Two way slab

Analysis and Design

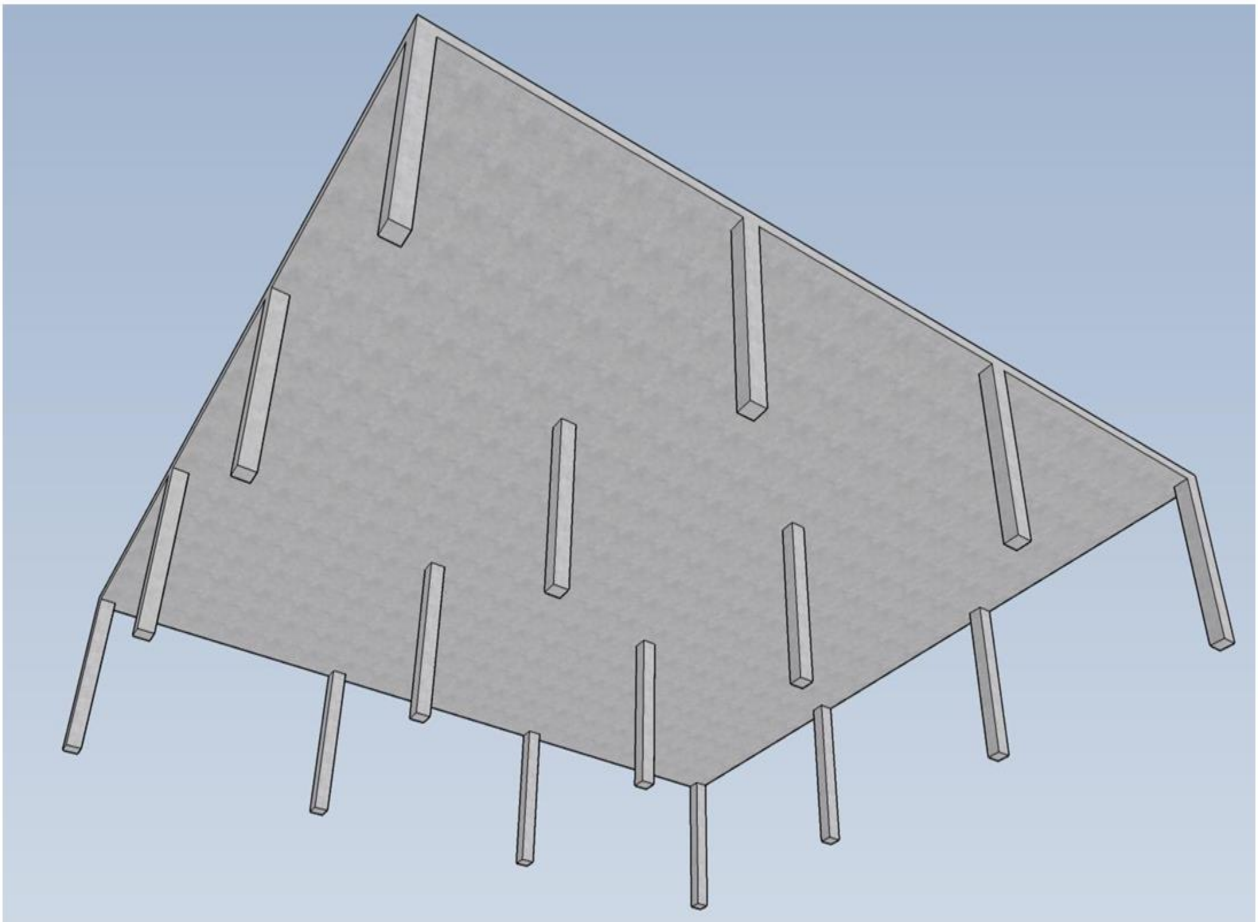
By

Equivalent Frame Method

Csi Safe Programe

Comparative the Results

Two-Way Flat Plate Concrete Floor System Analysis and Design



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ژمارەی پێناس : ٩٦٦٥

1- Scope of Work:

The project works is concerned with the analysis and design of different slabs. Analysis of slab using software program (SAFE). A hand calculation used (**Equivalent Frame Method** for analysis of slabs and compare it with computer program) to show that the safe program is faster and easier for solution than the others method. A computer program for the design of reinforced concrete two-way slabs made by excel worksheet used for design the slabs by **Equivalent Frame Method**.

1. To use Autocad to sketch the floor plan and the details.

2. To use Microsoft EXCEL to facilitate the computations.

3. To use Safe package for the analysis of Multi story building.

4. To familiarize with ACI Code and other codes.

5. To use Reinforced concrete design Suite for the design of slabs, beams, column.

2- Equivalent Frame Method (FEM)

FEM is the most comprehensive and detailed procedure provided by the ACI 318 for the analysis and design of two-way slab systems where the structure is modeled by a series of equivalent frames (interior and exterior) on column lines taken longitudinally and transversely through the building.

The equivalent frame method involves the representation of the three-dimensional slab system by a series of two-dimensional frames that are then analyzed for loads acting in the plane of the frames. This method of analysis of two way slabs based on the moment distribution method and it is more general with no limitations

The ACI Code presents two general methods for calculating the longitudinal distribution of moments in two-way slab systems. These are the direct-design method and equivalent-frame methods are intended for use in analyzing moments in any practical slab column frame. Their scope is thus wider than the direct-design method, which is subject to the limitations presented in Section 9.9.1 (ACI Code Section 13.6.1). In the direct-design method, the statical moment, is calculated for each slab span. This moment is then divided between positive- and negative-moment regions using arbitrary moment coefficients, which are adjusted to reflect pattern loadings. For equivalent-frame methods, a stiffness analyses of a slab–column frame is used to determine the longitudinal distribution of bending moments, including possible pattern loadings. The transverse distribution of moments to column and middle strips, as defined in the prior section, is the same for both methods

SAFE is the ultimate tool for designing concrete floor and foundation systems. From framing layout all the way through to detail drawing production, SAFE integrates every aspect of the engineering design process in one easy and intuitive environment. SAFE provides unmatched benefits to the engineer with its truly unique combination of power, comprehensive capabilities, and ease-of-use.

Laying out models is quick and efficient with the sophisticated drawing tools, or use one of the import options to bring in data from CAD, spreadsheet, or database programs. Slabs or foundations can be of any shape, and can include edges shaped with circular and spline curves.

Post-tensioning may be included in both slabs and beams to balance a percentage of the self-weight. Suspended slabs can include flat, two-way, waffle, and ribbed framing systems. Models can have columns, braces, walls, and ramps connected from the floors above and below. Walls can be modeled as either straight or curved.

Mats and foundations can include nonlinear uplift from the soil springs, and a nonlinear cracked analysis is available for slabs. Generating pattern surface loads is easily done by SAFE with an automated option. Design strips can be generated by SAFE or drawn in a completely arbitrary manner by the user, with complete control provided for locating and sizing the calculated reinforcement. Finite element design without strips is also available and useful for slabs with complex geometries.

Comprehensive and customizable reports are available for all analysis and design results. Detailed plans, sections, elevations, schedules, and tables may be generated, viewed, and printed from within SAFE or exported to CAD packages.

SAFE provides an immensely capable yet easy-to-use program for structural designers, provideing the only tool necessary for the modeling, analysis, design, and detailing of concrete slab systems and foundations.

The equivalent frame consists of three parts:

1-Horizontal slab-beam strip, including any beams spanning in the direction of the frame. Different values of moment of inertia along the axis of slab-beams should be taken into account where the gross moment of inertia at any cross section outside of joints or column capitals shall be taken, and the moment of inertia of the slab-beam at the face of the column, bracket or capital divide by the quantity (1-c2/l2)^2 shall be assumed for the calculation of the moment of inertia of slab-beams from the center of the column to the face of the column, bracket or capital. ACI 318-14 (8.11.3)

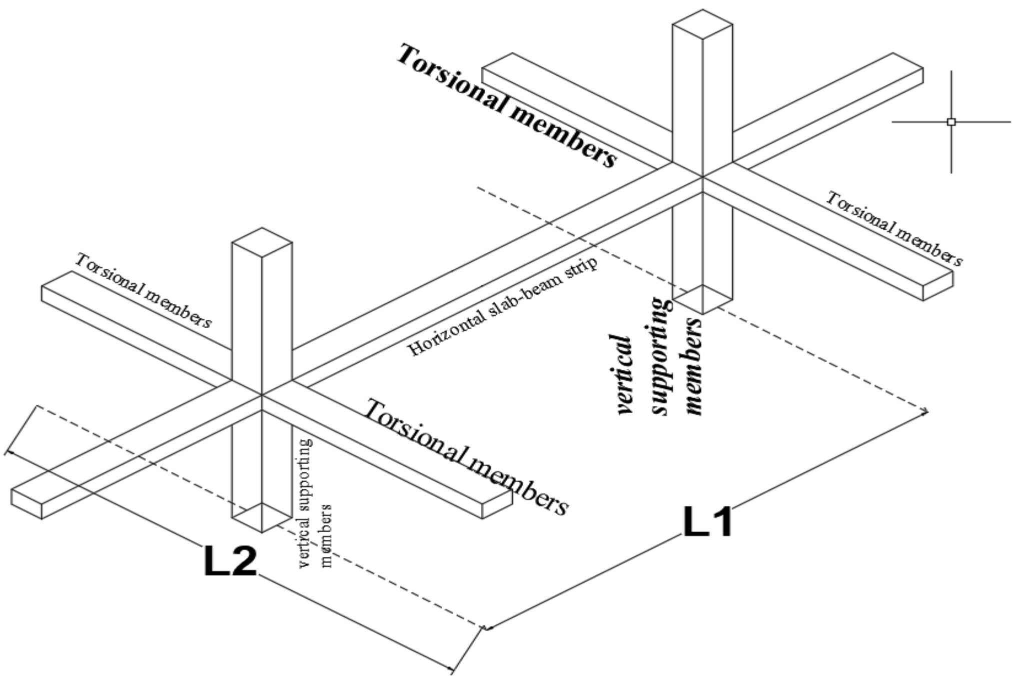
2- Columns or other vertical supporting members, extending above and below the slab. Different values of moment of inertia along the axis of columns should be taken into account where the moment of inertia of columns from top and bottom of the slab-beam at a joint shall be assumed to be infinite, and the gross cross section of the concrete is permitted to be used to determine the moment of inertia of columns at any cross section outside of joints or column capitals.
ACI 318-14 (8.11.4)

3- Elements of the structure (Torsional members) that provide moment transfer between the horizontal and vertical members. These elements shall be assumed to have a constant cross section throughout their length consisting of the greatest of the following:

(1) portion of slab having a width equal to that of the column, bracket, or capital in the direction of the span for which moments are being determined,

(2) portion of slab specified in (1) plus that part of the transverse beam above and below the slab for monolithic or fully composite construction,

(3) the transverse beam includes that portion of slab on each side of the beam extending a distance equal to the projection of the beam above or below the slab, whichever is greater, but not greater than four times the slab thickness. ACI 318-14 (8.11.5)



3- Assumptions ACI 13.7.2:

1-The structure shall be considered to be made up of equivalent frames on column lines taken longitudinally and transversely through the building:

2-Each frame shall consist of a row of columns or supports and slab-beam strips, bounded laterally by the centerline of panel on each side of the centerline of columns or supports.

