1 All	OK	3.72	115.25	99.34	U2 All	OK
	15.796	0.00	0.00	0.00	U1 All	OK	3.72	115.25	96.10	U2 All	OK
	16.796	1.24	-38.22	0.00	U1 All	OK	3.72	115.25	86.62	U2 All	OK
	18.667	1.24	-38.22	0.00	U1 All	OK	3.72	115.25	60.80	U2 All	OK
	19.667	2.17	-64.59	0.00	U1 All	OK	3.72	115.25	42.66	U2 All	OK
	23.083	2.17	-64.59	-56.35	U2 S3	OK	3.72	115.25	0.00	U1 All	OK
	23.500	2.17	-64.59	-72.95	U2 All	---	3.72	115.25	0.00	U1 All	---
Middle	0.000	3.72	-117.01	-51.17	U2 All	---	2.79	87.60	0.00	U1 All	---
	1.000	3.72	-117.01	-38.48	U2 All	OK	2.79	87.60	0.00	U1 All	OK
	5.350	3.72	-117.01	0.00	U1 All	OK	2.79	87.60	10.11	U2 All	OK
	6.350	0.00	0.00	0.00	U1 All	OK	2.79	87.60	24.75	U2 All	OK
	8.729	0.00	0.00	0.00	U1 All	OK	2.79	87.60	51.54	U2 All	OK
	11.750	0.00	0.00	0.00	U1 All	OK	2.79	87.60	69.16	U2 All	OK
	13.158	0.00	0.00	0.00	U1 All	OK	2.79	87.60	71.13	U2 All	OK
	15.354	0.00	0.00	0.00	U1 All	OK	2.79	87.60	66.23	U2 All	OK
	18.225	0.00	0.00	0.00	U1 All	OK	2.79	87.60	45.22	U2 All	OK
	19.225	4.34	-136.43	0.00	U1 All	OK	2.79	87.60	34.02	U2 All	OK
	23.083	4.34	-136.43	-14.09	U2 S3	OK	2.79	87.60	0.00	U1 All	OK
	23.500	4.34	-136.43	-18.24	U2 All	---	2.79	87.60	0.00	U1 All	---
4 Column	0.000	2.17	-64.59	-49.68	U2 S3	---	0.00	0.00	0.00	U1 All	---
	0.417	2.17	-64.59	-46.54	U2 S3	OK	0.00	0.00	0.00	U1 All	OK
	3.597	2.17	-64.59	-30.32	U2 All	OK	0.00	0.00	0.00	U1 All	OK
	4.597	1.24	-38.22	-28.09	U2 Odd	OK	0.00	0.00	0.00	U1 All	OK
	4.850	1.24	-38.22	-27.83	U2 Odd	OK	0.00	0.00	0.00	U1 All	OK
	6.750	1.24	-38.22	-27.59	U2 Odd	OK	0.00	0.00	0.00	U1 All	OK
	8.650	1.24	-38.22	-30.35	U2 Odd	OK	0.00	0.00	0.00	U1 All	OK
	8.903	1.24	-38.22	-30.94	U2 Odd	OK	0.00	0.00	0.00	U1 All	OK
	9.903	2.17	-64.59	-34.39	U2 All	OK	0.00	0.00	0.00	U1 All	OK
	10.550	2.17	-64.59	-37.33	U2 All	OK	0.00	0.00	0.00	U1 All	OK
	11.550	2.79	-81.07	-42.79	U2 All	OK	0.00	0.00	0.00	U1 All	OK
	13.083	2.79	-81.07	-53.34	U2 All	OK	0.00	0.00	0.00	U1 All	OK
	13.500	2.79	-81.07	-56.80	U2 S4	---	0.00	0.00	0.00	U1 All	---

