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THE EFFECT OF BEAMS STIFFNESSES ON THE LOAD DISTRIBUTION IN A SINGLE SIMPLY SUPPORTED TWO-WAY RIBBED SLAB

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Abstract: SAP2000 program is used to analyze single simply supported two-way ribbed slab models from 5 x 5m to 5 x 25m, supported on beams of different stiffnesses. This paper concentrates on the distribution of the loads to the perimeter beams and to the ribs in both directions.
The discussion of results showed that the distribution of moments along the parallel ribs in the short and long direction depends, in addition to the aspect ratio, on the relative stiffnesses of the slab (ribs) and the beams on which these ribs are supported. Also, the distribution of loads to the perimeter beams depends on the relative stiffness between the beams and the slab (ribs) in addition to the panel aspect ratio.
Tables and curves that relate the load distribution factors with the aspect ratio and the relative stiffnesses of the supporting beams are presented as an outcome of this study.

Introduction

Two-way slabs are those slabs supported by columns arranged generally in rows so that they can deflect in two directions. A widely spread type of the two-way slabs used is the two-way ribbed slab or waffle slab composed of closely spaced parallel T-section small beams in each of the two directions of the slab.

The exact analysis and design of this type of slabs is complex so that designers use simple procedure based on the use of certain coefficients to distribute the load in both directions, with the consideration that the moments on parallel ribs in one direction are equal. The stiffnesses of the beams on which the ribs are supported are not taken into consideration in distributing the moments along the different parallel ribs in each direction.

Analysis and design of two-way slabs is usually complex, so the designers use simple procedures for calculating the bending moments in each direction that depend on certain coefficients to distribute the load in both directions. These coefficients do not depend on the panel perimeter beams, stiffness or supporting conditions. In this paper, the distribution of moments in both directions will be illustrated by a simply supported two way ribbed slab with different perimeter beams stiffnesses. It will be seen that the moment’s distribution in each direction depends on the beams, stiffnesses which is relative to the slab stiffness.

Background

Two-way slabs may be solid slabs that may be strengthened by the addition of beams between the columns, by thickening the slabs around the columns and by flaring the columns under the slabs, or they may be ribbed slabs (waffle slabs) that are used in large spans to carry light to medium loads. [3]

Two-way slabs bend under gravitational load into dish-shaped surfaces, so there is bending in both principal directions. To understand the flexural performance of the two-way slab it is convenient to think of it as consisting of two sets of parallel strips, in each of the two directions, intersecting each other. The waffle or the two-way ribbed slab is composed of parallel ribs (small T-section beams) in each of the two directions, this is similar to the assumed strips in the solid slab. It is very clear that part of the load is carried by one set and transmitted to one pair of edge supports and the remainder of the load by the other. Figure 1.a shows the two center strips of a rectangular slab with short span l_a and long span l_b. If the load on the slab is a uniform load w per square meter of the slab, each of the two strips acts approximately like a simple beam loaded by its share of the load w. Because these strips or ribs are part of the same monolithic slab, their deflections at the intersection point must be the same. Equating the center deflections of the short and long strips gives:

Where w_a is the share of the load w carried in the short direction and w_b is the share of the load w carried in the long direction. Consequently,

It is very clear that the share of the load w carried in the short direction w_a is larger than the share of the load carried in the long direction w_b .

This result is approximate because the actual behavior of a slab is more complex than that of the two intersecting strips. Numerical methods such as finite difference and finite elements are required, but such methods are not really practical for routine design.[4]

$$\frac{5w_a l_a^{\;4}}{384EI} = \frac{5w_b l_b^{\;4}}{384EI} \qquad (1)$$

$$\frac{w_a}{w_b} = \frac{l_b^{\;4}}{l_a^{\;4}} \qquad (2)$$

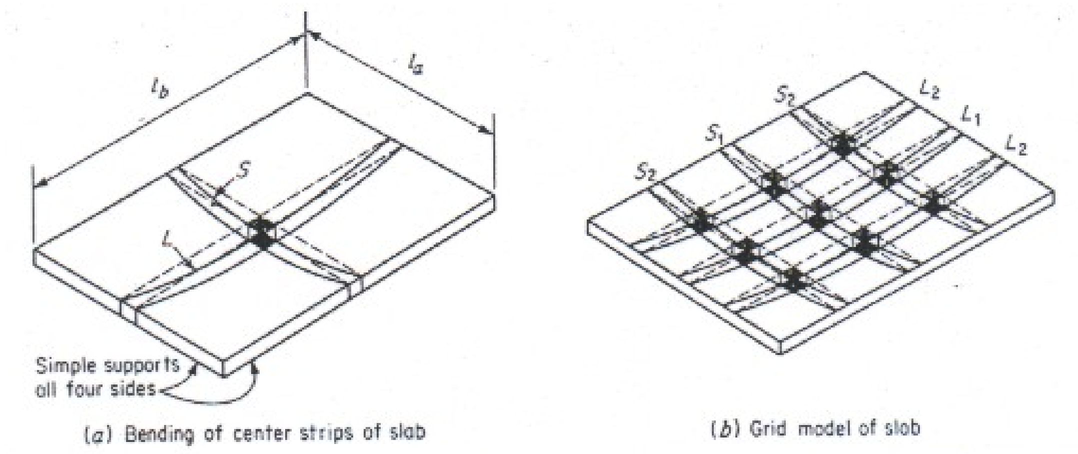


Figure 1 Two-way slab on simple edge supports [5]