3-Columns or supports shall be assumed to be attached to slab-beam strips by torsional members transverse to the direction of the span for which moments are being determined (L1).

4-Frames adjacent and parallel to an edge shall be bounded by that edge and the centerline of adjacent panel.

5-Analysis of each equivalent frame in its entirety shall be permitted. Alternatively, for gravity loading, a separate analysis of each floor or roof with far ends of columns considered fixed shall be permitted.

6-Where slab-beams are analyzed separately, determination of moment at a given support assuming that the slab-beam is fixed at any support two panels distant therefrom, shall be permitted, provided the slab continues beyond that point.

4- SLAB ANALYSIS BY THE EQUIVALENT FRAME METHOD (EFM).

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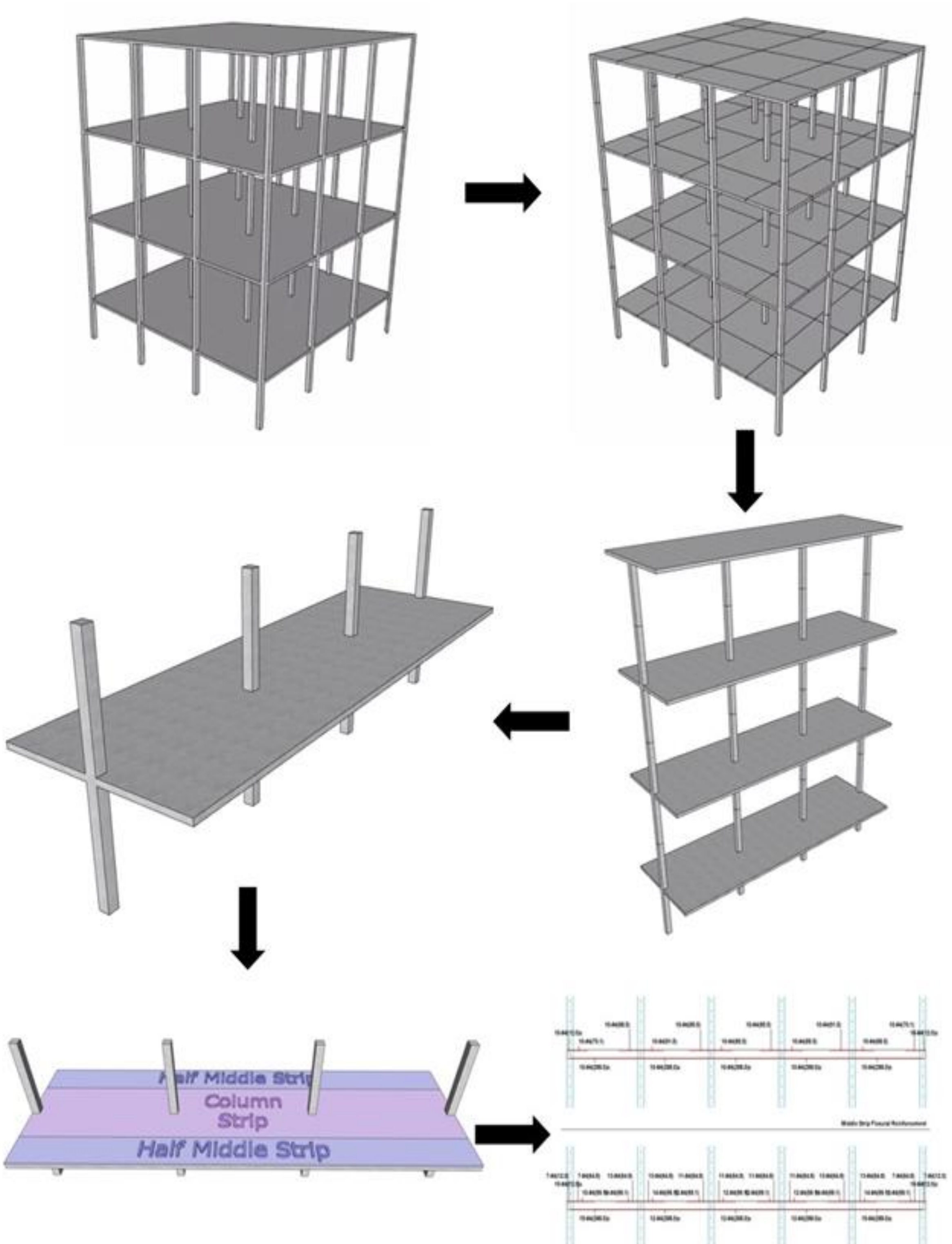
The design requirements can be explained as follows.

1. Description of the equivalent frame: An equivalent frame is a two-dimensional building frame obtained by cutting the three-dimensional building along lines midway between columns . The resulting equivalent frames are considered separately in the longitudinal and transverse directions of the building. For vertical loads, each floor is analyzed separately, with the far ends of the upper and lower columns assumed to be fixed. The slab-beam may be assumed to be fixed at any support two panels away from the support considered, because the vertical loads contribute very little to the moment at that support.

2. Load assumptions: When the ratio of the service live load to the service dead load is less than or equal to 0.75 , the structural analysis of the frame can be made with the factored dead and live loads acting on all spans instead of a pattern loading. When the ratio of the service live load to the service dead load is greater than 0.75 , pattern loading must be used, considering the following conditions:


Column
Strip
Half Middle Strip

a. Only of the full-factored live load may be used for the pattern loading analysis.

b. The maximum negative bending moment in the slab at the support is obtained by loading only the two adjacent spans.

c. The maximum positive moment near a midspan is obtained by loading only alternate spans.

d. The design moments must not be less than those occurring with a full factored live load on all panels (ACI Code, Section 13.7.6).

e. The critical negative moments are considered to be acting at the face of a rectangular column or at the face of the equivalent square column having the same area for nonrectangular sections.

3. Slab-beam moment of inertia: The ACI Code specifies that the variation in moment of inertia along the longitudinal axes of the columns and slab beams must be taken into account in the analysis of frames. The critical region is located between the centerline of the column and the face of the column, bracket, or capital. This region may be considered as a thickened section of the floor slab. To account for the large depth of the column and its reduced effective width in contact with the slab beam, the ACI Code, Section 13.7.3.3, specifies that the moment of inertia of the slab beam between the center of the column and the face of the support is to be assumed equal to that of the slab beam at the face of the column divided by the quantity — , , where is the column width in the transverse direction and is the width of the slab beam. The area of the gross section can be used to calculate the moment of inertia of the slab beam.

4. Column moment of inertia: The ACI Code, Section 13.7.4, states that the moment of inertia of the column is to be assumed infinite from the top of the slab to the bottom of the column capital or slab beams.

5. Column stiffness, is the sum of the stiffness of the upper and lower columns at their ends,

6. Column moments: In frame analysis, moments determined for the equivalent columns at the upper end of the column below the slab and at the lower end of the column above the slab must be used in the design of a column.

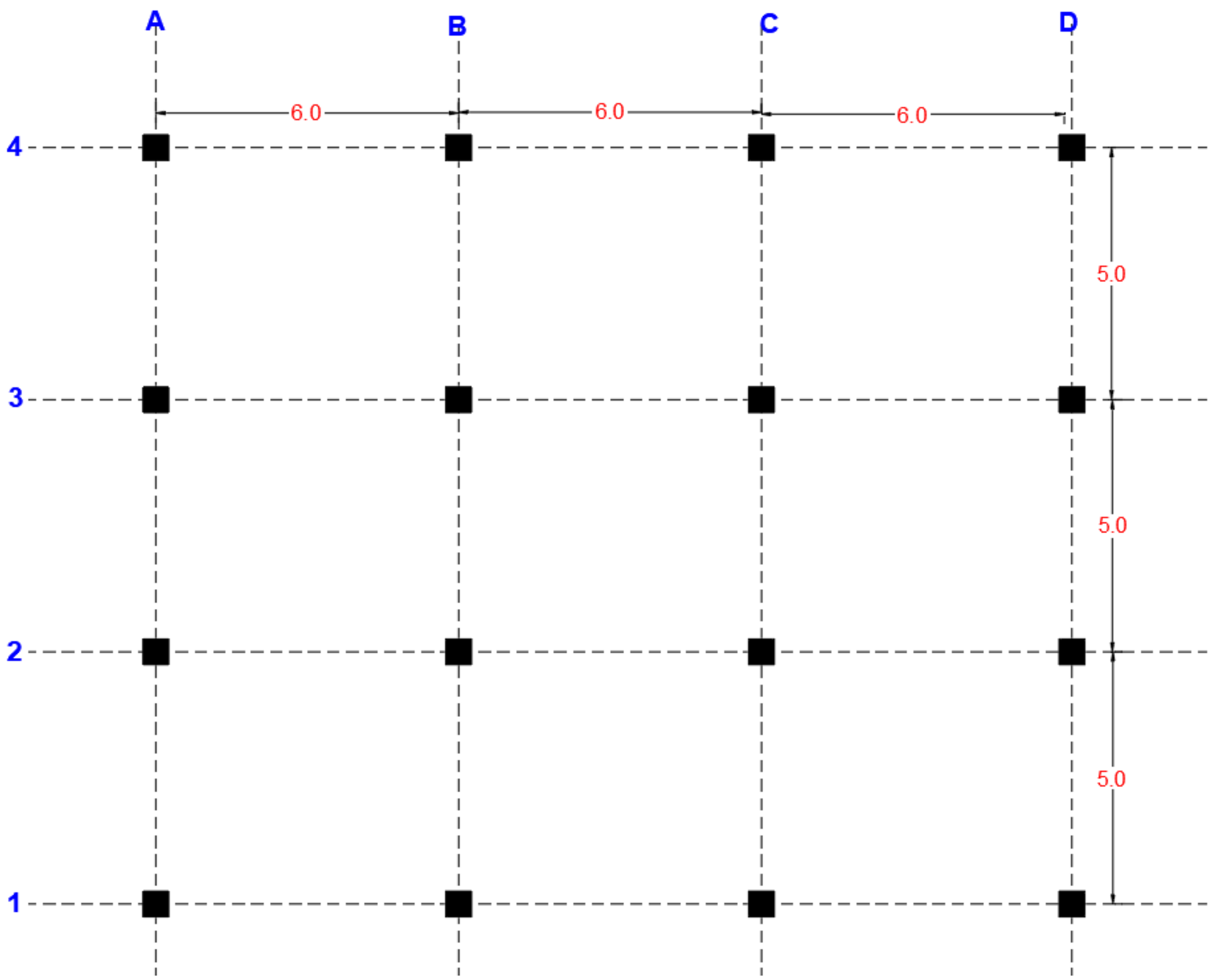
7. Negative moments at the supports: The ACI Code, Section 13.7.7, states that for an interior column, the factored negative moment is to be taken at the face of the column or capital but at a distance not greater than from the center of the column. For an exterior column, the factored negative moment is to be taken at a section located at half the distance between the face of the column and the edge of the support. Circular section columns must be treated as square columns with the same area.

