ISSN 2072-0149

The AUST

Journal of Science and Technology

Volume-2 Issue-1 January 2010

Ahsanullah University of
Science and Technology

Editorial Board

Editor

THE AUST
Journal of Science and Technology
Volume-2, Issue-1, January-2010

Structural Analysis on Punched and Suspended Slabs

Dr. Md. Mahmudur Rahman[1], Ahmad Omar[2],
Md. Masfiqul Islam[3]

ABSTRACT : *Slabs with different sizes of openings are frequently encountered in different types of building structures. Simple ACI moment co-efficient tables, direct design methods may not be applied to slabs with opening because of their limitations. Thus engineers face difficulties to obtain the bending moment values at critical locations for design. To facilitate a way of designing slabs with different opening sizes, attempt has been made numerical analysis for structural design with the help of computer software STAAD.Pro. By the comparative statements between the numerical and approximate analysis, a set of moment coefficient tables were developed which can be reasonably used to obtain critical moments for different sizes of slabs with different sizes of openings.*

Keyword: *Opening in slabs, structural analysis, moment co-efficient, slab odeling.*

1. Introduction:

Slab is a load carrying structure which transmits the load to the beams or directly to the columns. Slabs are considered to be sometimes the most important part of the structure [1]. The problem of openings in concrete slabs was not widely and precisely described either in codes or literature [2]. In this research, slabs with openings and without openings were analyzed with the objective of determining the moment coefficients. ACI code [3] permits opening of any size if it can be shown by analysis that the slab is safe for service loads. Coefficients method is permitted in BNBC code [2] for two way slabs.

Rasel Ahmmad [4], 2009 studied the influence of structure parameters for flat plates with opening. He found that opening in flat slab has great influence on deflection, moment and shear capacity of flat plates. Due to changes in location of opening in the panel, the shear capacity changes significantly.

---

[1] Associate Professor, Department of Civil Engineering, Ahsanullah University of Science and Technology.
[2] Student (Batch Fall 2005), Department of Civil Engineering, Ahsanullah University of Science and Technology.
[3] Lecturer, Department of Civil Engineering, Ahsanullah University of Science and Technology.

Piotr Rusinowski [5], 2005 did research on Experimental and Finite element analysis on two way slabs with openings. He carried out finite element analysis of tested RC slabs with opening. He also strengthened the slabs with opening by Carbon Fiber Reinforced Polymers (CFRP). He concluded that extra reinforcements only at the openings may not be sufficient. Concrete slabs with openings are usually designed with the help of traditional rules of thumb [5]. Such methods, however, introduce limitations concerning size of slabs.

For openings of small size, it is usually suggested to provide some extra reinforcements at the edges of the opening [1]. Larger openings require special consideration and analysis. In this study, a set of moment coefficients tables are derived based on Finite element analysis for different sizes of slabs with openings.

2. Slab Geometry and Analysis criteria

Two-way slabs of 3 different sizes e.g.15'x15', 20'x20' and 25'x25' with four sides fixed and varied openings (all square in shape and 4sq.ft – 100 sq.ft) were considered for the analysis purpose. All slabs were of the same thickness (6") as lower limit recommended by ACI code [3]. The slabs were modeled with sufficient number of small plate elements for the purpose of analysis as shown in Fig1. The loading on the slab was 60 psf as live load in addition to its self weight (75 psf) [2].

3. Modeling and Analysis

It transmits the load of the structures to the beams or in slabs of flat plate directly to the columns. Slabs are used to provide flat and useful surfaces. In this research, the analysis was on the changes of moment for a full slab and slabs with opening. The moment changes occur due to the change of shape and size of slab and opening were estimated by making computer simulations in software STAAD. Pro. First a 20ft x 20ft slab having an opening (10ft x 10ft) at its central part with fixed support surrounding the periphery was chosen for analysis. Similarly analysis was also done a 15ft x 15ft slab and 25ft x 25ft slab to get the design moment (Mx) of the middle plate of the slab. Once the analysis was done the results were plotted using Microsoft Excel to see the variation in moment with the sizes of the slabs and their opening dimensions. Here, we modeled the slabs with sufficiently small plate elements, to analyze by the software STAAD.Pro. From the software analysis, the bending moments at the critical sections (maximum positive

moment, maximum negative moment etc.) were obtained. By dividing these moments with moments calculated by analytical formula, moment co-efficient tables were prepared. Here, different slab sizes, different opening sizes were considered. The moment changes due to the shape and size of slab and opening were calculated.