An understanding of the behavior of the slab can be gained from Fig. 1b which shows a slab model consisting of two sets of three strips or ribs each. It is seen that the two central strips S_1 and L_1 bend in a manner similar to that of Fig. 1a. The outer strips S_2 and L_2 are not only bent but they are also twisted. The twisting results in torsional stresses and torsional moments, are seen to be most pronounced near the corners. [11]

The bending moments in elastic slabs are smaller than those that might be

$$\frac{(w/2)l^2}{8} = 0.0625wl^2 \tag{3}$$

computed for sets of unconnected strips loaded by w_a and w_b. As an example, for a simply supported square slab w_a=w_b=w/2. If only bending moments were present, the maximum moment in each strip would be:

The exact theory of bending elastic plates shows that the maximum moment in such a square slab is only $0.048wl^2$. This means that in this case the twisting moments relieve the bending moments by about 25 percent. [5]

The exact theoretical determination of moments in two-way slabs with various conditions of continuity at the supported edges is very difficult and not suited to design practice. Thus, various simplified methods have been adopted for determining the moments; shears, and reactions in such slabs. In earlier editions of the ACI code, three different methods were presented, the most widely used of which is the coefficients method based on elastic analysis and accounts for inelastic redistribution.

In this method, tables of moment coefficients for variety of end conditions are used. The moments in. the two directions are computed from:

Where,

$$M_a = C_a w l_a^2 \qquad (4a)$$

$$M_b = C_b w l_b^2 \qquad (4b)$$

w: uniform load per meter square

C_a, C_b: tabulated moment coefficients

l_a, l_b: length of clear span in short and long directions, respectively

The above mentioned method was deleted from the 1971 and later editions of the ACI Code so that all types of two-way concrete construction, including edge-supported slabs, flat plates, and waffle slabs could be treated by one uniform method.

A method introduced by the ACI code in the early seventies approximates the actual distribution of the transverse moments by regions of constant moment. The center strip of slab, is termed middle strip and the outside edges are termed the half column strips. In an actual two-way slab, the ratio of the moments in the column and middle strips is not a constant value but varies with the slab's length-to-width ratio l_l/l_2 and the flexural stiffness of the beams (if any) along column centerlines. [1]The complexity of the generalized method for design of two-way systems introduced in the ACI Codes after 1970 has led many engineers to use the coefficients method suggested by the previous codes for the special case of edge-supported slabs.

Among different building codes, the reinforced concrete design code issued by the Jordanian National Council in 1993 allowed the use of the coefficients method or the Direct Design method in the design of two-way ribbed slabs. Many engineers prefer to use the coefficients method in which they calculate, the moments in the short and long directions based on calculating the fraction of load carried in each direction .[8] This fraction depends on the ratio of the short to long span lengths as shown in Table (1). Considering that all ribs in one direction are subjected to the same moment, one typical rib is analyzed and designed as a T-section taking into consideration its ends continuity. The effect of the stiffnesses of the edge beams on which the ribs are supported is not taken into consideration in calculating the resulting moments on the different parallel ribs.

Table 1 Load distribution coefficients
C_x: for shorter direction, C_y: for longer direction

Aspect ratio L_b/L_a	**Moment Coefficients**	
	C_x	**C_y**
1.0	0.500	0.500
1.1	0.595	0.405
1.2	0.672	0.378
1.3	0.742	0.258
1.4	0.797	0.203
1.5	0.834	0.166
1.6	0.867	0.133
1.7	0.893	0.107
1.8	0.914	0.086
1.9	0.928	0.072
2.0	0.941	0.059

One of the methods used in the analysis of structures and had proved to be of adequate accuracy for design purposes is the Finite Element Method. Many computer programs such as SAP, ANSYS, and STAAD III available throughout the world are based on the finite element approach in the analysis of structures.

A study made by Al-Qadamani and Touqan on the analysis of Two-way solid slabs using finite element method in comparison with different applied methods showed that the coefficients method can not be used for slabs without beams. Al-Qadamani and Touqan used STAADIII software in their study.[7]

Hashim Abdul-Wahab and Mohammed Khalil tested to failure 8 large-scale models of reinforced concrete waffle slabs with varied rib sizes. The validity of the (equivalent thickness) Concept was examined and also the theoretical analysis based on the conventional theories gave satisfactory predictions. An alternative simplified approximate method based on the "effective modulus of elasticity" was also proposed in this study. [10]

A brief history of two-way reinforced concrete slab design leading to the current code procedures was presented in a paper authored by S. Simmonds. In his paper he made a
critical review of the Equivalent Frame Method in the current code and gave suggestions for improving and simplifying provisions for elastic frame in future codes.[13]

Methodology

SAP2000 program is used to analyze two-way ribbed simply supported rectangular slab models ranging from 5 x 5m to 5 x 25m; the long span to short span ranges from 1 to 5, supported on beams of different stiffnesses. Figure 2 shows the grid of a typical model used in the analysis procedure. The analysis is done to determine the moment and shear distribution in the ribs and beams in each direction to study the effect of the panel aspect ratio and the beam stiffnesses on the distribution of moment and shear in each direction.