8. Sum of moments: A two-way slab floor system that satisfied the limitations of the direct design method can also be analyzed by the equivalent frame method. To ensure that both methods will produce similar results, the ACI Code, Section 13.7.7, states that the computed moments determined by the equivalent frame method may be reduced in such proportion that the numerical sum of the positive and average negative moments used in the design must not exceed the total statical moment, .

5- Example : Two-Way Flat Plate Concrete Floor System Analysis and Design

The concrete floor slab system shown below is for an intermediate floor to be designed considering partition weight = 2 Kn/m^2, and unfactored live load = 3 Kn/m^2. Flat plate concrete floor system does not use beams between columns or drop panels and it is usually suited for lightly loaded floors with short spans typically for residential and hotel buildings. The lateral loads are independently resisted by shear walls. The hand solution from EFM is also used for a detailed comparison with the analysis and design results of the engineering software program Csi Safe Program. fc' = 28 Mpa (for slabs) fc' = 30 Mpa (for columns) fy = 420 Mpa

All Column Dimension (50 cm * 50 cm)



Two-Way Flat Concrete Floor System

5-1 Solution :

1. Preliminary Member Sizing

a. Slab minimum thickness – Deflection ACI 318-14 (8.3.1.1)

In this example deflection will be calculated and checked to satisfy project deflection limits. Minimum member thickness and depths from ACI 318-14 will be used for preliminary sizing.

Using ACI 318-14 minimum slab thickness for two-way construction without interior beams in Table 8.3.1.1

Exterior Panels: $h = \frac{Ln}{30} = \frac{670}{30} \cong 23\ cm$

But not less than 125 mm

Interior Panels: $h = \frac{Ln}{33} = \frac{670}{33} \cong 21\ cm$

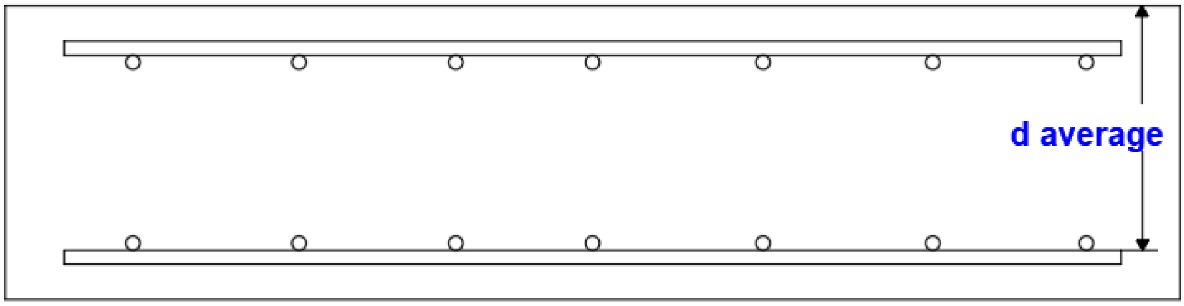
But not less than 125 mm.

Where ln = length of clear span in the long direction = 700 – 30 = 670 cm .

Try 25 cm. slab for all panels (self-weight = 6.25 Kn/m^2)

b. Slab shear strength – one way shear

Evaluate the average effective depth = 25 – 3 cover -1.2 cm (bar) = 20.8 cm



F.L = 1.4 D.L + 1.6 L.L

= 1.4 *(6.25+2) + 1.6*3 = 16.35 Kn/m^2

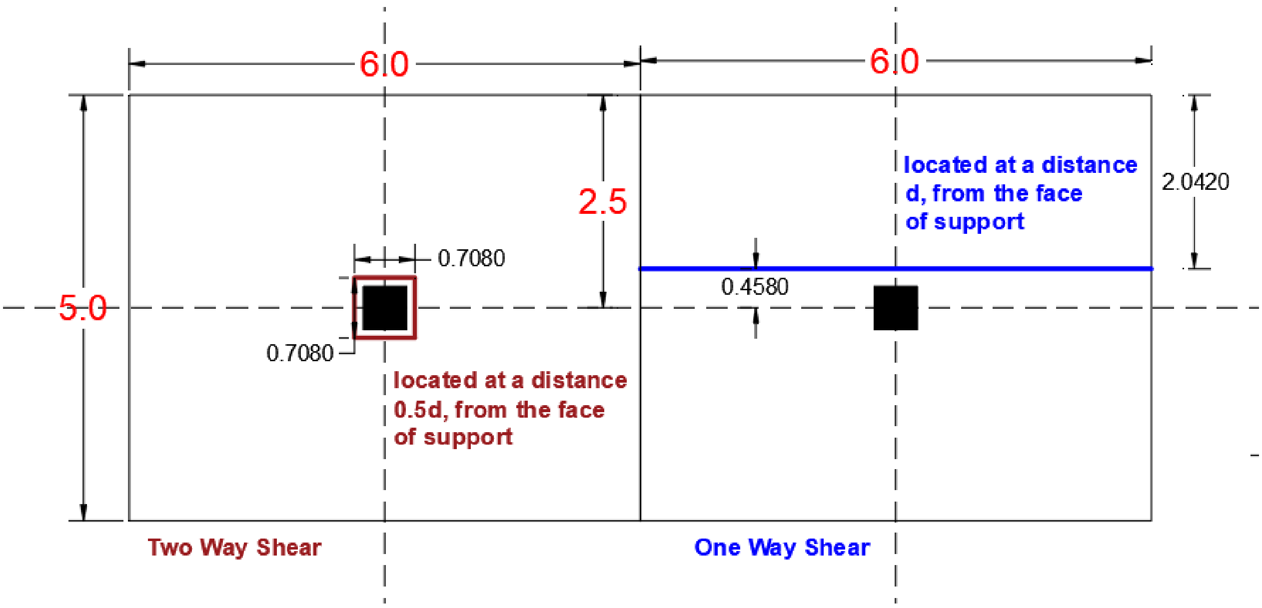
Area One way shear = 6 * 2.042 = 12.252 m^2

Vu = F.L * Area =16.35*12.252 = 200 Kn

Vc = ϕ *0.17 *FC ^0.5 * b * d

=0.65 * 0.17 * 28^0.5 * 6 * 0.208*1000

= 730 Kn > 200 Kn O.K Slab thickness of 250 mm is adequate for one-way shear



c. Slab shear strength – two-way shear

Check the adequacy of slab thickness for punching shear (two-way shear) at an interior column

Shear prerimeter b o = 4*0.708 = 2.832 m

αs =4 interior Column

βc = 1 (ratio of long side to short side of the column)

Area Two way shear = 6 * 5 – 0.708 * 0.708 = 29.50 m^2

Vu = F.L * Area =16.35* 29.5 = 482 Kn

The factored resisiting shear stress, Vr shall be the smallest of :

1- Vc $=\left(1+\frac{2}{\beta}\right) * 0.19 * \lambda * \phi * \sqrt{Fc}$

=(1+2)*0.19*1*0.65*28^0.5

=1960 Kn

2- Vc $=(\frac{\alpha s * d}{b\ o} + 0.19) * \lambda * \phi * \sqrt{Fc}$

$=(\frac{4 * 0.208}{2.832} + 0.19) * 1 * 0.65 * \sqrt{28}$

=1664 Kn

3- Vc $= 0.38 * \lambda * \phi * \sqrt{Fc}$

$= 0.38 * 1 * 0.65 * \sqrt{28}$

=1307 Kn (control) > 482 Kn O.K

Slab thickness of 250 mm is adequate for two-way shear.

5-2 - Equivalent frame method limitations

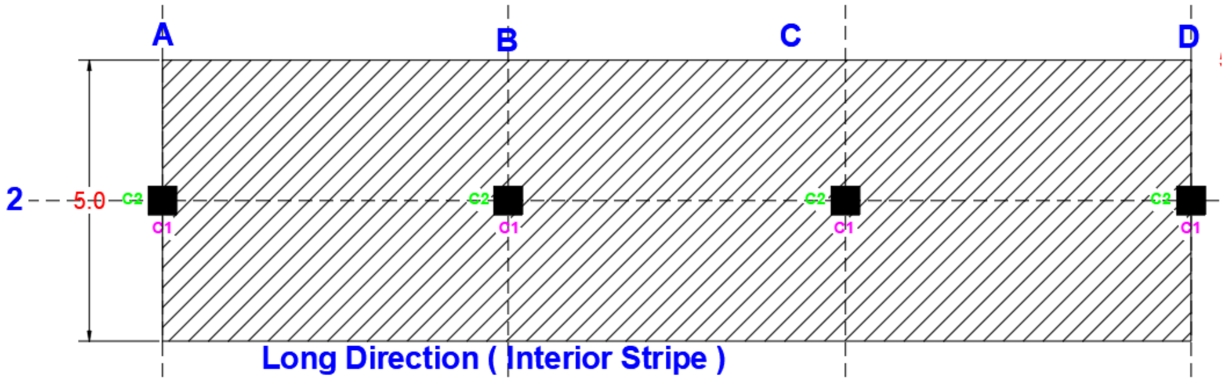
5-2-1 In EFM, live load shall be arranged in accordance with 6.4.3 which requires slab systems to be analyzed and designed for the most demanding set of forces established by investigating the effects of live load placed in various critical patterns. ACI 318-14 (8.11.1.2 & 6.4.3) Complete analysis must include representative interior and exterior equivalent frames in both the longitudinal and transverse directions of the floor ACI 318-14 (8.11.2.1) Panels shall be rectangular, with a ratio of longer to shorter panel dimensions, measured center-to-center of supports, not to exceed 2. ACI 318-14 (8.10.2.3)

5.2.2. Frame members of equivalent frame Determine moment distribution factors and fixed-end moments for the equivalent frame members. The moment distribution procedure will be used to analyze the equivalent frame. Stiffness factors k, carry over factors COF, and fixed-end moment factors FEM for the slab-beams and column members are determined using the design aids tables at Appendix 20A of PCA Notes on ACI 318-11. These calculations are shown below.

a. Flexural stiffness of slab-beams at both ends, K_{sb}.

