Parametric studies on load enhancement of two way rectangular alkali activated concrete simply supported slabs

Shivaraj G Nayak[1], R Mourougane[2]

[1]Research Scholar, Department of Civil Engineering, M S Ramaiah Institute of Technology, Bengaluru, Karnataka, India (Affiliated to VTU Belgavi, Karnataka, India)

[2]Associate Professor, Department of Civil Engineering, M S Ramaiah Institute of Technology,Bengaluru, Karnataka, India (Affiliated to VTU Belgavi, Karnataka, India)

ABSTRACT

The experimental ultimate load for reinforced concrete slabs is found to be more than the theoretical yield line load. Due to a change in geometry and boundary conditions, which will result in the development of in-plane forces, the load has increased over the yield line load. The membrane analysis consider these effects into account, and a number of modern techniques are based on the rigid plastic approach. The investigations conducted at the M.S.R.I.T research centre in Bangalore resulted in a satisfactory prediction of the complete load deflection behaviour of simply supported two way rectangular alkali activated concrete slabs subjected to distributed loading by making some modifications to the prior methods. The aforementioned methodology was employed in the current study to determine the effects of several parameters, including the coefficient of orthotropy, aspect ratio, span -depth ratio, and percentage of reinforcement. For typical data from the experiment work, numerical findings have been obtained, and the variations are shown in graphical form.

Keywords: alkali activated concrete, membrane action, yield line load, load enhancement

DOI Number: 10.14704/nq.2022.20.13.NQ88368 **Neuro Quantology 2022; 20(13):2953-2958**

1.0 Introduction

The experimental ultimate load in rectangular slabs of simply supported two-way reinforced concrete is more than the calculated johansen's yield line load. This results from the development of in plane membrane forces at large deflections. The supported edges' centre region has a tendency to shift inward with significant midspan deflection, but is restrained from doing so by surrounding outer regions. This leads to the development of tensile membrane stresses in the slab's centre and a compression ring close to its edges as shown in fig.1. The yield criteria benefits from the compressive forces at the edges, and as a result, the slab load carrying capacity rises above johansen's yield line load. Wood [1], examined circular isotropic slabs while accounting for this membrane activity. With slight modifications, the analysis performed by Park [2] for rectangular restrained slabs at large deflections can also be applied to simply supported slabs. He anticipated that for significant slab deflections, the reinforcement would function as a plastic membrane. When the slab truly behaves like a plastic net at extremely large deflections, it apperas that such an analysis would be valid, but at somewhat large deflections, the load will be carried by both membrane action and bending. A kinematical method for analyzing membrane activity in simply supported slabs was presented by Sawzuk and Winnick [3]. For simply supported slabs, the general extension of the yield line method described by Morley [4] is also applicable. However, as this study is for isotropic slabs, orthotropic slabs cannot be directly applied. For simply supported square slabs, Kemp [5], provided an upper bound solution that takes membrane activity into account. This technique applies the analysis proposed by wood for circular isotropic slabs. This analysis was not used by Kemp to examine orthotropic rectangular slabs. The theoretical load deformation graphs produced by these prior investigations, which used the rigid plastic approach, did not correspond to the slab's actual experimental deformation behaviour.. Desayi and Kulkarni [6], proposed a solution for rectangular simply supported slabs and generalised the influence of the deflections that occur before the aforementioned analytical technique to simply supported skew slabs. In the current study, by Shivaraj G Nayak et al., these analysis were modified and used to determine the load increase beyond the yield line load and its variation with respect to a number of factors, including span to depth ratio, aspect ratio, and percentage of reinforcement. Certain ranges are assumed for the above parameters and the obtained results for these slabs are presented.