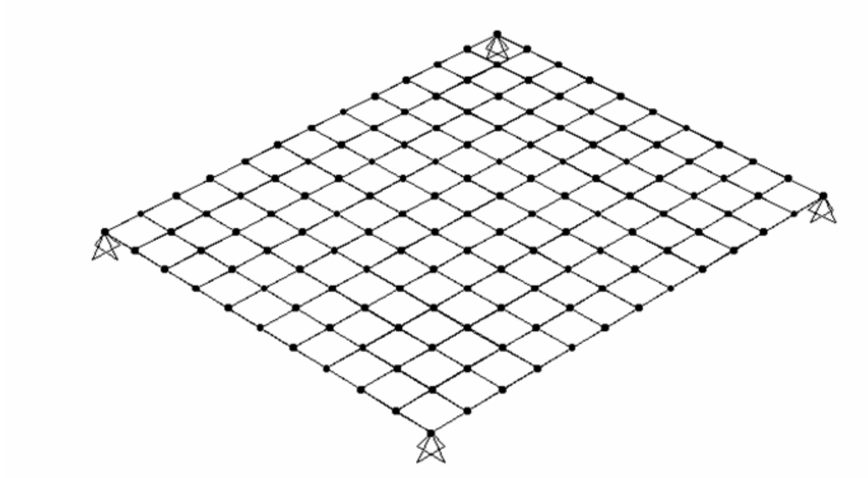


Figure 2: Grid model of a typical slab

Slab model:

The two-way ribbed slab consists of ribs in both directions. Each rib is a T-section of 25cm total depth, 50cm flange width, 8cm flange thickness and 10cm web width as shown in Fig.3. This type of rib is commonly used in practice in normal residential buildings slabs. A range of spans 5x5m to 5x25m is used to study the distribution of moments in each direction as the aspect ratio (long span/short span: L_b/L_a) of spans varies from 1 to 5. The panel perimeter beams are 0.25x0.25m(width x depth), 0.5x0.25m, 0.7x0.25m, 1.0x0.25m, 0.2x0.6m, 0.2x0.8m, 0.2x1.0m, 0.2x1.2m, 0.2x1.5, 0.2x2.0m and wall beam (very stiff beam, 0.2x10m).

Slab analysis:
The model is a grid system and the ribs are 0.5m apart in each direction. The slab rests on four pin supports at the corners. This system is analyzed using the computer program SAP2000.[12] The used load is $2t/m^2$, so the internal joint will take 0.5x0.5x2=0.5t, the edge joint will take 0.25t and the corner joint will take 0.125t.

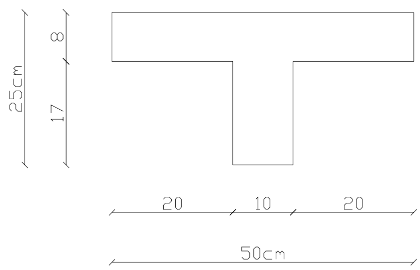


Figure 3 Rib cross section dimensions

The outcome results of analysis give the shear force and the moment values at each joint from which the load factors can be calculated using empirical equations such as

where, c_a: moment load factor in certain direction
w: uniform load per meter square
l_a: span length

$$M_a = C_a w l_a^2 /8 \qquad (5)$$

Discussion of results
From the analysis results, it is seen that the distribution of moments and shears in each direction depends on the panel aspect ratio and the perimeter beam stiffnesses. Actually, these factors depend on the relative stiffnesses of the perimeter beams to the slab or ribs stiffnesses and not the absolute stiffnesses of the beams.
The beam shear load factors in each direction are calculated by the shear values in the beams from the results of analysis using SAP2000. These factors are shown in Tables 2 and 3 and presented in Figures 4 and 5. It is seen that, as the beam stiffness is increased, the shear load factor in the short direction will increase for a specified panel aspect ratio. Also, as the panel aspect ratio is increased, the beam shear load factor will

increase in the short direction and decrease in the long direction. The maximum beam load factor in the short direction is 0.916 for an aspect ratio of 5 with very stiff beams (wall support) and it equals to 0.084 in the long direction. The summation of the beam shear factors in both directions is equal to one. The shear load factor in the short direction is equal to 0.79 for panel of aspect ratio of 2 which is the usual limit between one way and two way slabs, and it is equal to 0.21 in the long direction.

Beam moment load factors in each direction

The beam moment load factors are calculated from the beams, moments in each direction. These factors are shown in Figures 6 and 7. It is seen that as the beam stiffness is increased the moment load factor increases in the short direction. Also, as the aspect ratio is increased, the moment load factor will increase in the panel short direction (long beam). But, in the long direction (short beam), the beam moment load factor will increase as the beam stiffness is increased for low panel aspect ratios (less than 1.3) and remains approximately constant for larger panel aspect ratios as the panel goes to one way slab.