$\frac{C1A}{l1} = \frac{0.5}{6} = 0.083$ For Column A-2

$\frac{C1B}{l1} = \frac{0.5}{6} = 0.083$ For Column B-2

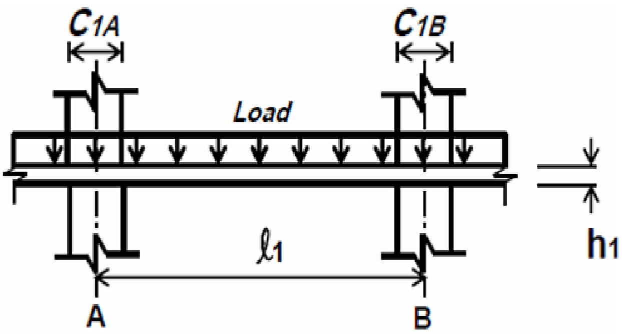


From Table A

C1 A/L1	C1 B/L1	M AB	M BA	K AB	K BA	COF AB	COF BA
0.05	0.05	0.084	0.084	4.05	4.05	0.503	0.503
0.0833	**0.0833**	**0.0847**	**0.0847**	**4.1366**	**4.1366**	**0.5097**	**0.5097**
0.1	0.1	0.085	0.085	4.18	4.18	0.513	0.513

Table (A)

Coefficients for slabs (without drop panel) or with column capital and slab with beams. Ref.[1]



Column Dimension		Uniform Load FEM=Coeff.($wl_2l_1^2$)		Stiffness Factor		Carry Over Factor	
C_{1A}/l_1	C_{1B}/l_1	M_{AB}	M_{BA}	K_{AB}	K_{BA}	COF_{AB}	COF_{BA}
0.00	0.00	0.083	0.083	4.00	4.00	0.500	0.500
	0.05	0.083	0.084	4.01	4.04	0.504	0.500
	0.10	0.082	0.086	4.03	4.15	0.513	0.499
	0.15	0.081	0.089	4.07	4.32	0.528	0.498
	0.20	0.079	0.093	4.12	4.56	0.548	0.495
	0.25	0.077	0.097	4.18	4.88	0.573	0.491
0.05	0.05	0.084	0.084	4.05	4.05	0.503	0.503
	0.10	0.083	0.086	4.07	4.15	0.513	0.503
	0.15	0.081	0.089	4.11	4.33	0.528	0.501
	0.20	0.080	0.092	4.16	4.58	0.548	0.499
	0.25	0.078	0.096	4.22	4.89	0.573	0.494
0.10	0.10	0.085	0.085	4.18	4.18	0.513	0.513
	0.15	0.083	0.088	4.22	4.36	0.528	0.511
	0.20	0.082	0.091	4.27	4.61	0.548	0.508
	0.25	0.080	0.095	4.34	4.93	0.573	0.504
0.15	0.15	0.086	0.086	4.40	4.40	0.526	0.526
	0.20	0.084	0.090	4.46	4.65	0.546	0.523
	0.25	0.083	0.094	4.53	4.98	0.571	0.519
0.20	0.20	0.088	0.088	4.72	4.72	0.543	0.543
	0.25	0.086	0.092	4.79	5.05	0.568	0.539
0.25	0.25	0.090	0.090	5.14	5.14	0.563	0.563

$Ksb\ for\ all\ span = k * \frac{E*Is}{l1} = 4.1366 * \frac{24870*6510416666}{6000} = 111{,}379{,}163{,}663$ n.mm

E= 4700*Fc^0.5 =4700 * 28^0.5 = 24870 N.mm^2

Is = bh^3/12 =5000*250^3/12 =6,510,416,666 mm^4

Carry-over factor COF = 0.5097

Fixed-end moment FEM =0.0847

b. Flexural stiffness of column members at both ends, Kc .

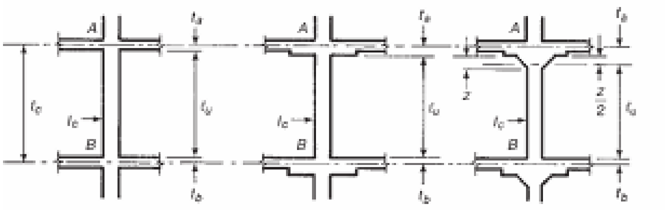
ta = 0.5 * 250 = 125 mm , tb =0.5 * 250 = 125 mm

$\frac{ta}{tb} = \frac{125}{125} = 1$, L c =4000 mm , lu =3750 mm , Lc/Lu =1.07

	Lc / Lu		
	1.05	1.07	1.1
KAB	4.52	4.71	5.09
CAB	0.54	0.55	0.57

TABLE A-17 Stiffness and Carryover Factors for Columns

$K_c = k\frac{EL_c}{\ell_c}$



		ℓ_c/ℓ_u								
t_a/t_b		1.05	1.10	1.15	1.20	1.25	1.30	1.35	1.40	1.45
0.00	k_{AB}	4.20	4.40	4.60	4.80	5.00	5.20	5.40	5.60	5.80
	C_{AB}	0.57	0.65	0.73	0.80	0.87	0.95	1.03	1.10	1.17
0.2	k_{AB}	4.31	4.62	4.95	5.30	5.65	6.02	6.40	6.79	7.20
	C_{AB}	0.56	0.62	0.68	0.74	0.80	0.85	0.91	0.96	1.01
0.4	k_{AB}	4.38	4.79	5.22	5.67	6.15	6.65	7.18	7.74	8.32
	C_{AB}	0.55	0.60	0.65	0.70	0.74	0.79	0.83	0.87	0.91
0.6	k_{AB}	4.44	4.91	5.42	5.96	6.54	7.15	7.81	8.50	9.23
	C_{AB}	0.55	0.59	0.63	0.67	0.70	0.74	0.77	0.80	0.83
0.8	k_{AB}	4.49	5.01	5.58	6.19	6.85	7.56	8.31	9.12	9.98
	C_{AB}	0.54	0.58	0.61	0.64	0.67	0.70	0.72	0.75	0.77
1.0	k_{AB}	4.52	5.09	5.71	6.38	7.11	7.89	8.73	9.63	10.60
	C_{AB}	0.54	0.57	0.60	0.62	0.65	0.67	0.69	0.71	0.73
1.2	k_{AB}	4.55	5.16	5.82	6.54	7.32	8.17	9.08	10.07	11.12
	C_{AB}	0.53	0.56	0.59	0.61	0.63	0.65	0.66	0.68	0.69
1.4	k_{AB}	4.58	5.21	5.91	6.68	7.51	8.41	9.38	10.43	11.57
	C_{AB}	0.53	0.55	0.58	0.60	0.61	0.63	0.64	0.65	0.66
1.6	k_{AB}	4.60	5.26	5.99	6.79	7.66	8.61	9.64	10.75	11.95
	C_{AB}	0.53	0.55	0.57	0.59	0.60	0.61	0.62	0.63	0.64
1.8	k_{AB}	4.62	5.30	6.06	6.89	7.80	8.79	9.87	11.03	12.29
	C_{AB}	0.52	0.55	0.56	0.58	0.59	0.60	0.61	0.61	0.62
2.0	k_{AB}	4.63	5.34	6.12	6.98	7.92	8.94	10.06	11.27	12.59
	C_{AB}	0.52	0.54	0.56	0.57	0.58	0.59	0.59	0.60	0.60
2.2	k_{AB}	4.65	5.37	6.17	7.05	8.02	9.08	10.24	11.49	12.85
	C_{AB}	0.52	0.54	0.55	0.56	0.57	0.58	0.58	0.59	0.59
2.4	k_{AB}	4.66	5.40	6.22	7.12	8.11	9.20	10.39	11.68	13.08
	C_{AB}	0.52	0.53	0.55	0.56	0.56	0.57	0.57	0.58	0.58
2.6	k_{AB}	4.67	5.42	6.26	7.18	8.20	9.31	10.53	11.86	13.29
	C_{AB}	0.52	0.53	0.54	0.55	0.56	0.56	0.56	0.57	0.57
2.8	k_{AB}	4.68	5.44	6.29	7.23	8.27	9.41	10.66	12.01	13.48
	C_{AB}	0.52	0.53	0.54	0.55	0.55	0.55	0.56	0.56	0.56
3.0	k_{AB}	4.69	5.46	6.33	7.28	8.34	9.50	10.77	12.15	13.65
	C_{AB}	0.52	0.53	0.54	0.54	0.55	0.55	0.55	0.55	0.55
3.5	k_{AB}	4.71	5.50	6.40	7.39	8.48	9.69	11.01	12.46	14.02
	C_{AB}	0.51	0.52	0.53	0.53	0.54	0.54	0.54	0.53	0.53
4.0	k_{AB}	4.72	5.54	6.45	7.47	8.60	9.84	11.21	12.70	14.32
	C_{AB}	0.51	0.52	0.52	0.53	0.53	0.52	0.52	0.52	0.52
4.5	k_{AB}	4.73	5.56	6.50	7.54	8.69	9.97	11.37	12.89	14.57
	C_{AB}	0.51	0.52	0.52	0.52	0.52	0.52	0.51	0.51	0.51
5.0	k_{AB}	4.75	5.59	6.54	7.60	8.78	10.07	11.50	13.07	14.77
	C_{AB}	0.51	0.51	0.52	0.52	0.51	0.51	0.51	0.50	0.49
6.0	k_{AB}	4.76	5.63	6.60	7.69	8.90	10.24	11.72	13.33	15.10
	C_{AB}	0.51	0.51	0.51	0.51	0.50	0.50	0.49	0.49	0.48
7.0	k_{AB}	4.78	5.66	6.65	7.76	9.00	10.37	11.88	13.54	15.34
	C_{AB}	0.51	0.51	0.51	0.50	0.50	0.49	0.48	0.48	0.47
8.0	k_{AB}	4.78	5.68	6.69	7.82	9.07	10.47	12.01	13.70	15.54
	C_{AB}	0.51	0.51	0.50	0.50	0.49	0.49	0.48	0.47	0.46
9.0	k_{AB}	4.80	5.71	6.74	7.89	9.18	10.61	12.19	13.93	15.83
	C_{AB}	0.50	0.50	0.50	0.49	0.48	0.48	0.47	0.46	0.45

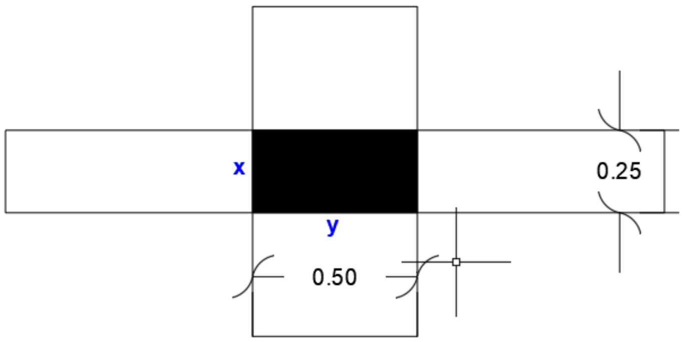
$$Kc = K * \frac{Ec * Ic}{Lc} = 4.71 * \frac{25743 * 5208333333}{4}$$

= 157,876,748,118 n.mm

Ic =bh^3/12 =500*500^3/12 =5208333333 mm^4

Ec =4700*30^0.5 =25743 n.mm^2

c. Torsional stiffness of torsional members, Kt .