Span	Strip	Top						Bottom				
		x	$A_{s,top}$	ΦM_n-	M_u-	Comb Pat	Status	$A_{s,bot}$	ΦM_n+	M_u+	Comb Pat	Status
		ft	in²	k-ft	k-ft			in²	k-ft	k-ft		
	Middle	0.000	4.34	-118.45	-12.42	U2 S3	---	0.00	0.00	0.00	U1 All	---
		0.417	4.34	-118.45	-11.64	U2 S3	OK	0.00	0.00	0.00	U1 All	OK
		2.203	4.34	-118.45	-8.86	U2 All	OK	0.00	0.00	0.00	U1 All	OK
		3.203	0.93	-28.99	-7.89	U2 All	OK	0.00	0.00	0.00	U1 All	OK
		4.850	0.93	-28.99	-6.96	U2 Odd	OK	0.00	0.00	0.00	U1 All	OK
		6.750	0.93	-28.99	-6.90	U2 Odd	OK	0.00	0.00	0.00	U1 All	OK
		8.650	0.93	-28.99	-7.59	U2 Odd	OK	0.00	0.00	0.00	U1 All	OK
		10.297	0.93	-28.99	-9.03	U2 All	OK	0.00	0.00	0.00	U1 All	OK
		11.297	2.17	-64.59	-10.33	U2 All	OK	0.00	0.00	0.00	U1 All	OK
		13.083	2.17	-64.59	-13.34	U2 All	OK	0.00	0.00	0.00	U1 All	OK
		13.500	2.17	-64.59	-14.20	U2 S4	---	0.00	0.00	0.00	U1 All	---
5	Column	0.000	2.79	-81.07	-88.08	U2 All	---	2.48	76.29	0.00	U1 All	---
		0.208	2.79	-81.07	-82.30	U2 All	---	2.48	76.29	0.00	U1 All	---
		0.417	2.79	-81.07	-76.61	U2 All	OK	2.48	76.29	0.00	U1 All	OK
		4.833	2.79	-81.07	0.00	U1 All	OK	2.48	76.29	16.48	U2 All	OK
		5.833	1.55	-47.23	0.00	U1 All	OK	2.48	76.29	28.87	U2 All	OK
		8.354	1.55	-47.23	0.00	U1 All	OK	2.48	76.29	52.92	U2 All	OK
		9.354	0.00	0.00	0.00	U1 All	OK	2.48	76.29	59.65	U2 All	OK
		9.896	0.00	0.00	0.00	U1 All	OK	2.48	76.29	62.61	U2 All	OK
		13.146	0.00	0.00	0.00	U1 All	OK	2.48	76.29	70.46	U2 All	OK
		14.250	0.00	0.00	0.00	U1 All	OK	2.48	76.29	69.25	U2 All	OK
		18.021	0.00	0.00	0.00	U1 All	OK	2.48	76.29	50.33	U2 All	OK
		18.563	0.00	0.00	0.00	U1 All	OK	2.48	76.29	45.73	U2 All	OK
		19.571	2.48	-76.29	0.00	U1 All	OK	2.48	76.29	35.90	U2 All	OK
		22.083	2.48	-76.29	0.00	U1 All	OK	2.48	76.29	4.65	U2 S4	OK
		23.092	4.65	-137.05	-14.98	U2 All	OK	2.48	76.29	0.00	U1 All	OK
		27.500	4.65	-137.05	-131.18	U2 All	OK	2.48	76.29	0.00	U1 All	OK
		27.750	4.65	-137.05	-139.02	U2 All	---	2.48	76.29	0.00	U1 All	---
		28.500	4.65	-137.05	-163.35	U2 All	---	2.48	76.29	0.00	U1 All	---
	Middle	0.000	2.17	-68.06	-22.02	U2 All	---	1.55	48.54	0.00	U1 All	---
		0.417	2.17	-68.06	-19.15	U2 All	OK	1.55	48.54	0.00	U1 All	OK
		5.375	2.17	-68.06	0.00	U1 All	OK	1.55	48.54	15.59	U2 All	OK
		6.375	0.00	0.00	0.00	U1 All	OK	1.55	48.54	23.27	U2 All	OK
		9.896	0.00	0.00	0.00	U1 All	OK	1.55	48.54	41.74	U2 All	OK
		13.146	0.00	0.00	0.00	U1 All	OK	1.55	48.54	46.97	U2 All	OK
		14.250	0.00	0.00	0.00	U1 All	OK	1.55	48.54	46.17	U2 All	OK
		18.021	0.00	0.00	0.00	U1 All	OK	1.55	48.54	33.55	U2 All	OK
		20.391	0.00	0.00	0.00	U1 All	OK	1.55	48.54	17.81	U2 All	OK
		21.391	3.10	-94.22	0.00	U1 All	OK	1.55	48.54	9.35	U2 All	OK
		27.500	3.10	-94.22	-32.79	U2 All	OK	1.55	48.54	0.00	U1 All	OK
		28.500	3.10	-94.22	-40.84	U2 All	---	1.55	48.54	0.00	U1 All	---
6	Column	0.000	4.65	-137.05	-97.60	U2 All	---	1.55	48.65	0.00	U1 All	---
		1.000	4.65	-137.05	-74.96	U2 All	OK	1.55	48.65	0.00	U1 All	OK
		2.200	4.65	-137.05	-50.88	U2 All	OK	1.55	48.65	0.00	U1 All	OK
		3.200	3.10	-94.22	-35.45	U2 Odd	OK	1.55	48.65	0.00	U1 All	OK
		3.630	3.10	-94.22	-30.28	U2 Odd	OK	1.55	48.65	0.00	U1 All	OK
		4.630	1.55	-48.54	-19.78	U2 Odd	OK	1.55	48.65	0.40	U3 Even	OK
		4.850	1.55	-48.65	-17.77	U2 Odd	OK	1.55	48.65	1.65	U3 Even	OK
		6.250	1.55	-48.65	-8.56	U3 Odd	OK	1.55	48.65	8.14	U2 Even	OK
		8.000	1.55	-48.65	-4.66	U3 Odd	OK	1.55	48.65	11.41	U2 Even	OK
		8.150	1.55	-48.65	-4.63	U3 Odd	OK	1.55	48.65	11.34	U2 Even	OK
		8.370	1.55	-48.65	-4.64	U3 Odd	OK	1.55	48.65	11.16	U2 Even	OK