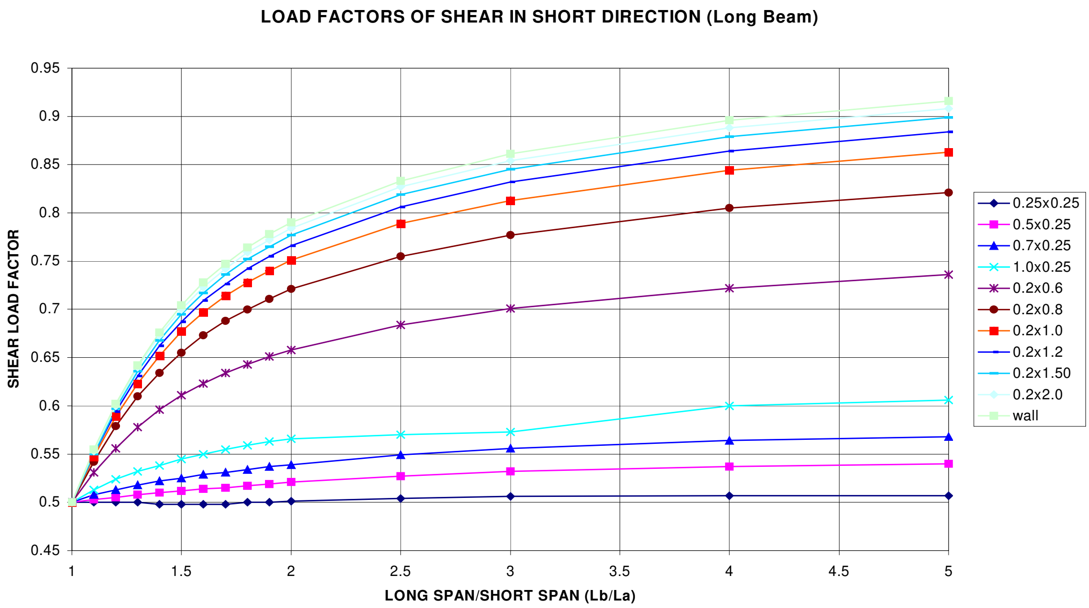


Figure 4 Beam shear load factors in short direction (long beam)

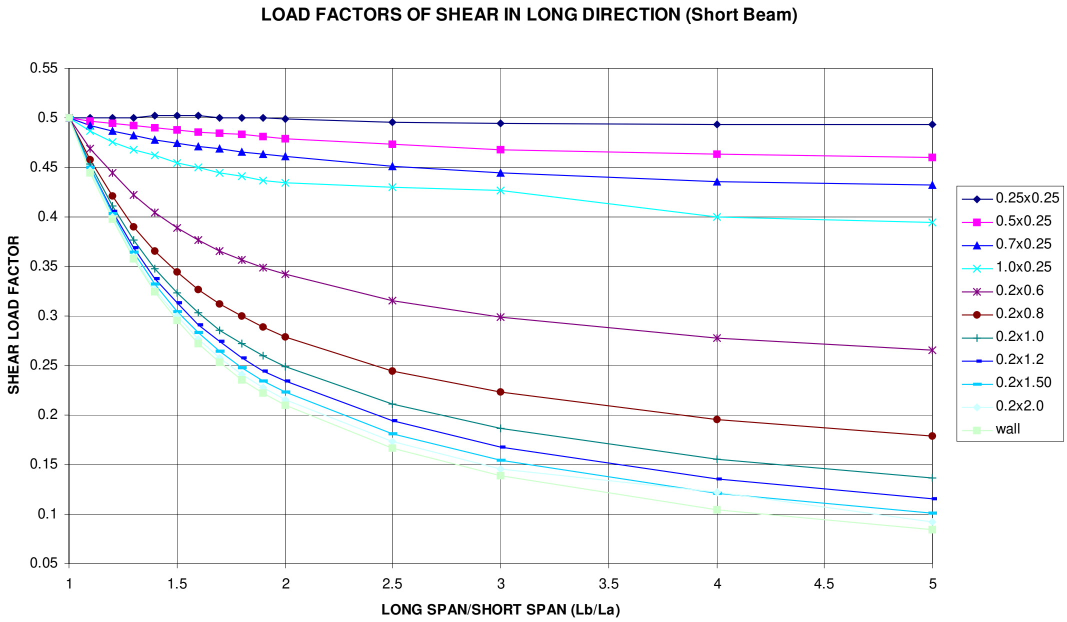


Figure 5 Beam shear load factors in long direction (short beam)

