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Analysis of 2-way R.C. Slabs Under Concentrated Load. A Review of the Egyptian Code 203-2007 Provisions.

Magdy Israel Salama*

Abstract:

The analysis of rectangular two-way slabs subjected to concentrated load uniformly distributed over defined area after dispersion down in the two directions to the reinforcement is a practically important case. As presented by Egyptian code for design and construction of concrete structures ECCS 203-2007, the analysis of this problem can be performed by using the elastic analysis or by using an approximate method which depends on the distribution of the concentrated load in the two directions by the ratio of the long length and short length of the rectangular slab. Significant differences between the results of these methods must take our attention. An alternative approximate method for determining the bending moments of the slab under study in the two directions directly is investigated in this paper based on the elastic analysis. Two closed-form expressions were obtained which describe the relation between the bending moments and all the factors that affect in it (the span ratio, the dimensions ratio of the loaded area and the ratio between the short span to the parallel length of the loaded area). Comparisons between the straining actions in the two directions resulting from the present analysis and that from the existing approximate method of the ECCS 203-2007 with the straining actions obtained by international codes as British Standards BS8110 and that obtained by finite element method are given also in this paper.

Keywords:
Slab, Two ways, Concentrated load, Bending moment, Elastic analysis.

1. Introduction:

When a slab is supported other than on two opposite sides only, the precise amount and distribution of the load taken by each support, and consequently the magnitude of the bending moments on the slab, are not easily calculated if assumptions resembling practical conditions are made. Therefore approximate analyses are generally used. The method applicable in any particular case depends on the shape of the panel of slab, the condition of restraint at supports, and the type of load.

Two basic methods [1-3] are commonly used to analyse slabs spanning in two directions. These are the theory of plates which based on elastic analysis under service loads, and yield-line theory in which the behaviour of the slab as collapse approaches is considered. A less well-known alternative to the latter is Hillerborg's strips method [2], [4].

* Lecturer, Faculty of Engineering, Kafrelsheikh University, Egypt

For rectangular panel carrying uniform load simply supported along all four edges and which no provision is made at the corners to prevent them lifting or to resist torsion, the Grashof and Rankine method [4] is applicable. When the corners of the slab are prevented from lifting and torsional restraint is provided, the simple Grashof and Rankine method is inappropriate. A more exact elastic analysis, assuming a value of Poisson's ratio, is performed and the resulting service bending moments at mid-span is given in tables for simplicity as used in most international codes [5-6].
When a slab carries a load concentrated on a part only of the slab, such as a wheel load on the deck of a bridge, the contact area of the load is first extended by dispersion through the thickness of the slab and the flooring (if any). If the slab supported on two opposite sides only, the width of slab carrying the load may be assumed and the total concentrated load is then divided by this width to give the load carried on a unit width of slab for purpose of calculating the bending moments. For slabs spanning in two directions carrying a load uniformly distributed over a defined area on a part only of the slab, the British Standards BS8110 [6] gives the bending moments on simply supported panel along all four sides with restrained corners by curves based on Pigweed's theory but the Egyptian code ECCS 203-2007 [7] presents an approximate method which depends on the distribution of the load in the two direction.
In this paper, firstly focus our attention to the Significant differences between the results of these methods and the Comparison between these results and the finite element method shows the results from international codes as British Standards BS8110 is agree to the results obtained by finite element method with a good accuracy but in the opposite side, the difference between the results of the ECCS 203-2007 and the finite element method is not acceptable.
Also in this paper, closed-form expressions are obtained using a theoretical analysis based on the theory of plates to determine the bending moments in the two directions directly as a function of the variables. A comparison of the results with finite element method as programmed in SAP2000 [8] is given in this thesis.

2. Model and Assumptions:

Consider a rectangular plate simply supported along all four edges as shown in Fig. 1, carrying a concentrated load (P) uniformly distributed over a defined area with the following assumptions

- There is no deformation in the middle plane of the plate. This plane remains neutral during bending.
- The corners of the slab are prevented from lifting and torsional restraint is provided.