Span	Strip	Top						Bottom				
		x (ft)	$A_{s,top}$ (in²)	ΦM_n- (k-ft)	M_u- (k-ft)	Comb Pat	Status	$A_{s,bot}$ (in²)	ΦM_n+ (k-ft)	M_u+ (k-ft)	Comb Pat	Status
		9.370	2.48	-76.58	-6.00	U3 Odd	OK	1.55	48.65	8.92	U2 Even	OK
		12.000	2.48	-76.58	-28.53	U2 All	OK	1.55	48.65	0.00	U1 All	OK
		12.500	2.48	-76.58	-37.99	U2 All	---	1.55	48.65	0.00	U1 All	---
	Middle	0.000	3.10	-97.25	-27.24	U2 All	---	2.79	87.68	0.00	U1 All	---
		1.000	3.10	-97.25	-18.74	U2 All	OK	2.79	87.68	0.00	U1 All	OK
		2.420	3.10	-97.25	-9.88	U2 All	OK	2.79	87.68	0.00	U1 All	OK
		3.420	2.79	-87.77	-6.05	U2 Odd	OK	2.79	87.68	0.00	U1 All	OK
		4.850	2.79	-87.68	-2.66	U2 Odd	OK	2.79	87.68	1.10	U3 Even	OK
		6.250	2.79	-87.68	-1.00	U3 Odd	OK	2.79	87.68	5.42	U2 Even	OK
		8.000	2.79	-87.68	-0.37	U3 Odd	OK	2.79	87.68	7.61	U2 Even	OK
		8.150	2.79	-87.68	-0.35	U3 Odd	OK	2.79	87.68	7.56	U2 Even	OK
		12.000	2.79	-87.68	0.00	U2 All	OK	2.79	87.68	0.00	U1 All	OK
		12.500	2.79	-87.68	0.34	U2 All	---	2.79	87.68	0.00	U1 All	---
7	Column	0.000	2.48	-76.58	-42.97	U2 All	---	0.00	0.00	0.00	U1 All	---
		0.500	2.48	-76.58	-32.90	U2 All	OK	0.00	0.00	0.00	U1 All	OK
		0.655	2.48	-76.58	-30.09	U2 All	OK	0.00	0.00	0.00	U1 All	OK
		1.655	2.17	-67.38	-14.81	U2 All	OK	0.00	0.00	0.00	U1 All	OK
		1.725	2.17	-67.38	-13.92	U2 All	OK	0.00	0.00	0.00	U1 All	OK
		2.000	2.17	-67.38	-10.74	U2 All	OK	0.00	0.00	0.00	U1 All	OK
		2.775	2.17	-67.38	-4.05	U2 All	OK	0.00	0.00	0.00	U1 All	OK
		4.000	2.17	-67.38	0.00	U1 All	OK	0.00	0.00	0.00	U1 All	OK
	Middle	0.000	2.79	-87.68	0.00	U2 All	---	0.00	0.00	0.00	U1 All	---
		0.500	2.79	-87.68	0.00	U2 All	OK	0.00	0.00	0.00	U1 All	OK
		1.725	2.79	-87.68	0.00	U2 All	OK	0.00	0.00	0.00	U1 All	OK
		2.000	2.79	-87.68	0.00	U2 All	OK	0.00	0.00	0.00	U1 All	OK
		2.775	2.79	-87.68	0.00	U2 All	OK	0.00	0.00	0.00	U1 All	OK
		4.000	2.79	-87.68	0.00	U1 All	OK	0.00	0.00	0.00	U1 All	OK