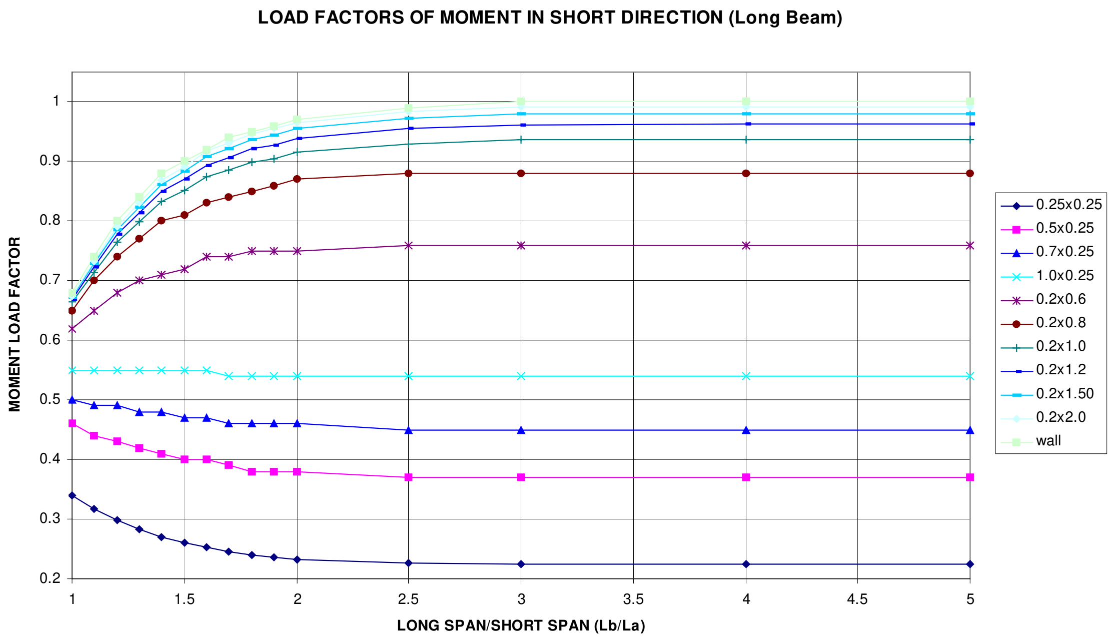
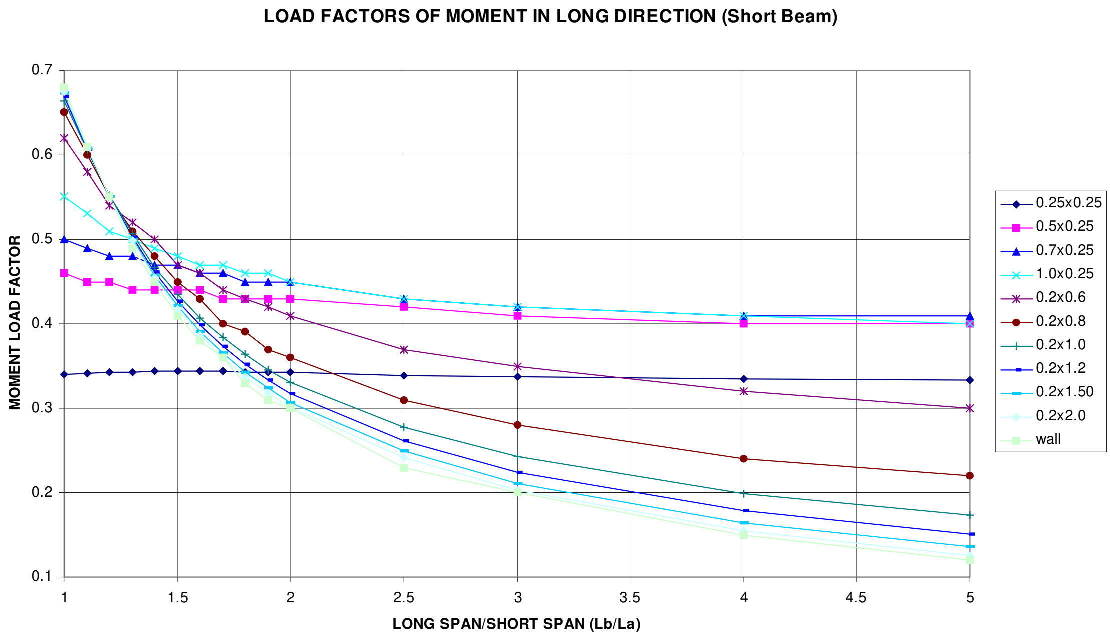


Figure 6 Beam moment load factors in short direction (long beam)
Figure 7 Beam moment load factors in long direction (short beam)



Moments in ribs

From the analysis results, it is seen that the moments vary in each direction along the panel width, no representative rib exists. It is seen that the column strip ribs have larger moments than the middle strip ribs for beams with small cross section (moment of inertia: stiffness) and the middle strip ribs have larger moments than the column strip ribs for large beams cross section (moment of inertia: stiffness). Also, it is seen that, as the panel aspect ratio is increased, the moments in the middle ribs in the short direction reach the values for one way slab with stiff beam and aspect ratio of two or more.

Load distribution factors in ribs (slab)

From slab model analysis using SAP2000, it is seen that the ribs have different bending moments and shear forces in each direction. Also, it is found that the end ribs in one direction have larger bending moments than the middle ribs for beams of small stiffness. As the beam cross section is increased, the end ribs moments is decreased and the beam moment is increased. For beams of large stiffness, the middle ribs have bending moments larger than the end ribs and larger than the bending moments in the case of having small stiffness beams. This relation is also valid for shear force in the ribs in both directions.