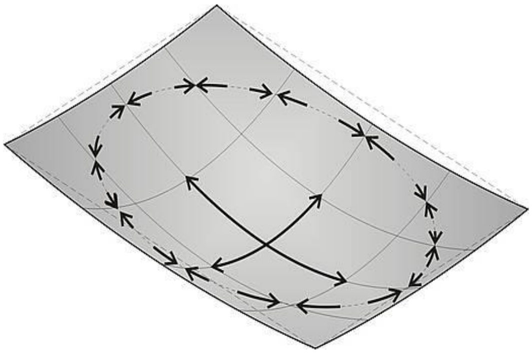

Fig.1. Tensile membrane action in simply supported slab

1.1 Proposed analysis for simply supported rectangular slabs

The analytical method was developed in two stages. The load deflection behaviour up to yield load was established in the first stage. By modifing the bending stiffness of the slab section, the cracking effect and reduced modulus of elasticity of the concrete were taken into consideration. In the second stage, the behaviour of the load deflection beyond the yield load is predicted by accounting for the tensile membrane's action. The load enhancement of simply supported reinforced concrete rectangular slabs was determined in relation to the following parameters the coefficient of orthotropy, aspect ratio, percentage of reinforcement, and span-depth ratio.

2.0 Parametric study on alkali activated concrete rectangular simply supported slabs

The proposed analysis was used to investigate the effect of the variation of several parameters which affect the load-deflection behaviour of alkali activated concrete slab. Computer programs were designed and used to perform parametric studies. The following parameters are taken into account.

1. Coefficient of orthrotropy
2. Aspect ratio
3. Span/depth ratio
4. Percentage of reinforcement

For the current investigation, the following materials and slab sectional properties from the tests conducted were considered.

L_x = span in x direction

L_y= span in y direction

S_x = reinforcement spacing in x-direction

S_y = reinforcement spacing in y- direction

d_x = effective depth of slab in x direction

d_y = effective depth of slab in y direction

$f_{y\,=}$ yield stress `

L_x = 900 mm, L_y =1400mm, S_x = 125 mm

S_y = 150 mm, dx =49 mm, dy= 55 mm, fy = 553 N/mm^2, Percentage of steel= 0.36

2.1 Effect of coefficient of orthotropy

The coefficient of orthotropy (CO) varied between 1.0 and 2.5 and increased by 0.25. Effect of CO on load enhancement is shown in fig. 2.0. It is observed that as the CO increased, the load enhancement decreased for all the slabs.

Table1: load enhancement v/s coefficient of orthotropy

CO fck (N/mm^2)	1.0	1.25	1.5	1.75	2.0	2.25	2.5
150	47.75	48.25	47.91	46.93	45.45	43.54	41.25
200	51.99	52.69	52.63	52.04	51.02	49.65	47.98
300	58.97	59.66	59.7	59.3	58.58	57.6	56.41
400	64.8	65.35	65.29	64.86	64.16	63.27	62.22
500	69.95	70.3	70.09	69.56	68.8	67.89	66.86
600	74.63	74.77	74.4	73.73	72.88	71.91	70.85
700	78.97	78.91	78.36	77.55	76.59	75.53	74.42

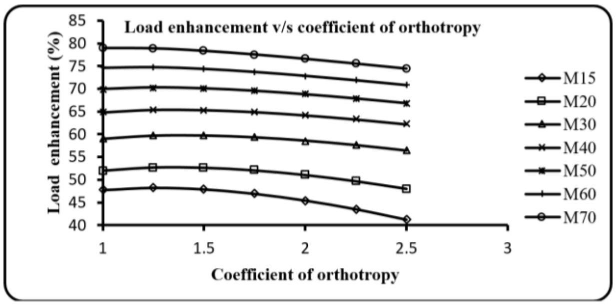

Fig. 2.0 – Effect of coefficient of orthotropy on the load enhancement of AAC slabs

2.2 Effect of aspect ratio

The aspect ratio was varied in 0.25 increments from 1.0 to 2.25. The graph shows that load enhancement falls as aspect ratio is increased. As seen in fig.3, the load enhancement increased with a higher concrete grade for a given aspect ratio.