Torsional Stiffness

$$Kt = \frac{9*Es*C}{(l2*\left(1-\frac{c2}{l2}\right)^3)}$$

$$Kt = \frac{9 * 24870 * 1783854167}{(5000 * \left(1 - \frac{500}{5000}\right)^3)}$$

Kt =**103675087005 n.mm**

$$C = (1 - 0.63\frac{x}{y})(\frac{x^3 * y}{3})$$

$$C = (1 - 0.63\frac{250}{500})(\frac{250^3 * 500}{3})$$

C =1783854167

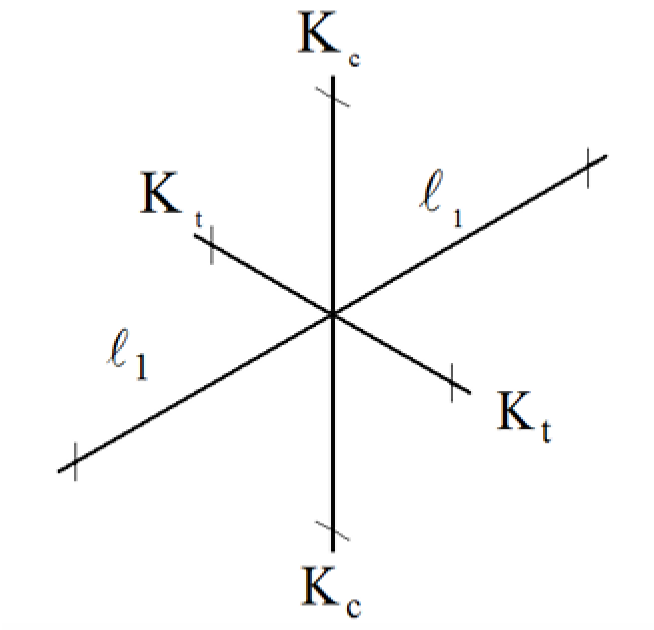
d. Equivalent column stiffness k ec

$$Kec = \frac{\sum kc * \sum kt}{\sum kc + \sum kt}$$

$$Kec = \frac{2 * 157,876,748,118 * 2 * \mathbf{103675087005}}{2 * 157,876,748,118 + 2 * \mathbf{103675087005}}$$

Kec =**125159784022**

Where ∑kt is for two torsional members one on each side of the column, and ∑kc is for the upper and lower columns at the slab beam joint of an intermediate floor.



e. Slab-beam joint distribution factors, DF.

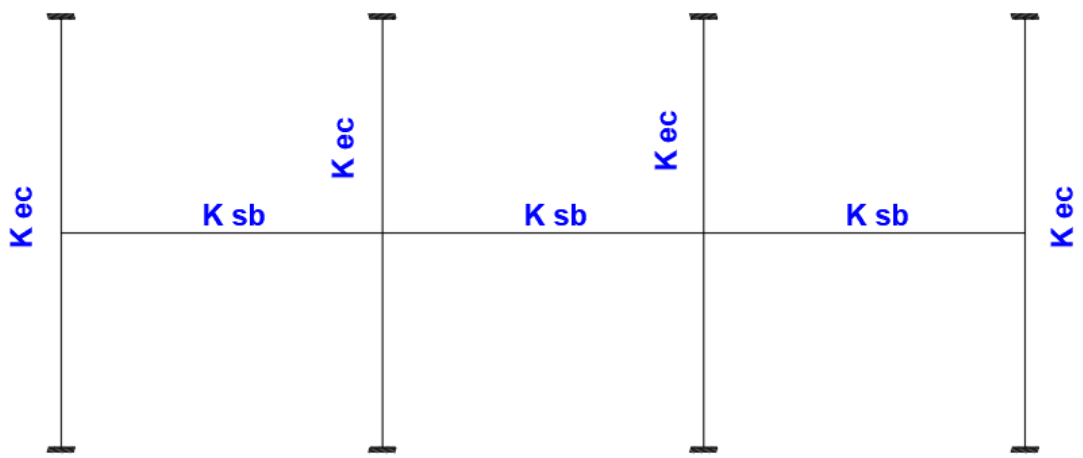
At exterior joint,

$$D.F = \frac{Ksb}{Ksb + Kec} = \frac{111{,}379{,}163{,}663}{111{,}379{,}163{,}663 + \mathbf{125159784022}} = 0.471$$

At interior joint,

$$D.F = \frac{Ksb}{2 * Ksb + Kec} = \frac{111{,}379{,}163{,}663}{111{,}379{,}163{,}663 + 111{,}379{,}163{,}663 + \mathbf{125159784022}} = 0.32$$

COF for slab-beam =0.5097



Slab and Column Stiffness

5-3. Equivalent frame analysis

Determine negative and positive moments for the slab-beams using the moment distribution method. Since the unfactored live load does not exceed three-quarters of the unfactored dead load, design moments are assumed to occur at all critical sections with full factored live on all spans. ACI 318-14 (6.4.3.2)

$$\frac{L.L}{D.L} = \frac{3}{8.25} = 0.36 < 0.75$$

a. Factored load and Fixed-End Moments (FEM's)

$$FEM's\ for\ slab - beams = m * F.L * L1 * L2^2$$

$$FEM's\ for\ slab - beams = 0.0847 * 16.35 * 6 * 5^2$$

$$FEM's\ for\ slab - beams = 176\ Kn.m$$

b. Moment distribution Counterclockwise rotational moments acting on the member ends are taken as positive. Positive span moments are determined from the following equation:

$$Mu\ midspan = Mo - \frac{(Mu\ \ L + Mu\ R)}{2}$$

Where

Mo is the moment at the midspan for a simple beam.

When the end moments are not equal, the maximum moment in the span does not occur at the midspan, but its value is close to that midspan for this example.

Positive moment in span A-B:

$$Mu\ midspan = (F.L * L2 * L1^2/8) - \frac{(Mu\ \ L + Mu\ R)}{2}$$

$$Mu\ midspan = (16.35 * 5 * 36/8) - \frac{(137.716 + 287.812)}{2}$$

$$Mu\ midspan = 155.11$$

Positive moment in span B-C:

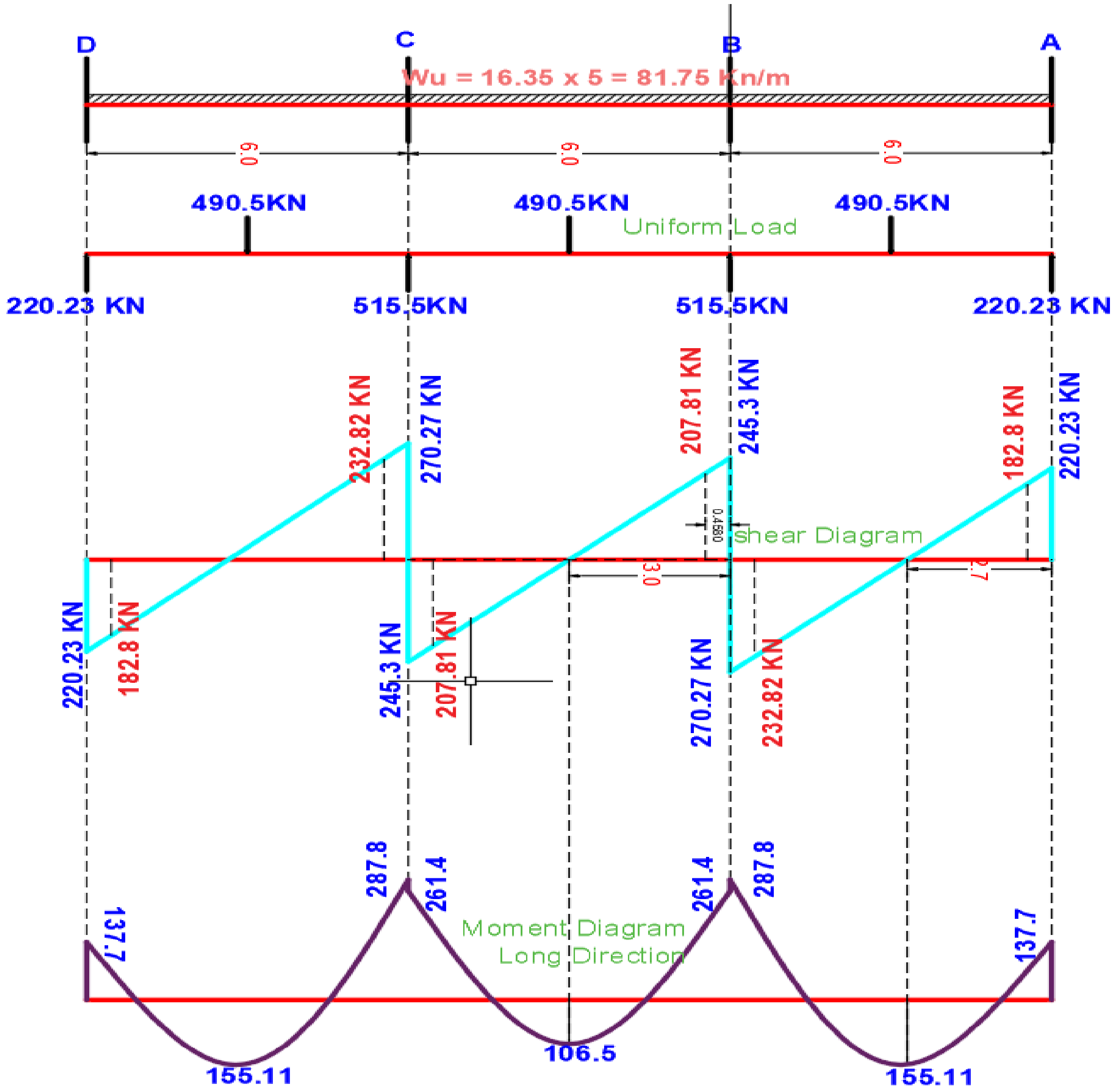
$$Mu\ midspan = (F.L * L2 * L1^2/8) - \frac{(Mu\ \ L + Mu\ R)}{2}$$

$$Mu\ midspan = (16.35 * 5 * 36/8) - \frac{(261.377 + 261.377)}{2}$$

$$Mu\ midspan = 106.498$$

Moment Distribution for Equivalent Frame

Interior Stripe						
Long Direction						
COF	0.5097	0.5097	0.5097	0.5097	0.5097	0.5097
Joint	1	2		3		4
Member	ab	ba	bc	cb	cd	dc
D.F	0.471	0.320	0.320	0.320	0.320	0.471
FEM	249.172	-249.172	249.172	-249.172	249.172	-249.172
Bal. M	-117.467	0.000	0.000	0.000	0.000	117.467
COF	0.000	-59.868	0.000	0.000	59.868	0.000
Bal. M	0.000	19.181	19.181	-19.181	-19.181	0.000
COF	9.776	0.000	-9.776	9.776	0.000	-9.776
Bal. M	-4.609	3.132	3.132	-3.132	-3.132	4.609
COF	1.596	-2.349	-1.596	1.596	2.349	-1.596
Bal. M	-0.753	1.264	1.264	-1.264	-1.264	0.753
_M k.ft	**137.716**	**-287.812**	**261.377**	**-261.377**	**287.812**	**-137.716**
.+M	**155.111**		**106.498**		**155.111**	
Exterior Stripe = 0.5 * Interior Stripe (symmetry Plan)						
_M k.ft	**68.858**	**-143.906**	**130.688**	**-130.688**	**143.906**	**-68.858**
.+M	**77.555**		**53.249**		**77.555**	