The ACI code Direct Design Method of two- way slab specifies that, the panel can be divided into two regions. The two end regions, which are called two half column strips of total width equal to half the short span dimension, and the middle region, which is called the middle strip of width, equals to span width, minus half the short span length. Considering this idea, the outcome results can be easily transformed to specific approximate values for the distribution load factors using the average moment and shear values of the ribs in the considered direction as shown in tables 2 to 5.

Table 2 Column and Middle strips moment load factors in ribs in panel short direction (panel short span = 5m)

L_b/L_a		Dimensions of the surrounding beams in meter						Wall
		0.5x0.25	**0.7x0.25**	**1.0x0.25**	**0.2x0.4**	**0.2x0.6**	**0.2x0.8**	
1	C. S	0.7	0.6	0.51	0.56	0.35	0.28	0.23
5x5	M. S	0.52	0.51	0.5	0.51	0.48	0.48	0.47
1.1	C. S	0.74	0.63	0.53	0.59	0.36	0.3	0.26
5x5.5	M. S	0.51	0.51	0.51	0.51	0.52	0.53	0.55
1.2	C. S	0.79	0.66	0.56	0.62	0.38	0.32	0.27
5x6	M. S	0.49	0.5	0.52	0.51	0.56	0.6	0.63
1.3	C. S	0.84	0.7	0.58	0.64	0.39	0.32	0.28
5x6.5	M. S	0.49	0.5	0.52	0.51	0.59	0.63	0.67
1.4	C. S	0.89	0.74	0.6	0.68	0.39	0.33	0.29
5x7	M. S	0.74	0.49	0.53	0.5	0.62	0.68	0.73
1.5	C. S	0.94	0.77	0.63	0.71	0.4	0.33	0.29
5x7.5	M. S	0.47	0.49	0.53	0.51	0.63	0.69	0.76
1.6	C. S	1.0	0.81	0.65	0.74	0.4	0.33	0.3
5x8	M. S	0.45	0.48	0.52	0.5	0.65	0.73	0.8
1.7	C. S	1.05	0.85	0.67	0.77	0.41	0.33	0.3
5x8.5	M. S	0.45	0.49	0.53	0.5	0.65	0.73	0.81
1.8	C. S	1.10	0.88	0.7	0.8	0.41	0.33	0.29
5x9	M. S	0.44	0.48	0.53	0.5	0.67	0.76	0.85
1.9	C. S	1.15	0.92	0.72	0.83	0.42	0.33	0.29
5x9.5	M. S	0.45	0.48	0.52	0.51	0.67	0.76	0.85
2	C. S	1.21	0.96	0.75	0.86	0.42	0.33	0.29
5x10	M. S	0.43	0.47	0.53	0.5	0.68	0.78	0.87

Table 3 Column and Middle strips shear load factors in ribs in panel short direction (panel short span = 5m)

L_b/L_a		Dimensions of the surrounding beams in meter						Wall
		0.5x0.25	**0.7x0.25**	**1.0x0.25**	**0.2x0.4**	**0.2x0.6**	**0.2x0.8**	
1	C. S	0.55	0.5	0.45	0.48	0.38	0.35	0.32
5x5	M. S	0.37	0.41	0.45	0.42	0.51	0.54	0.56
1.1	C. S	0.58	0.52	0.47	0.5	0.39	0.36	0.33
5x5.5	M. S	0.36	0.41	0.45	0.42	0.54	0.58	0.62
1.2	C. S	0.61	0.54	0.49	0.52	0.4	0.37	0.35
5x6	M. S	0.35	0.4	0.45	0.42	0.57	0.62	0.68
1.3	C. S	0.65	0.57	0.5	0.54	0.4	0.37	0.35
5x6.5	M. S	0.35	0.4	0.45	0.42	0.58	0.65	0.71
1.4	C. S	0.68	0.59	0.52	0.57	0.41	0.37	0.36
5x7	M. S	0.33	0.39	0.45	0.42	0.6	0.68	0.75
1.5	C. S	0.72	0.62	0.54	0.59	0.41	0.38	0.36
5x7.5	M. S	0.33	0.39	0.46	0.42	0.61	0.69	0.77
1.6	C. S	0.76	0.65	0.55	0.61	0.41	0.38	0.36
5x8	M. S	0.32	0.39	0.45	0.41	0.62	0.71	0.79
1.7	C. S	0.79	0.68	0.57	0.64	0.42	0.38	0.35
5x8.5	M. S	0.33	0.39	0.46	0.42	0.62	0.71	0.80
1.8	C. S	0.83	0.7	0.59	0.66	0.42	0.37	0.35
5x9	M. S	0.32	0.38	0.46	0.41	0.63	0.73	0.82
1.9	C. S	0.87	0.73	0.61	0.68	0.43	0.37	0.35
5x9.5	M. S	0.33	0.39	0.46	0.42	0.63	0.72	0.82
2	C. S	0.90	0.75	0.63	0.7	0.43	0.37	0.35
5x10	M. S	0.32	0.38	0.46	0.41	0.64	0.74	0.84