4. Results and Discussions

As it is mentioned earlier, the analysis concentrated on the opening size of the slab, moments of the slab from supports to opening edges were processed further as to show how moment was related to distance from the support and how it varied with change in distance. Emphasis was given on the variation of moment, change of moment from negative to positive and the pathway of the change. Other researchers-Rasel Ahmmad [4], 2009 studied the influence of structure parameters for flat plates with opening. He found that opening in flat slab has great influence on deflection, moment and shear capacity of flat plates. Another Researcher, Piotr Rusinowski [5], who did research on Experimental and Finite Element analysis on two way slabs with openings concluded that extra reinforcements only at the openings may not be sufficient.

Table 1: Bending Moment, Mx of the middle plate of the 15ft x 15ft slab with fixed support

Plate No.	Distance ft	Mx lb-in/in (full slab)	Mx lb-in/in (2ft opening)	Mx lb-in/in (4ft opening)
451	0.25	-1342.85	-1325.22	-1218.35
452	0.75	-965.249	-956.22	-880.481
453	1.25	-646.94	-646.589	-599.134
454	1.75	-380.971	-389.704	-369.21
455	2.25	-160.304	-178.959	-185.674
456	2.75	21.377	-8.627	-44.55
457	3.25	169.716	126.068	56.657
458	3.75	289.683	228.725	118.179
459	4.25	385.603	301.269	136.929
460	4.75	461.182	342.772	105.17
461	5.25	519.536	345.835	28.688
462	5.75	563.219	284.392	
463	6.25	594.244	68.877	
464	6.75	614.105		
465	7.25	623.79		

Table 2: Bending Moment, Mx of the middle plate of the 20ft x 20ft slab with fixed support

Plate No.	Distance (ft)	Mx lb-in/in (full slab)	Mx lb-in/in (2ft opening)	Mx lb-in/in (4ft opening)	Mx lb-in/in (6ft opening)	Mx lb-in/in (8ft opening)	Mx lb-in/in (10ft opening)
801	0.25	-2481.05	-2465.54	-2378.07	-2160.08	-1804.36	-1361.22
802	0.75	-1955.42	-1946.11	-1880.79	-1705.68	-1412.8	-1044.33
803	1.25	-1492.13	-1489.12	-1444.75	-1308.17	-1071.06	-770.152
804	1.75	-1085.91	-1089.4	-1065.37	-964.224	-777.59	-538.428
805	2.25	-731.126	-741.454	-737.703	-670.146	-530.392	-348.494
806	2.75	-422.533	-440.217	-457.292	-422.62	-327.66	-199.584
807	3.25	-155.258	-181.044	-220.17	-218.852	-167.922	-90.908
808	3.75	75.193	40.255	-22.977	-56.777	-50.16	-21.643
809	4.25	272.932	227.373	136.899	64.707	26.21	8.83
810	4.75	441.696	383.449	261.084	145.467	61.568	4.346
811	5.25	584.855	510.959	349.797	183.956	55.978	
812	5.75	705.425	611.516	401.067	177.676	15.955	
813	6.25	806.08	685.446	409.304	123.855		
814	6.75	889.163	730.844	363.322	32.908		
815	7.25	956.697	741.343	244.341			
816	7.75	1010.398	699.305	64.033			
817	8.25	1051.681	553.032				
818	8.75	1081.67	132.754				
819	9.25	1101.199					
820	9.75	1110.826					