Strip Forces - Summary

File Format-Filter-Sort Select Options

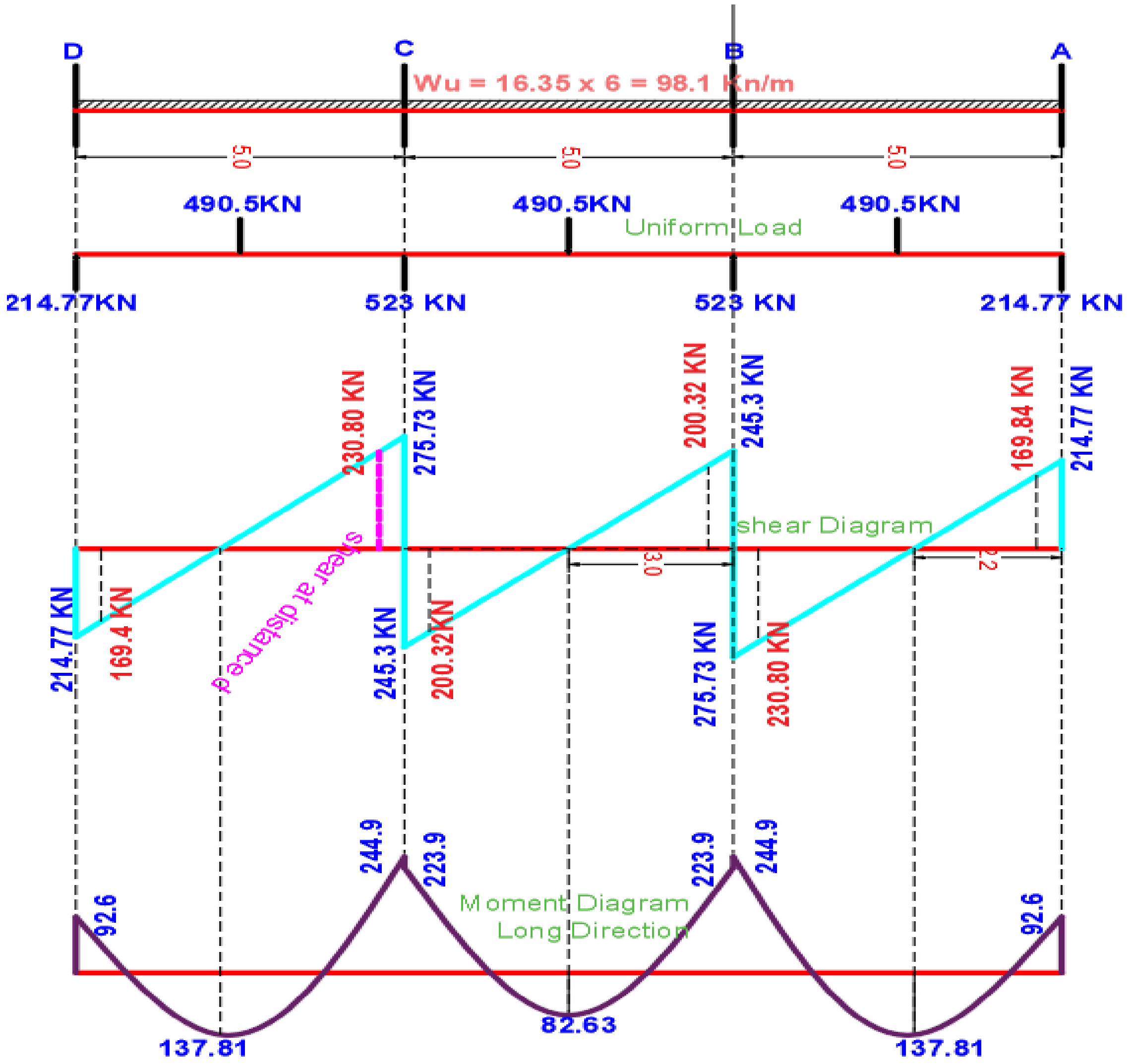
Units: As Noted — Strip Forces - Summary

Strip Text	SpanID Text	Location Text	OutputCase	CaseType Text	AbsMaxP kN	AbsMaxV2 kN	AbsMaxT kN-m	MaxM3 kN-m	MinM3 kN-m
CSA2	Span 1	Start	COMB2	Combination	-38.64	-207.522	-2.4599	111.7423	-131.5793
CSA2	Span 1	Middle	COMB2	Combination	-39.144	130.382	2.5848	170.0581	38.2172
CSA2	Span 1	End	COMB2	Combination	-37.258	260.068	2.5126	37.4479	-284.274
CSA2	Span 2	Start	COMB2	Combination	-31.817	-236.237	1.0783	21.8791	-264.8308
CSA2	Span 2	Middle	COMB2	Combination	-33.505	-106.229	-0.6394	117.0211	22.7571
CSA2	Span 2	End	COMB2	Combination	-31.817	236.237	-1.0783	21.8791	-264.8308
CSA2	Span 3	Start	COMB2	Combination	-37.258	-260.068	-2.5126	37.4479	-284.274
CSA2	Span 3	Middle	COMB2	Combination	-39.144	-130.382	-2.5848	170.0581	38.2172
CSA2	Span 3	End	COMB2	Combination	-38.64	207.522	2.4599	111.7423	-131.5793

Record: << < 9 > >> of 9 — Add Tables... — Done

Moment Distribution for Equivalent Frame

Interior Stripe						
Short Direction						
COF	0.5130	0.5130	0.5130	0.5130	0.5130	0.5130
Joint	1	2		3		4
Member	ab	ba	bc	cb	cd	dc
D.F	0.584	0.369	0.369	0.369	0.369	0.584
FEM	208.463	-208.463	208.463	-208.463	208.463	-208.463
Bal. M	-121.752	0.000	0.000	0.000	0.000	121.752
COF	0.000	-62.459	0.000	0.000	62.459	0.000
Bal. M	0.000	23.029	23.029	-23.029	-23.029	0.000
COF	11.814	0.000	-11.814	11.814	0.000	-11.814
Bal. M	-6.900	4.356	4.356	-4.356	-4.356	6.900
COF	2.235	-3.540	-2.235	2.235	3.540	-2.235
Bal. M	-1.305	2.129	2.129	-2.129	-2.129	1.305
_M k.ft	**92.554**	**-244.947**	**223.928**	**-223.928**	**244.947**	**-92.554**
.+M	**137.812**		**82.635**		**137.812**	
Exterior Stripe = 0.5 * Interior Stripe (symmetry Plan)						
_M k.ft	**46.277**	**-122.474**	**111.964**	**-111.964**	**122.474**	**-46.277**
.+M	**68.906**		**41.317**		**68.906**	