2.10. Slab Shear Capacity

Span	Strip	b (in)	d_v (in)	β	V_{ratio}	ΦV_c (kip)	V_u (kip)	X_u (ft)
1	Column	63.00	6.84	0.210	1.000	50.59	17.66	4.93
	Middle	81.00	6.84	0.210	0.000	65.04	0.00	0.00
2	Column	63.00	6.84	0.210	0.813	50.59	25.79	8.93
	Middle	195.00	6.84	0.210	0.187	156.58	5.92	8.93
3	Column	121.50	6.84	0.210	0.800	97.56	46.48	1.57
	Middle	136.50	6.84	0.210	0.200	109.61	11.62	1.57
4	Column	36.00	6.84	0.210	0.800	28.91	7.76	12.51
	Middle	36.00	6.84	0.210	0.200	28.91	1.94	12.51
5	Column	69.00	6.84	0.210	0.800	55.41	29.87	26.93
	Middle	69.00	6.84	0.210	0.200	55.41	7.47	26.93
6	Column	75.00	6.84	0.210	0.810	60.22	21.59	1.57
	Middle	141.00	6.84	0.210	0.190	113.22	5.05	1.57
7	Column	75.00	6.84	0.210	1.000	60.22	15.74	1.07
	Middle	141.00	6.84	0.210	0.000	113.22	0.00	0.00

2.11. Flexural Transfer of Negative Unbalanced Moment at Supports

Support	Width (in)	Width-c (in)	d (in)	M_{unb} (k-ft)	Comb Patt	γ_f	$A_{s,req}$ (in²)	$A_{s,prov}$ (in²)	Add Bars
1	32.25	32.25	7.59	49.23	U2 Odd	0.542	0.856	1.860	---
2	40.50	40.50	7.59	90.06	U2 All	0.542	1.593	3.720	---

Support	Width in	Width-c in	d in	M_{unb} k-ft	Comb	Patt	γ_f	$A_{s,req}$ in²	$A_{s,prov}$ in²	Add Bars
3	38.50	38.50	7.59	31.26	U2	All	0.600	0.593	2.170	---
4	38.50	38.50	7.59	39.27	U2	All	0.600	0.749	2.790	---
5	40.50	40.50	7.59	81.55	U2	Odd	0.542	1.435	2.790	---
6	40.50	40.50	7.59	7.12	U2	Odd	0.600	0.133	1.550	---