Table 4 Column and Middle strips moment load factors in ribs in panel long direction (panel short span = 5m)

L_b/L_a		Dimensions of the surrounding beams in meter						Wall
		0.5x0.25	**0.7x0.25**	**1.0x0.25**	**0.2x0.4**	**0.2x0.6**	**0.2x0.8**	
1	C. S	0.7	0.6	0.51	0.56	0.35	0.28	0.23
5x5	M. S	0.52	0.51	0.5	0.51	0.48	0.48	0.47
1.1	C. S	0.7	0.6	0.51	0.56	0.33	0.25	0.18
5x5.5	M. S	0.55	0.52	0.49	0.51	0.43	0.40	0.37
1.2	C. S	0.7	0.6	0.51	0.56	0.31	0.22	0.15
5x6	M. S	0.58	0.54	0.49	0.52	0.39	0.34	0.30
1.3	C. S	0.7	0.6	0.51	0.56	0.30	0.2	0.16
5x6.5	M. S	0.6	0.54	0.49	0.52	0.36	0.29	0.23
1.4	C. S	0.7	0.61	0.51	0.56	0.29	0.19	0.14
5x7	M. S	0.62	0.56	0.49	0.53	0.34	0.26	0.18
1.5	C. S	0.7	0.6	0.51	0.56	0.28	0.17	0.07
5x7.5	M. S	0.63	0.57	0.49	0.53	0.32	0.23	0.14
1.6	C. S	0.7	0.61	0.51	0.56	0.28	0.16	0.05
5x8	M. S	0.65	0.58	0.5	0.54	0.31	0.21	0.11
1.7	C. S	0.7	0.61	0.51	0.56	0.28	0.16	0.04
5x8.5	M. S	0.66	0.58	0.5	0.54	0.30	0.19	0.08
1.8	C. S	0.7	0.61	0.51	0.57	0.27	0.15	0.03
5x9	M. S	0.67	0.59	0.5	0.55	0.29	0.17	0.07
1.9	C. S	0.7	0.61	0.51	0.57	0.27	0.14	0.02
5x9.5	M. S	0.68	0.59	0.5	0.55	0.28	0.16	0.05
2	C. S	0.7	0.61	0.51	0.57	0.27	0.14	0.02
5x10	M. S	0.68	0.6	0.51	0.56	0.28	0.16	0.04

Table 5 Column and Middle strips shear load factors in ribs in panel long direction (panel short span = 5m)

L_b/L_a		Dimensions of the surrounding beams in meter						Wall
		0.5x0.25	**0.7x0.25**	**1.0x0.25**	**0.2x0.4**	**0.2x0.6**	**0.2x0.8**	
1	C. S	0.55	0.5	0.45	0.48	0.38	0.35	0.32
5x5	M. S	0.37	0.41	0.45	0.42	0.51	0.54	0.56
1.1	C. S	0.55	0.5	0.45	0.48	0.36	0.32	0.28
5x5.5	M. S	0.38	0.41	0.44	0.42	0.48	0.49	0.50
1.2	C. S	0.55	0.5	0.45	0.48	0.35	0.3	0.25
5x6	M. S	0.38	0.41	0.43	0.42	0.45	0.45	0.44
1.3	C. S	0.56	0.5	0.45	0.49	0.34	0.28	0.22
5x6.5	M. S	0.39	0.41	0.43	0.42	0.43	0.41	0.40
1.4	C. S	0.56	0.51	0.45	0.49	0.33	0.27	0.20
5x7	M. S	0.39	0.41	0.42	0.42	0.41	0.39	0.36
1.5	C. S	0.56	0.51	0.45	0.49	0.33	0.26	0.18
5x7.5	M. S	0.40	0.42	0.42	0.42	0.39	0.36	0.32
1.6	C. S	0.56	0.51	0.45	0.49	0.32	0.25	0.17
5x8	M. S	0.40	0.42	0.42	0.42	0.38	0.34	0.30
1.7	C. S	0.57	0.51	0.45	0.49	0.32	0.24	0.16
5x8.5	M. S	0.40	0.42	0.42	0.41	0.37	0.33	0.27
1.8	C. S	0.57	0.51	0.45	0.49	0.31	0.23	0.15
5x9	M. S	0.40	0.42	0.41	0.41	0.36	0.31	0.26
1.9	C. S	0.57	0.51	0.45	0.49	0.31	0.23	0.14
5x9.5	M. S	0.40	0.41	0.41	0.41	0.35	0.30	0.24
2	C. S	0.57	0.51	0.45	0.49	0.31	0.22	0.13
5x10	M. S	0.40	0.41	0.41	0.41	0.35	0.29	0.23

The results of this research can be used to calculate the moments and shears in the perimeter beams and in the ribs in each direction for the given aspect ratio; panel dimensions; slab thickness, and beams dimensions for a given slab load. The previous tables (tables 2 to 5) and graphs (figures 4 to 7) that illustrate the load factors of moments and shears in each direction of slab panel are for specific beams and slab dimensions. These tables and graphs can be transformed to general beam/slab stiffness and panel aspect ratio instead of specific beam dimensions and slab thickness but this needs more explanation that the paper will be of large size and research will be beyond the scope of a research paper. The following example will illustrate the use of the previous tables and charts.