Table2: load enhancement v/s coefficient of orthotropy

CO fck(N/mm^2)	1.0	1.25	1.5	1.75	2.0	2.25
15	59.35	59.04	58.04	57.04	56.22	55.64
20	65.38	64.84	63.69	61.86	60.49	59.35
25	70.43	69.74	67.98	66.07	64.31	62.78
30	73.71	74.05	72.05	69.85	67.77	65.94
40	82.43	81.51	79.15	76.49	73.94	71.63
50	88.96	87.95	85.31	81.4	79.39	76.71
55	91.95	90.9	88.14	84.99	81.91	79.07
60	94.8	93.72	90.85	87.55	84.33	81.34
70	100.15	99.02	95.94	92.39	88.9	85.65

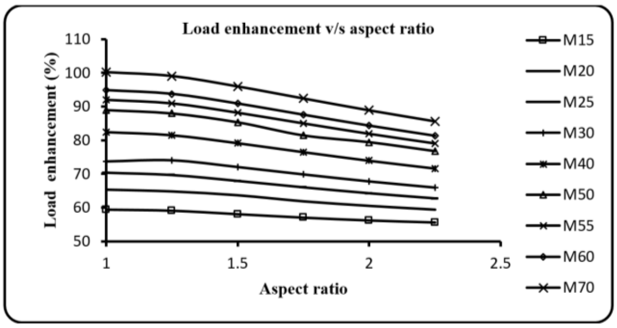

Fig.3. - load enhancement of AAC slabs v/s aspect ratio

2.3 Effect of span-depth ratio

The increment used to change the span depth ratio from 15 to 35 was 5. A graph of the span-depth ratio v/s. load improvements is as shown in Fig. 4. It has been observed that the load enhancement generally increased as the span-depth ratio increases.

Table 3: load enhancement v/s span to depth ratio

CO fck(N/mm^2)	15	20	25	30	35
15	56.05	88.92	143.58	252.1	523.39
20	60.74	91.2	138.87	224.07	419
30	67.81	95.64	137.17	205.89	342.24
40	73.44	99.72	138.16	199.87	316.03
50	78.3	103.49	139.94	197.51	302.99
70	86.69	110.36	144.21	196.78	290.41

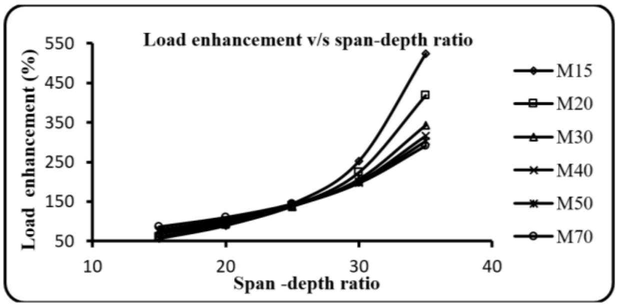

Fig.4. - load enhancement of AAC slabs v/s span-depth ratio

2.4 Effect due to percentage of reinforcement

The slabs contained reinforcement to varying degrees, ranging from 0.2 to 0.8 percent. A plot of reinforcement percentages versus load enhancement is as shown in fig. 5. It has been observed that load enhancement reduced as the percentage of reinforcement increased in slabs.

Table 4. load enhancement v/s percentage of reinforcement

CO fck(N/mm^2)	0.2	0.3	0.4	0.5	0.6	0.7	0.8
30	45.34	45.28	43.78	41.46	38.55	35.14	31.29
40	49.76	49.58	48.2	46.19	43.77	41.01	37.96
50	53.63	53.21	51.77	49.85	47.65	45.21	42.56
60	57.12	56.43	54.86	52.93	50.81	48.53	46.13
70	60.35	59.37	57.63	55.64	53.54	51.34	49.08