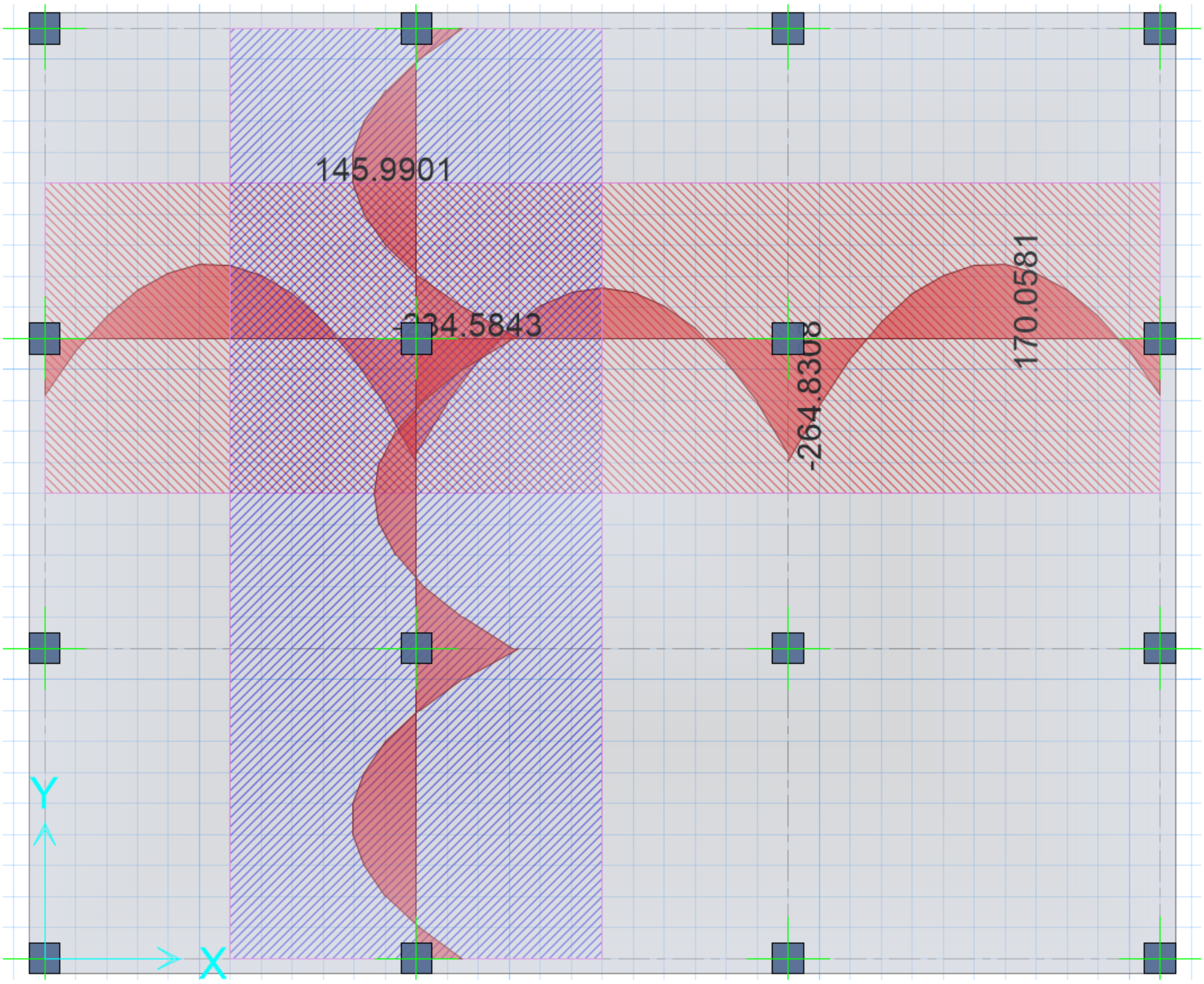
Strip Forces - Summary

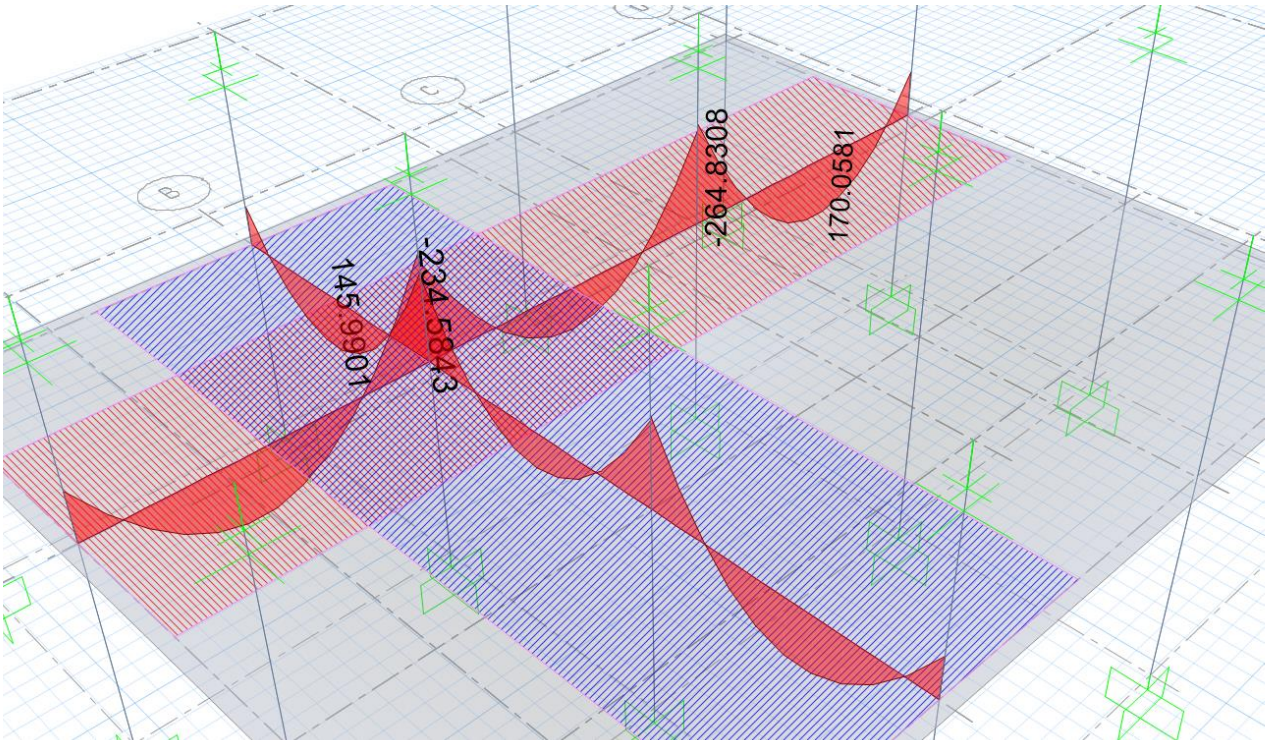
File Format-Filter-Sort Select Options

Units: As Noted

Strip Forces - Summary

Strip Text	SpanID Text	Location Text	OutputCase	CaseType Text	AbsMaxP kN	AbsMaxV2 kN	AbsMaxT kN-m	MaxM3 kN-m	MinM3 kN-m
CSB1	Span 1	Start	COMB2	Combination	-31.635	-204.089	-1.1083	70.1028	-106.6263
CSB1	Span 1	Middle	COMB2	Combination	-32.019	153.098	1.991	145.9901	69.9369
CSB1	Span 1	End	COMB2	Combination	-30.878	256.579	1.7487	-5.1434	-234.5843
CSB1	Span 2	Start	COMB2	Combination	-27.085	-232.199	1.3721	-16.5753	-222.3572
CSB1	Span 2	Middle	COMB2	Combination	-27.713	-128.506	0.4377	98.1873	46.445
CSB1	Span 2	End	COMB2	Combination	-27.085	232.199	-1.3721	-16.5753	-222.3572
CSB1	Span 3	Start	COMB2	Combination	-30.878	-256.579	-1.7487	-5.1434	-234.5843
CSB1	Span 3	Middle	COMB2	Combination	-32.019	-153.098	-1.991	145.9901	69.9369
CSB1	Span 3	End	COMB2	Combination	-31.635	204.089	1.1083	70.1028	-106.6263


145.9901
-234.5843
-264.8308
170.0581
Y
X


-264.8308
170.0581
145.9901
-234.5843

Long Direction

Span	Moment	Equivalent Frame Method	CSI Safe Program	Similarity
Exterior	_ M	137.7	131.6	95.57%
	M	155.11	170.05	91.21%
	_ M	287.8	284.27	98.77%
Interior	_ M	261.4	264.83	98.70%
	M	106.5	117	91.03%

Short Direction

Span	Moment	Equivalent Frame Method	CSI Safe Program	Similarity
Exterior	_ M	92.6	106.63	86.84%
	M	137.81	145.99	94.40%
	_ M	244.9	234.58	95.79%
Interior	_ M	223.9	222.36	99.31%
	M	82.63	98.19	84.15%

In all of the hand calculations illustrated above by Equivalent Frame Method that approved by ACI Code, the results are in close or exact agreement with the automated analysis and design results obtained from the Csi Safe model

5-4. Two-Way Slab Shear Strength

Shear strength of the slab in the vicinity of columns/supports includes an evaluation of one-way shear (beam action) and two-way shear (punching)

1. One-Way (Beam action) Shear Strength

One-way shear is critical at a distance d from the face of the column as shown in Figure 3. Figure 11 shows the factored shear forces (Vu) at the critical sections around each column. In members without shear reinforcement, the design shear capacity of the section equals to the design shear capacity of the concrete:

$$ØVc = Ø2\lambda\beta\sqrt{Fc} * bw * d$$

λ=1 for normal weight concrete

β= 0.21for slabs with overall thickness not greater than 350 mm

$$Vc = 0.75 * 2 * 1 * 0.21 * \sqrt{F28} * 6 * 0.208$$

$$Vc = 0.75 * 2 * 1 * 0.21 * \sqrt{F28} * 6 * 0.208$$

$$Vc = 554.72\ Kn\ > Max\ shear\ at\ distance\ d\ from\ face\ of\ column = 245\ Kn$$

2. Two-Way (Punching) Shear Strength ACI 318-14 (22.6)

Two-way shear is critical on a rectangular section located at d/2 away from the face of the column

a. Exterior column:

The factored shear force (Vu) in the critical section is computed as the reaction at the centroid of the critical section minus the self-weight and any superimposed surface dead and live load acting within the critical section (d/2 away from column face).

$$Vu = 220.23 - 16.35 * 0.604 * 0.708 = 213.242\ Kn$$

The factored unbalanced moment used for shear transfer, Munb, 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.

$$b1 = c1 + 0.5 * d = 0.5 + 0.5 * 208 = 0.604$$

$$b2 = c2 + d = 0.5 + 208 = 0.708$$

The length of the critical perimeter for the exterior column:

$$b\ o = b2 + 2 * b1 = 0.604 + 0.708 = 1.916$$

$$C\ AB = \frac{\text{moment of area of the sides about AB}}{area\ of\ sides}$$

$$C\ AB = \frac{2 * \mathrm{b1} * \mathrm{d} * 0.5 * \mathrm{b1}}{2 * b1 * d + b2 * d} = \frac{2 * 0.604 * 0.208 * 0.5 * 0.604}{2 * 0.604 * 0.208 + 0.708 * 0.208} = 0.19\ m$$

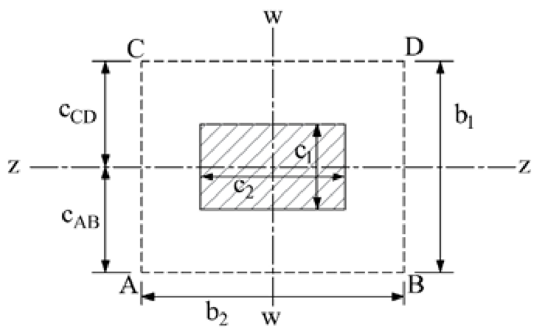
$M\ unb = 137.7 - 213.242 * (0.604 - 0.19 - 0.5 * 0.5) = 102.83$

The polar moment Jc of the shear perimeter is:

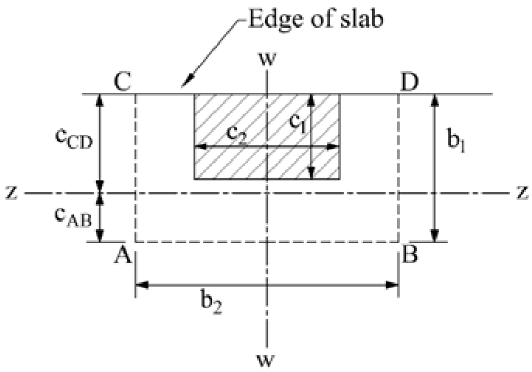
$$Jc = 2 * (\frac{b1 * d^3}{12} + \frac{d * b1^3}{12} + (b1 * d)\left(\frac{b1}{2} - C\ AB\ )^2\right) + b2 * d * \ C\ AB^2$$

$Jc = 0.017\ m^4$

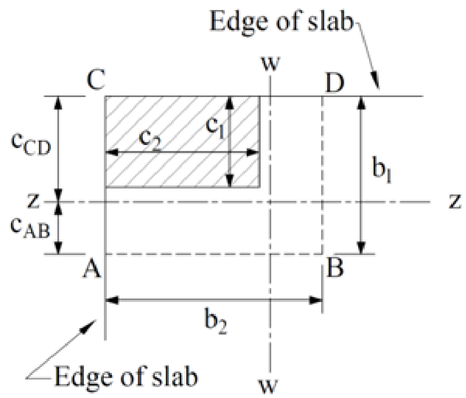
$$ɣ\ f = \frac{1}{1 + \frac{2}{3} * \sqrt{\frac{b1}{b2}}} = 0.619 \quad , \qquad ɣ\ v = 1 - 0.619 = 0.381$$