Example:

Calculate the bending moment and shear force in the perimeter beams and in the ribs in each direction of a simply supported two-way ribbed slab panel 5x7m. The beams are 20cm width and 80cm depth. The slab thickness is

25cm, rib width= 10cm, ribs clear spacings= 40cm and the bricks height is 17cm. The uniformly distributed load is equal to 1.6t/m^2.

Solution:

The moments and shears in the perimeter beams are calculated as follows:

Panel aspect ratio=7/5=1.4

For the long beam (short direction):

Span= 7m

Load=1.6t/m^2

Shear load factor= 0.634 (table 2)

Moment load factor= 0.8 (table 4)

Shear force= load/m^2*shear load factor*(short span/2)*(long span/2)= 1.6*0.634 *(5/2) * (7/2) =8.876t

Moment= load/m^2*moment load factor*(short span/2)*(long span) ^{2}/8= 1.6*0.8* (5/2)*7^2 /8= 19.6ton.meter

For the short beam (long direction):

Span= 5m

Load=1.6t/m^2

Shear load factor= 0.366 (table 3)

Moment load factor= 0.48 (table 5)

Shear force= load/m^2*shear load factor*(long span/2)*(short span/2)= 1.6*0.366 *(7/2) * (5/2) =5.124t

Moment= load/m^2*moment load factor*(long span/2)*(short span) ^{2}/8= 1.6*0.48* (7/2)*5^2 /8= 8.4ton.meter

The moments and shear forces in the ribs are calculated as follows:

Ribs in the short direction:

Load on rib= 0.5x1.6= 0.8t/m

Column strip moment load factor=0.33 (table 2)

Middle strip moment load factor= 0.68 (table 2)

Column strip shear load factor=0.37 (table 3)

Middle strip shear load factor= 0.68 (table 3)

Column strip moment= $wl^2/8$= 0.33x0.8x25/8= 0.825t.m/rib

Middle strip moment= $wl^2/8$= 0.68x0.8x25/8= 1.70t.m/rib

Column strip shear= wl/2= 0.37x0.8x5/2= 0.74t/rib

Middle strip shear= wl/2= 0.68x0.8x5/2= 1.36t/rib

Ribs in the long direction:

Load on rib= 0.5x1.6= 0.8t/m

Column strip moment load factor=0.19 (table 4)

Middle strip moment load factor= 0.26 (table 4)

Column strip shear load factor=0. 27 (table 5)

Middle strip shear load factor= 0.39 (table 5)
Column strip moment= $wl^2/8$= 0.19x0.8x49/8= 0.93t.m/rib
Middle strip moment= $wl^2/8$= 0.26x0.8x49/8= 1.27t.m/rib
Column strip shear= wl/2= 0.27x0.8x7/2= 0.76t/rib
Middle strip shear= wl/2= 0.39x0.8x7/2= 1.09t/rib
Based on the coefficients method (Table 1) the load factors and the resulting shear forces and bending moments will be as follows:
The load factor in the short direction= 0.797
The load factor in the long direction= 0.203
The bending moment in the short direction= 0.797x0.8x25/8= 1.99t.m/rib
The bending moment in the long direction= 0.203x0.8x49/8= 0.99t.m/rib
The shear force in the short direction= 0.797x0.8x5/2= 1.59.m/rib
The shear force in the long direction= 0.203x08.x7/2= 0.57t.m/rib
Comparing the calculated values using the outcome results of this paper and those using the coefficients method, adopted by the Jordan National Building Council reinforced concrete 1993, it can be seen that the results of the coefficients method are conservative in the short direction ribs, moments and shears, but, they estimate smaller values in the long direction. The difference will be greater when the perimeter's beams have smaller stiffnesses.

Conclusions

From the tables and graphs, the following conclusions can be stated:

1. The bending moments in ribs vary in each direction of panel depending on perimeter beams stiffness; no general representative rib is exists.
2. In the short direction, as the transverse beam stiffness increased, its bending moment will be increased.
3. In each direction, as the transverse beams stiffness increased, the average bending moment of ribs in this direction will be decreased for small panel aspect ratios.
4. In any direction, as the parallel beam stiffnesses increased, the bending moments of the end ribs (column strip ribs) will be decreased and the bending moments of middle ribs (middle strip ribs) will be increased relating to the end ribs (column strip ribs) and vice versa.
5. Perimeter beams with low stiffness leads to have column strip ribs having bending moments larger than middle strip ribs and so perimeter beams with large stiffness leads to have middle strip ribs having bending moments larger than column strip ribs.

6. As the panel spans aspect ratio increased, the load ratio of shear in the short direction will be increased and vice versa and the rate of increase or decrease depends on the perimeter beams stiffness.
7. To ensure one way slab action, it is recommended to decrease the stiffness of the beams parallel to the short direction.

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