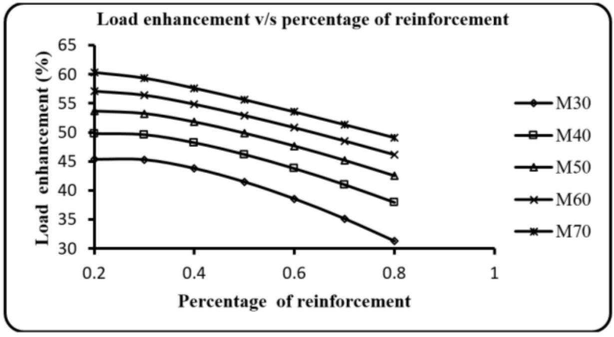

Fig. 5. - load enhancement of AAC slabs v/s percentage of reinforcement

3.0 Conclusions:

Following conclusions are drawn from the present study.

- For all grades of concrete, the load enhancement decreases as the orthotropy coefficient increases.
- As the aspect ratio increases, load enhancement gets decreased.
- The load enhancements were higher as the span-depth ratio increases.
- As the percentage of reinforcement increased, the load enhancement decreased.

References

[1] Wood, R.H. and Armer, "The theory of the strip method for design of slabs, proceedings of institution civil engineers (London), 1968,41,285-307

[2] Park, R."The lateral stiffness and strength required to ensure membrane action at the ultimate load of a reinforced concrete slab and beam floor", Magazine of concrete research, Vol.17,No.50, March1965,pp.29-38

[3] Sawzuck and Wininick,"Plastic behavior of simply supported plates at moderately large deflections",International Journal of solids and structures,Vol.1,No.1,Feb.1965.pp.97-111.

[4] Morley, C.T, "Yield line theory for reinforced concrete slabs at moderately large deflections", Magazine of Concrete Research, Vol 19, 1963, pp. 211-222.

[5] Eyre J R and Kemp K O, "A graphical solution for predicting the increase in strength of concrete slabs due to membrane action", Magazine of Concrete Research, Vol 35(124), 1983, pp 151-156.

[6] Desayi P and Muthu K.U," A brief review on strength, deflection and cracking of rectangular, skew and circular reinforced concrete slabs", Journal of institute of science, Vol 68, Mar-Apr 1988, pp 91-108.

[7] J. Davidovits "Geopolymers: Ceramic-Like Inorganic Polymers." Ceramic Engineering and Science Proceeding, (2017),DOI: 10.4416/JCST2017-00038.

[8] Desayi P and Kulkarni, A.B., load deflection behavior of restrained reinforced concrete slabs, Journal of structural division,ASCE,1977,103,ST2,405-419.(Discussion 104,ST1,231).

[9] Shivaraj G Nayak, R Mourougane. "Strength and Deformation of Rectangular Simply Supported GPC Slab" Recent Trends in Civil Engineering & Technology, volume 9, Issue 1, pages 30.-37,(2019).

[10] Desayi P and Prabhakara A, "Simply supported RC skew slabs", International Journal of Structures (Roorkee), Vol. 7,

1987, p. 119-137.

[11] Prakash Desayi, K.U. Muthu, M.M. Lokesh, “Deflection control of simply supported rectangular RC slabs”, International Journal of Structures, Paper No. 117, IJS Vol 12, NO 1, June 1992, PP 21-38.

[12] Hayea,B,”Allowing for membrane action in the plastic analysis of rectangular reinforced concrete slabs”,magazine of concret research,Vol.20,No.65,Dec.1968,pp.205-211.

[13] Shivaraj G Nayak, R Mourougane “Mechanical properties of High strength Alkali Activated Concrete” Natural Volatiles & Essential oils, 2021; 8(4):5162-5170.

[14] Timoshenko, S. and Woinowsky – Krieger, “Theory of plates and shells”, second edition New York., McGraw-Hill Inc, 1959.

[15] Shivaraj G Nayak, R Mourougane, “Experimental study on load deformation behavior of three edges fixed and one edge simply supported AAC two way rectangular slabs”, Neuro quantology, Vol 20,sep.2022,Issue 9,page 6581-6584,doi:10.14754/nq.2022.20.9.NQ44769.

.