2.12. Punching Shear Around Columns

2.12.1. Critical Section Properties

Support	Type	b_1 in	b_2 in	b_0 in	d_{avg} in	CG in	$c_{(left)}$ in	$c_{(right)}$ in	A_c in²	J_c in⁴
1	Rect	31.59	19.59	102.34	7.59	0.00	15.79	15.79	776.25	1.1623e+005
2	Rect	31.59	19.59	102.34	7.59	0.00	15.79	15.79	776.25	1.1623e+005
3	Rect	17.59	17.59	70.34	7.59	0.00	8.79	8.79	533.53	28777
4	Rect	17.59	17.59	70.34	7.59	0.00	8.79	8.79	533.53	28777
5	Rect	31.59	19.59	102.34	7.59	0.00	15.79	15.79	776.25	1.1623e+005
6	Rect	19.59	19.59	78.34	7.59	0.00	9.79	9.79	594.21	39412

2.12.2. Punching Shear Results

Support	V_u kip	v_u psi	M_{unb} k-ft	Comb	Patt	γ_v	v_u psi	ΦV_c psi
1	35.25	45.4	-48.79	U2	All	0.458	81.9	212.4
2	104.56	134.7	90.06	U2	All	0.458	202.0	212.4
3	60.11	112.7	-31.26	U2	All	0.400	158.5	212.4
4	44.71	83.8	39.27	U2	All	0.400	141.4	212.4
5	73.79	95.1	-79.35	U2	All	0.458	154.4	212.4
6	40.07	67.4	5.33	U2	All	0.400	73.8	212.4

2.13. Integrity Reinforcement at Supports

Notes:
The sum of bottom reinforcement crossing the perimeter of the support on all sides shall not be less than the below listed values.

Support	V_{se} kip	A_{sb} in²
1	29.830	0.994
2	107.444	3.581
3	61.108	2.037
4	45.473	1.516
5	75.897	2.530
6	35.288	1.176

2.14. Material TakeOff

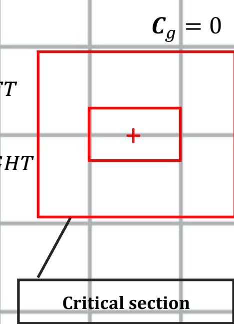
2.14.1. Reinforcement in the Direction of Analysis

Top Bars	1526.8 lb	<=>	15.42 lb/ft	<=>	1.008 lb/ft²
Bottom Bars	1273.4 lb	<=>	12.86 lb/ft	<=>	0.841 lb/ft²
Stirrups	0.0 lb	<=>	0.00 lb/ft	<=>	0.000 lb/ft²
Total Steel	2800.2 lb	<=>	28.28 lb/ft	<=>	1.849 lb/ft²
Concrete	1199.2 ft³	<=>	12.11 ft³/ft	<=>	0.792 ft³/ft²

5. Verify the output of the software and the method of solution

<u>Joint support 2 (Col. G/3):</u>

Envelope at the joint:



$$From\ the\ left = @10.5 = -128.74 - 37.06 = -165.8\ k.ft\ M_{LEFT}$$

$$From\ the\ right = @0.0 = -204.69 - 51.17 = -255.86\ k.ft\ M_{RIGHT}$$

$$Unbalanced\ moment, M_{unb} = (M_{LEFT} - M_{RIGHT}) - V_U.C_g$$

$$-165.8 - -255.86 - V_U(0) = 90.06\ k.ft$$

Support 2:

$$b_1 = 31.59\ in, \quad b_2 = 19.59\ in, \quad b_o = 2(b_1 + b_2) = 102.34\ in$$

$$d_{avg} = 7.59\ in, \quad A_C = 776.25\ in^2, \quad J_C = 1.1632 * 10^{15}\ \ in^4$$

$$V_U = \frac{\boxed{104.56}}{776.25} * 1000 = \boxed{134.7}\,psi$$

$$c_{AB} = 15.79\ in$$

$$v_{AB} = \frac{\gamma_v * M_{unb} * (1000 * 12) * c_{AB}}{J_C}$$

$$v_{AB} = \frac{0.458 * \boxed{90.06} * (1000 * 12) * 15.79}{1.1632 * 10^{15}} = 67.2\ psi$$

$$v_u = 134.7 + 67.2 = 202\ psi$$