Critical shear perimeter for interior column



Critical shear perimeter for exterior column



Critical shear perimeter for corner column

$$v\ u = \frac{Vu}{b\ o * d} + \frac{ɣv * Munb * C\ AB}{Jc} = \frac{213.242}{1.916 * 0.208} + \frac{0.381 * 102.83 * 0.19}{0.017} = 974\ Kn$$

The factored resisiting shear stress, Vr shall be the smallest of :

1- Vc $= \left(1 + \frac{2}{\beta}\right) * 0.19 * \lambda * \phi * \sqrt{Fc}$

=(1+2)*0.19*1*0.65*28^0.5

=1960 Kn

2- $Vc = (\frac{\alpha s * d}{b\,o} + 0.19) * \lambda * \phi * \sqrt{Fc}$

$= (\frac{3 * 0.208}{1.916} + 0.19) * 1 * 0.65 * \sqrt{28}$

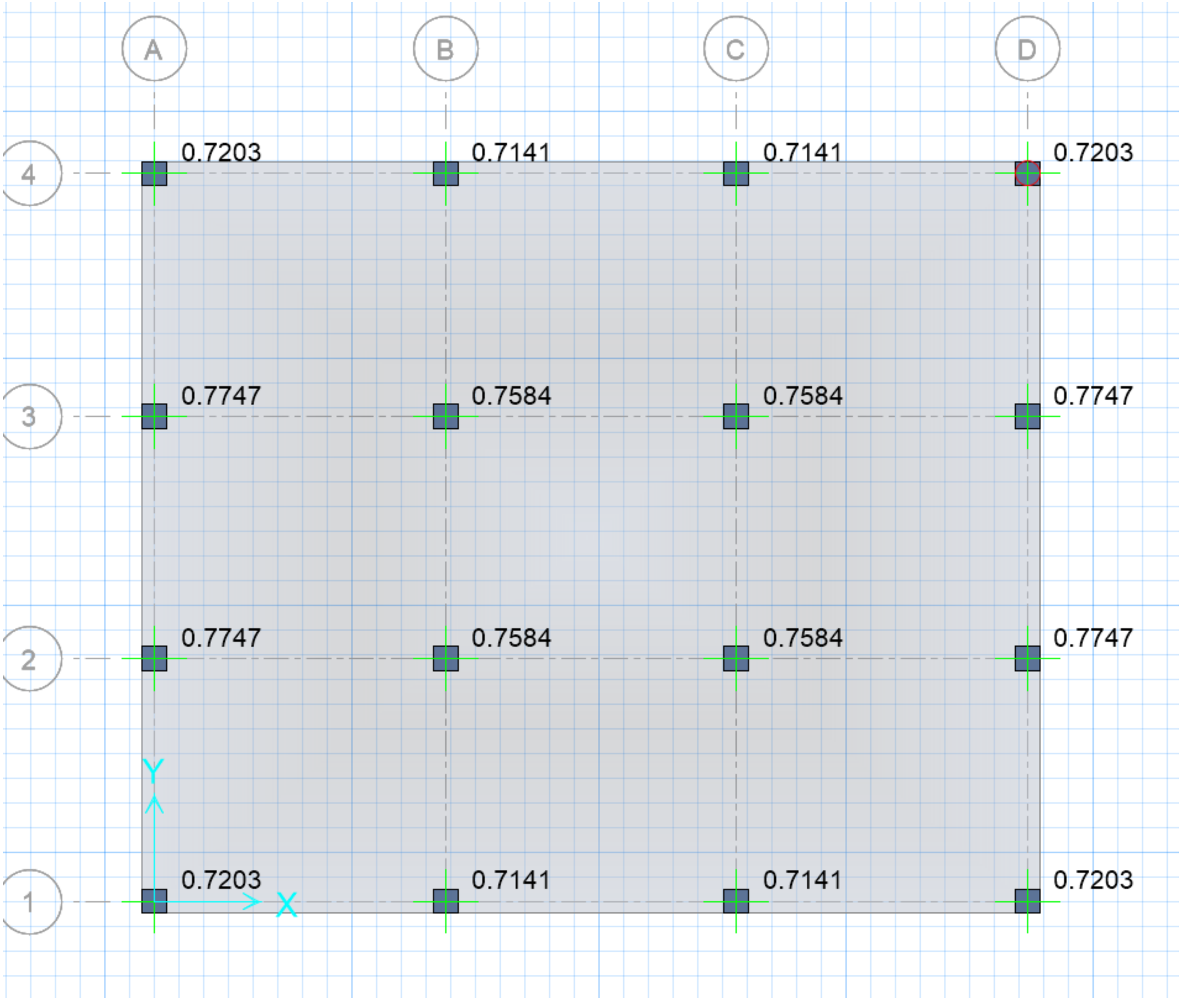
$= 1774$ Kn

3- $Vc = 0.38 * \lambda * \phi * \sqrt{Fc}$

$= 0.38 * 1 * 0.65 * \sqrt{28}$

=**1307** Kn (control) > 974 Kn O.K $\frac{974}{1307} = \mathbf{0.74}$

Interior Column			Corner Column	
Two way Shear Result				
b1=	708	mm	604	mm
b2=	708	mm	604	mm
b_o =	2832	mm	1208	mm
Vu =	507.320	Kn	104.152	Kn
C AB =	354	mm	151	mm
M unb =	26.435	KN.m	47.715	KN.m
Jc =	50273966080	mm^4	10001396011	mm^4
ɣ f=	0.6		0.6	
ɣ v=	0.4		0.4	
Vu =	0.936	Kn	0.703	Kn
Vc =	1.961	Kn	1.961	Kn
	1.664		1.838	
	1.307		1.307	
ϕ Vc =	1.307	Kn	0.980	Kn
	OK	0.72	OK	0.72


A
B
C
D
4
3
2
1
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0.7141
0.7141
0.7203
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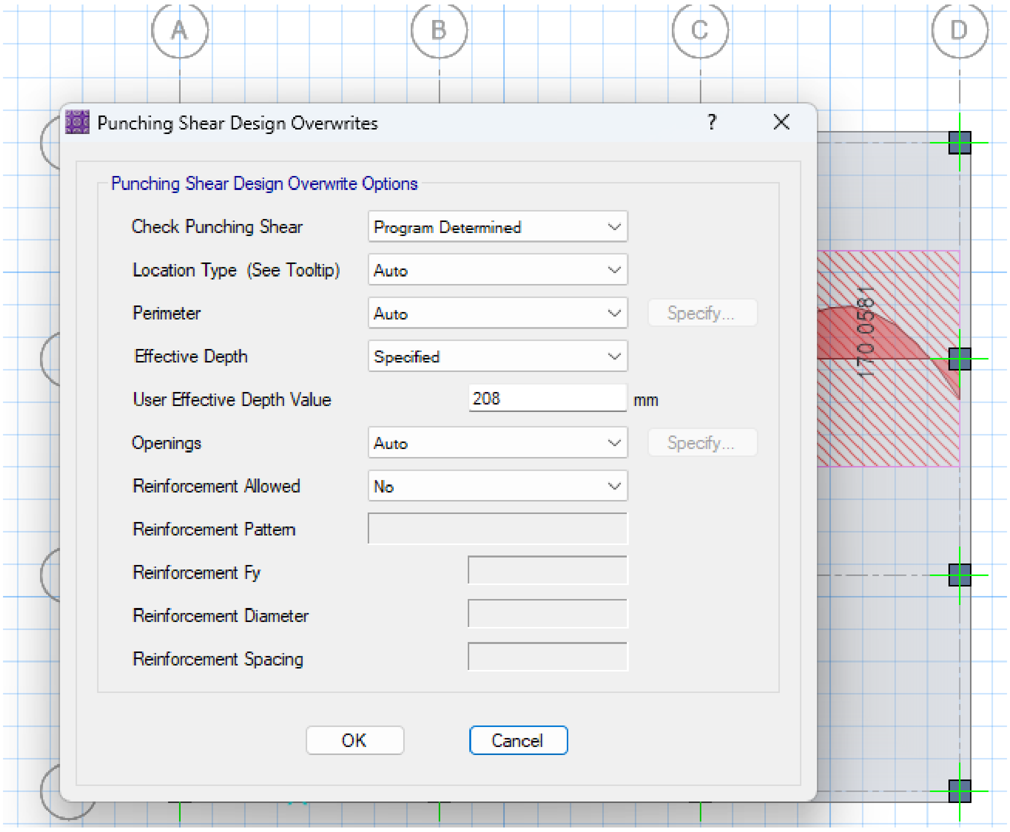
0.7203
Y
X


Punching Shear Design Overwrites
Punching Shear Design Overwrite Options
Check Punching Shear
Program Determined
Location Type (See Tooltip)
Auto
Perimeter
Auto
Specify...
Effective Depth
Specified
User Effective Depth Value
208
mm
Openings
Auto
Specify...
Reinforcement Allowed
No
Reinforcement Pattern
Reinforcement Fy
Reinforcement Diameter
Reinforcement Spacing
OK
Cancel

6-Conclusions & Recommendations

6-1 Conclusions: Slabs come in a wide amount of shapes, and have been adapted throughout history for a wide number of factors. RCC slab can be various types depending on various criteria. Such as ribbed slab, flat slab, solid slab, continuous slab, simply supported slab etc. There are many methods for design of two way slabs provided by ACI like (method II, The equivalent frame method, (EFM) and the direct design method (DDM). In this project we used Method I and the direct design method for calculation of Moment. the program gives the design of Chapter Fix Conclusions and Recommendation Design of Reinforced Concrete Slabs by Safe. We can choose ready shape slabs with different dimension or we can draw and entered our shape of building slabs. It gives complete shape in 2-D direction and 3 directions.

6-2 From compare the results between hands calculate and the program we find that:

1- The programs very fast and time consuming so that the results show according a minute while the hand calculating take a long time.
2- In this project we design and analysis of slabs depending on equations chart and tables to design and analysis and solving which take along time.
3- The degree of agreement of the results is good and accuracy of the results depends upon the inputs accuracy.
4- It's very easy for user while the hand calculate should be have more information for slab design and be more accrue in calculate.

6-3 Recommendations:

1- Design and analysis of different type of slabs (ribbed slab and waffle slabs…etc).
2- Design and analysis of slabs with other codes not just ACI codes and compare the results.
3- Design and analysis of footings (single footing, combined footing ..etc).

7-References

1. James G. MacGregor and James K. Wight, 2005, "Reinforced Concrete Mechanics and Design", prentice hall, Singapore.

2- design_of_reinforced_concrete_9th_edition_-_jack_c._mccormac

3-Reinforced Concrete Mechanics and Design 6th Edition by Wight MacGregor

4-Design of Concrete Structures Fourteenth Edition_ metric

5-Design of Reinforced Concrete Structures – ECP203-2017 Code Edition– Part 2.0