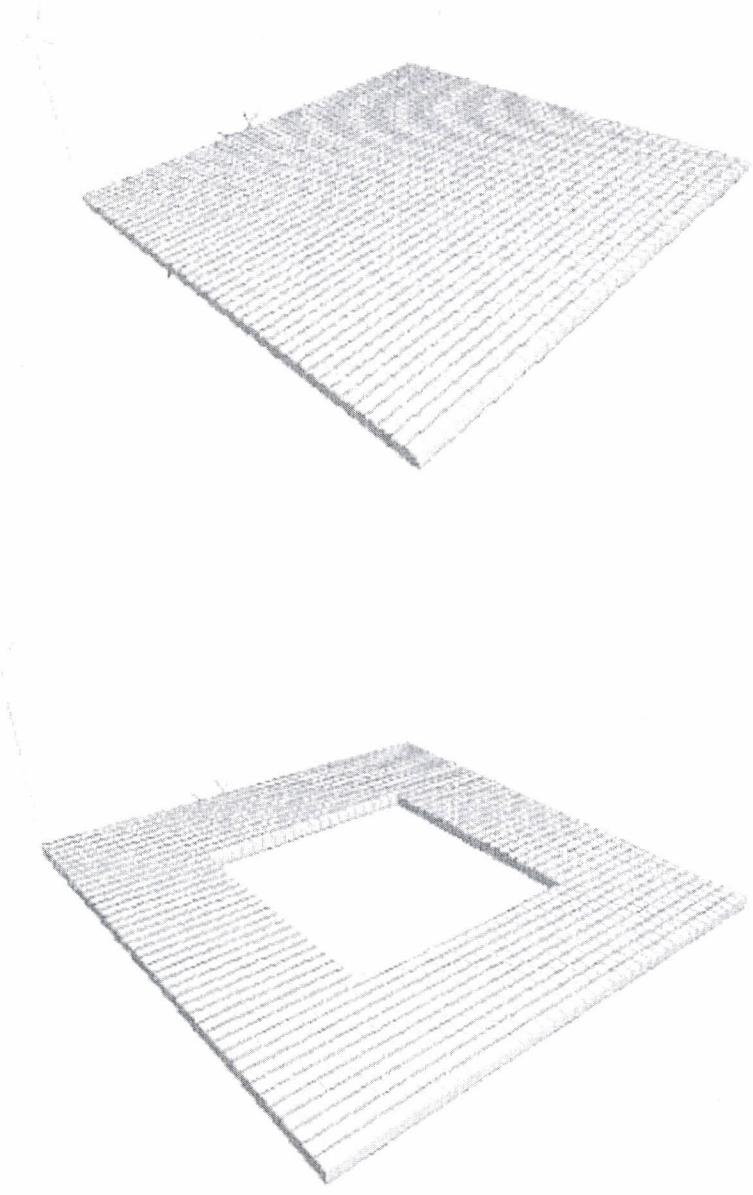

Fig 1: Typical three dimensional view of slab with an opening

Table 3: Bending Moment, Mx of the middle plate of the 25ft x 25ft slab with fixed support