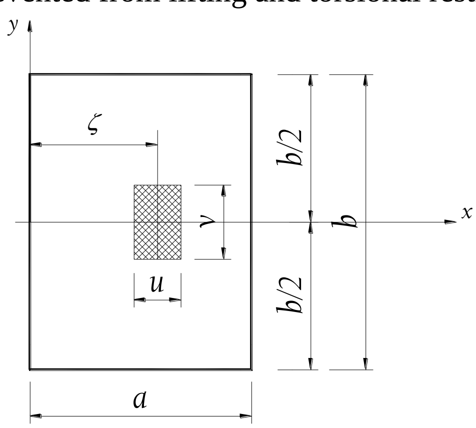

Figure (1): *Simply Supported Rectangular Slab Subjected to a Concentrated Load Uniformly Distributed Over a Defined Area*

3. Review of Egyptian Code (ECCS 203-2007) and British Standards (BS 8110):

From the results of the previous two examples, Table 1 shows the comparison of the bending moments obtained by Eqs. (16-17) of the present work, the approximate method given in clause (6-2-1-5) of the ECCS 203-2007 and the British standards BS8110 with the results obtained by elastic analysis as programmed as finite element method [8].
It can be noticed that although the present equations are simple, it gave accurate results compared with the solution by finite element method. Then, the present equations can be rather used by the designer engineers.

Table (1): Comparison of M_x and M_y obtained by P. W., ECCS 203-2007 and BS 8110 with F.E.M.[8]

Example		**F.E.M**	**P.W.**	**% Diff.**	**ECCS. 203**	**% Diff.**	**BS 8110**	**% Diff.**
Example 1 ***b* =3.00 m** ***a* =3.00 m** ***P* =200 *kN***	M_x	36.640	35.110	-4.18%	26.340	-28.11%	37.200	+1.53%
	M_y	32.220	32.070	-0.47%	30.950	-3.94%	32.400	+0.56%
Example 2 ***b* =3.75 m** ***a* =3.00 m** ***P* =200 *kN***	M_x	40.740	40.230	-1.25%	26.260	-35.54%	42.800	+5.06%
	M_y	31.480	30.780	-2.22%	25.820	-17.98%	31.600	+0.38%

7. Conclusions:

In this paper, a theoretical analysis based on the elastic analysis is developed to determine the service bending moments of the slab spanning in two directions carrying a concentrated load uniformly distributed over a defined area on a part only of the slab. From results and examples carried out in this paper, the following conclusion are drawn

1. Significant differences between the results of the approximate method introduced in clause (6-2-1-5) of the Egyptian code for design and construction of concrete structures ECCS 203-2007 and the elastic solution e.g. by finite element method. Also, Significant differences between the results of ECCS 203-2007 and that obtained by other international codes as the British Standards BS8110. These differences are large enough to consider the approximate method introduced in ECCS 203-2007 is unsafe.
2. The present analysis describes the relation between the bending moments and all the factors that affect in it which are the span ratio, the dimensions ratio of the loaded area and the ratio between the short span to the parallel length of the loaded area (represented by factors r, k and k_1 respectively).

The great advantage of the present analysis is the determination of the bending moments by using hand calculations only (without the use of curves or tables). Two numerical examples demonstrated the use of the obtained equations for slabs under study and comparing the results with British Standards

BS8110 [4, 6] as well as the finite element method, as programmed in SAP2000 [8].
Finally, the present analysis provides relatively simple two expressions from which the bending moments for slabs under study can be easily calculated. These equations can be of great help for design purposes. The comparison of the results with the finite element method confirms the accuracy of such equations.

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[8]

Nomenclatures:

M_x, M_y	Bending moments per unit length of sections of a plate perpendicular to *x* and *y*
E	Young's modulus
P	Concentrated load
Ln	Natural logarithm
(x, y)	Rectangular coordinates
t	Slab thickness
d	Slab depth
c	Flooring thickness
□	Poisson's ratio