Plate No.	Distance (ft)	Mx lb-in/in (full slab)	Mx lb-in/in (2ft opening)	Mx lb-in/in (4ft opening)	Mx lb-in/in (6ft opening)	Mx lb-in/in (8ft opening)	Mx lb-in/in (10ft opening)
1251	0.25	-3965.79	-3951.43	-3877.36	-3688.25	-3353.64	-2883.42
1252	0.75	-3291.77	-3282.24	-3224.95	-3068.69	-2784.84	-2381.09
1253	1.25	-2681.92	-2677.3	-2636.32	-2510.52	-2272.66	-1929.03
1254	1.75	-2132.09	-2132.52	-2107.58	-2010.46	-1814.82	-1526.17
1255	2.25	-1637.6	-1643.26	-1634.35	-1564.73	-1408.55	-1170.92
1256	2.75	-1194.03	-1205.17	-1212.55	-1169.81	-1051.21	-861.693
1257	3.25	-797.183	-814.152	-838.374	-822.431	-740.35	-597.039
1258	3.75	-443.095	-466.353	-508.292	-519.636	-473.861	-375.694
1259	4.25	-128.048	-158.193	-219.123	-258.869	-250.029	-196.671
1260	4.75	151.434	113.624	31.947	-38.049	-67.66	-59.283
1261	5.25	398.581	352.093	247.303	144.315	73.812	36.894
1262	5.75	616.388	559.895	428.82	288.951	174.253	92.123
1263	6.25	807.61	739.353	577.723	395.572	232.841	106.739
1264	6.75	974.776	892.387	694.369	462.535	248.291	80.76
1265	7.25	1120.19	1020.406	777.847	486.45	219.477	21.928
1266	7.75	1245.94	1124.135	825.279	461.976	145.368	
1267	8.25	1353.904	1203.276	830.509	382.865	37.896	
1268	8.75	1445.751	1255.826	781.717	243.534		
1269	9.25	1522.955	1276.546	658.224	62.747		
1270	9.75	1586.791	1253.379	427.649			
1271	10.25	1638.346	1156.508	110.813			
1272	10.75	1678.52	901.79				
1273	11.25	1708.028	215.735				
1274	11.75	1727.403					
1275	12.25	1737.003					

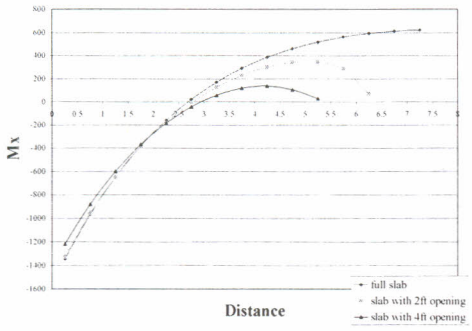

Fig 2: Mx Vs Distance from support to edge, La, along the mid plate of the 15ftx15ft slab and slab with opening.

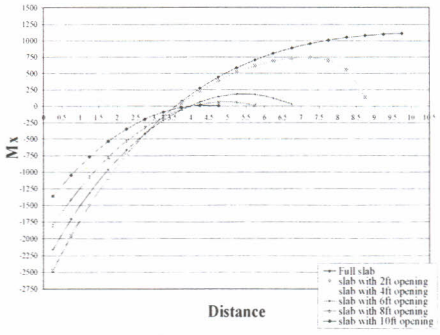

Fig 3: Mx Vs Distance from support to edge, La, along the mid plate of the 20ftx20ft slab and slab with opening.

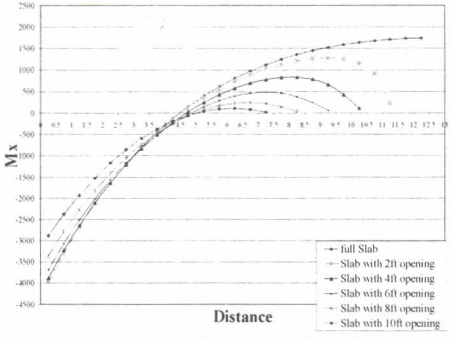

Fig 4: Mx Vs Distance from support to edge, La, along the mid plate of the 25'x25' slab and slab with opening.

From the above analysis, it is found that the bending moment changes with the variation of opening of the slab. It is also be scrutinized that the general behavior of slab was not performed for the opening of the slab. From this analysis it is developed the following observation- For a slab with fixed support, the maximum negative moment is found at the support of the slab. For opening of slab the maximum negative moment is found at the support also. But as the opening increases, the overall value of moment decreases. As for example, for 25ft x 25ft slab without opening the bending moment at support is -3965.79 lb-in/in but for 6ft opening at 25ft x 25ft slab the bending moment at support is -3688.25 lb-in/in. And for 10ft opening at 25ft x 25ft slab the bending moment at support is -2883.42 lb-in/in.

From the curve, it can be inferred that, the area of negative moment increases with the increase in opening. For instance, working with a full slab of measurement 25ft x 25ft full slab it is observed that a positive moment is found at a distance of 4.75ft from the support. When a 6ft opening is applied to the slab, the positive moment at an increase distance of 5.25ft from the support was found.

As slab behavior is concerned, maximum positive moment should take place in the middle point and this analysis has conformed to that. But as soon as an opening is introduced the deviation from this general principal is seen. Maximum positive moment does not appear at the edge of the opening, rather it decreases to a certain extent. In case of an opening, it is found that the maximum positive moment occurred at a distance of 1ft to 2ft from the edge of the opening. As the opening increases, it is noticed that notice that the distance of the point where maximum positive moment occurs decreases. For example, for a 20ft x 20ft slab with 2ft x 2ft opening maximum positive moment is found at a distance of 1.5ft from the edge of the opening. For 8ft x 8ft opening, maximum positive moment is found at a distance of 1ft from the edge of the opening.

The fall in the magnitude of the moment is also remarkable. Such as, for a 20ft x 20ft slab without opening, moment at a distance of 4.75ft from the support is 441.696 lb-in/in. For an opening of 6ft x 6ft, the moment at the same distance from the support is 145.467 lb-in/in. At the same time, for an opening of 10ft x 10ft, the moment at this point is 4.346 lb-in/in.

5. Proposed Moment Co-Efficient Tables:

After acquiring the result from analysis, these results were compared with the theoretical results. In this analysis, the applied load (w = DL + LL = (75 + 60) lb/ft^2 = 135 lb/ft^2) was uniformly distributed. Applying $wL_a^2/8$ formula moment was calculated. According to design criteria the original moments were compared with the calculated moments. So that the results were being related with support moment, edge moment, maximum positive moment and it was tried to figure out the changes in ratio between these moments with the increase in opening. So that it would be easy to calculate moments using theoretical moment with this co-efficient, later while designing. Using Microsoft Excel, graphs were plotted with distance from support to edge in x-axis and co-efficient on y-axis.

Table 4: Co-efficient table for 15ft x 15ft slab with fixed support

Opening of the slab	Distance from support to edge, L_a (ft)	Length of the slab, L (ft)	$wL_a^2/8$ (lb-in/in)	$wL^2/8$ (lb-in/in)	C(edge) = Bending Moment in edge/ $wL_a^2/8$	C (support) = Bending Moment in support / $wL^2/8$	C (+ve Max Moment) = +ve Max Bending Moment / $wL_a^2/8$
5ftx5ft	5	15	421.87	3796.87	0.042	0.2932	0.1648
4ftx4ft	5.5	15	510.46	3796.87	0.056	0.3208	0.2682
3ftx3ft	6	15	607.50	3796.87	0.081	0.3391	0.3723
2ftx2ft	6.5	15	712.96	3796.87	0.096	0.3490	0.4850

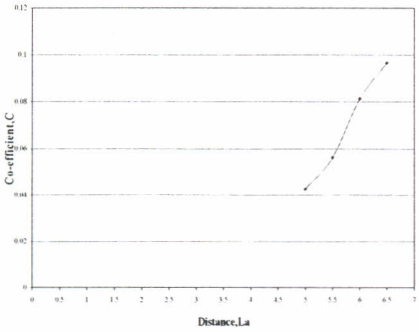

Fig 5:- Co-efficient (edge) Vs Distance from support to edge, L_a, along the mid plate of the 15'x15' slab with fixed support

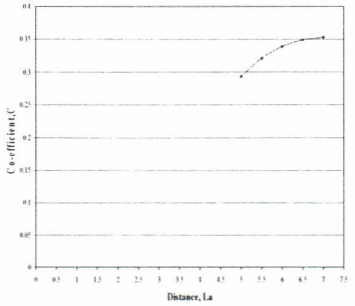

Fig 6:- Co-efficient (support) Vs Distance from support to edge, L_a, along the mid plate of the 15'x15' slab with fixed support

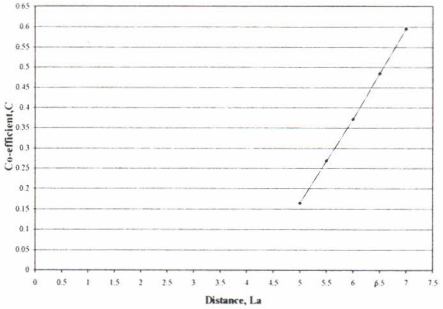

Fig 7:- Co-efficient (+ve max bending moment) Vs Distance from support to edge, L_a, along the mid plate of the 15'x15' slab with fixed support

Table 5: Co-efficient table for 20ft x 20ft slab with fixed support

Opining of the slab	Distance from support to edge, L_a (ft)	Length of the slab, L (ft)	$wL_a^2/8$ (lb-in/in)	$wL^2/8$ (lb-in/in)	C(edge) = Bending Moment in edge/ $wL_a^2/8$	C (support) = Bending Moment in support / $wL^2/8$	C(+ve max moment) = +ve Max Bending Moment / $wL_a^2/8$
10ftx10ft	5	20	421.87	6750	0.0103	0.2194	0.0209
8ftx8ft	6	20	607.50	6750	0.0262	0.2892	0.1013
6ftx6ft	7	20	826.87	6750	0.0397	0.3454	0.2224
4ftx4ft	8	20	1080.00	6750	0.0590	0.3801	0.3789
2ftx2ft	9	20	1366.87	6750	0.0971	0.3943	0.5423

Table 6: Co-efficient table for 25ft x 25ft slab with fixed support

Opening of the slab	Distance from support to edge, L_a (ft)	Length of the slab, L (ft)	$wL_a^2/8$ (lb-in/in)	$wL^2/8$ (lb-in/in)	C(edge) = Bending Moment in edge/ $wL_a^2/8$	C (support) = Bending Moment in support / $wL^2/8$	C(+ve max moment) = +ve Max Bending Moment / $wL_a^2/8$
10ftx10 ft	7.5	25	949.21	10546.88	0.0231	0.2733	0.1124
8ftx8ft	8.5	25	1219.21	10546.88	0.0310	0.3179	0.2036
6ftx6ft	9.5	25	1522.96	10546.88	0.0412	0.3497	0.3194
4ftx4ft	10.5	25	1860.46	10546.88	0.0595	0.3676	0.4463
2ftx2ft	11.5	25	2231.71	10546.88	0.0966	0.3746	0.5720

6. Conclusion :

In this study, a set of moment coefficients tables were developed based on Finite element analysis for slabs with openings. Analysis difficulties had been arisen not only in a complex stress state but also in limiting the boundary conditions. However the variations of bending moments along the distance from the support to the opening area were plotted. Support moment coefficients of slabs 20ftx20ft and 25ftx25ft varied within the range of 0.219 to 0.394 and 0.273 to 0.374 respectively. The bending moment co-efficient as found in the study may be recommended for designing punched slab resting on beam and column frame. Therefore, moment coefficient tables which have been developed may be used to find bending moments at critical locations of slabs with different openings. Thus, the research study here may

forward a recommendation for reviewing the existing building codes especially for the guidelines for slabs with openings.

6. Refferences

1. George Winter, L.C. Urquhart, C.E. O'Rourke, Arther H. Nilson, Design of Concrete Structure, 13th edition, McGraw-Hill.Inc
2. Bangladesh National Building Code (1993), First Edition, Housing and Building Research Institute, Dhaka, Bangladesh.
3. American Concrete Institute (2002), Building Code Requirements for Structural Concrete, ACI-318-02, Farmington Hills, MI.
4. Rasel Ahmmad (2009), Influence of openings on Behaviour of Flat Plates, an unpublished B.Sc (Engg.) Thesis submitted in the Department of Civil Engineering, BUET, Dhaka.
5. Piotr Rusinowski, (2005), Two-way Concrete Slabs with Openings-Experiments, Finite Element Analysis and Design, Thesis Paper, Master of Science Program,Lulea University of Technology, Lulea .