Analysis of reinforced concrete slabs on grade in industrial buildings

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Analysis of Reinforced Concrete Slabs-on-Grade in Industrial Buildings

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Introduction

Aim :
A parametric study was conducted to investigate the theoretical behaviour of industrial slab on grade to industrial trucks with single wheel axles loading.

Objective :
1. Applying NLFEA to study the structural response of industrial slab on grade to lift-trucks with single wheel axle loading.
2. The studied parameters were the load position in relation to slab edges, slab proportions, reinforcement content and its method of arrangement, and the modulus of subgrade reaction.
3. The subgrade was represented by boundary-spring elements of a non-tension feature to simulate the soil-resistance characteristics.
4. The numerical results were compared with the predicted response using the linear finite element

Non-Linear Finite Element Analysis

Finite element model

The code was modified to include boundary-spring elements to simulate the subgrade as a set of orthogonal springs. The vertical spring is a non-tension one that is capable of resisting compressive forces only, permitting the slab lift-off. The horizontal springs were assigned insignificant stiffness to fulfill in-plane stability. The stiffness matrix for the subgrade springs, K_{sub} is given by:

$$Ksub = \begin{vmatrix} Kx & 0 & 0 \\ 0 & Ky & 0 \\ 0 & 0 & Kz \end{vmatrix} \qquad (1)$$

Where K_x and K_y are the stiffness of the horizontal springs, and K_z is the stiffness of the vertical spring.

Analysis procedure

The numerical solution technique adopted for the analysis was an incremental load procedure. Incidentally, this procedure was applied to the sustained loads whereas the own weight of the slab was considered once at the outset. For each load increment, the iterative solution was performed in which the stiffness was reformulated every so often. The convergence criterion used was based on the iterative nodal displacements. The convergence tolerance varied from 1% - 2%.

Parametric Investigation

The studied parameters were the load position in relation to slab edges, slab proportions, the reinforcement content, the method of reinforcement arrangement, and modulus of subgrade reaction. The panels were subjected to two-point concentrated loading representing single wheel axles of lift-trucks with wheel spacing of 1000 mm. High-grade steel reinforcement with yield strength, f_y of 360 MPa was used. Concrete cube strength, f_{cu} was set at 20 MPa. Moduli of elasticity for steel bars and concrete, and modulus of rupture for concrete, were assumed as 200 KN / mm^2, 19.7 KN / mm^2 and 2.68 MPa, respectively.

Typical slab panel

The load-carrying capacity for slab on grade analysed using linear finite element approach is limited by bearing capacity of the subgrade. According to Bowles [16], the allowable bearing capacity, *qa* is related to the modulus of subgrade reaction, *Kz* as follows:

$$Kz = 40\,Fqa \quad \text{KN / m3} \qquad (2)$$

Where *F* is a safety factor

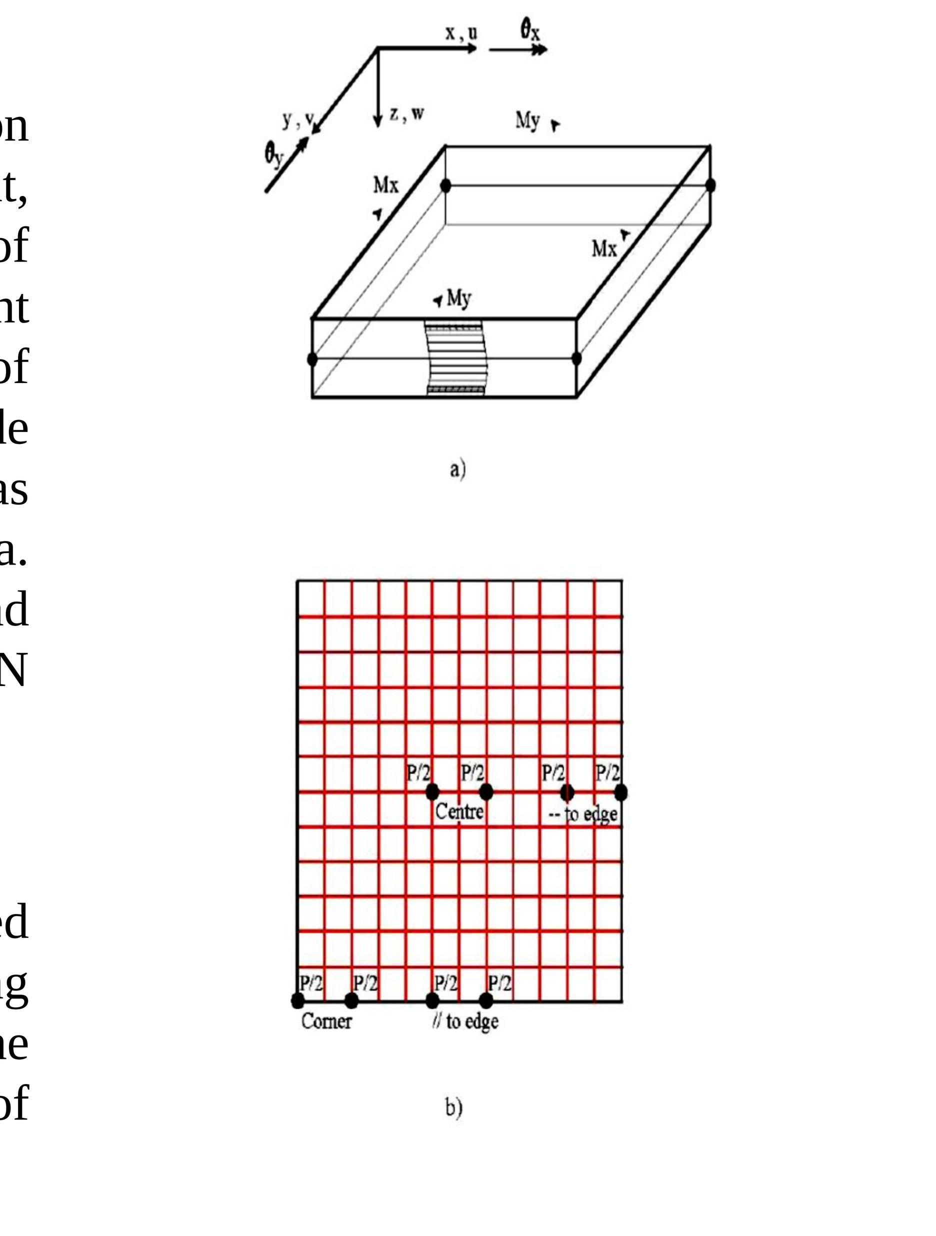

Figure 1 Finite element idealization of slab panels- a) plate-bending layered element and +ve directions of bending moments; b) typical mesh of elements

Results and Discussion

Table 1. Slab panels; details and analytical results

Series	Panel Id.	Load* Position	Thickness+ (mm)	Side Length (mm)	Reinf.	Subgrade Reaction (N/mm³)	Non-Linear Analysis: Cracking Load, $P_{cr.}$ (Kn)	Bearing Load, P_b (Kn)	Failure Load, P_f (Kn)	P_f / P_b	$\Delta_{av.}$ at Failure (mm)	Bearing^x Load, P_l (Kn)	P_b / P_l	P_f / P_l
Typical	RP	Corner	150	6000	5Y8 /m' T	0.020	48.0	68.0	108.0	1.59	0.442	70.2	0.97	1.54
A	LP1E	// to Edge	150	6000	5Y8 /m' T	0.020	60.0	151.4	228.0	1.51	0.582	154.9	0.98	1.47
	LP2E	- to Edge	"	"	"	"	60.0	184.4	312.0	1.69	0.480	196.8	0.94	1.59
	LP3C	Centre	"	"	"	"	120.0	437.2	768.0	1.76	-1.524	470.6	0.93	1.63
B	TH20	Corner	200	6000	5Y8 /m' T	0.020	84.0	95.3	156.0	1.64	0.575	96.6	0.99	1.61
	TH25	"	250	"	"	"	108.0	124.3	216.0	1.74	0.750	124.0	1.00	1.74
	TH30	"	300	"	"	"	156.0	154.2	288.0	1.87	0.959	151.4	1.02	1.90
	TH1.25	"	150 / 187.5	"	"	"	72.0	81.0	144.0	1.78	0.519	82.1	0.99	1.75
	TH1.50	"	150 / 225	"	"	"	84.0	93.2	192.0	2.06	0.655	93.1	1.00	2.06
C	SL300	Corner	150	3000	5Y8 /m' T	0.020	48.0	64.0	108.0	1.69	-1.361	66.8	0.96	1.62
	SL400	"	"	4000	"	"	48.0	68.0	108.0	1.59	0.749	70.2	0.97	1.54
	SL500	"	"	5000	"	"	48.0	68.0	108.0	1.59	0.522	70.2	0.97	1.54
D	PLAIN	Corner	150	6000	---	0.020	48.0	67.9	96.0	1.41	0.401	70.2	0.97	1.37
	RT10	"	"	"	5Y10 /m' T	"	48.0	68.0	108.0	1.59	0.435	70.2	0.97	1.54
	RT12	"	"	"	5Y12 /m' T	"	48.0	68.0	108.0	1.59	0.427	70.2	0.97	1.54
	RTB8	"	"	"	5Y8 /m'T&B	"	48.0	68.0	108.0	1.59	0.439	70.2	0.97	1.54
	RB8	"	"	"	5Y8 /m' B	"	48.0	67.9	96.0	1.41	0.393	70.2	0.97	1.37
E	K0.5	Corner	150	6000	5Y8 /m' T	0.005	48.0	27.0	60.0	2.22	1.036	29.9	0.90	2.01
	K1.0	"	"	"	"	0.010	48.0	43.8	96.0	2.19	0.791	45.6	0.96	2.11
	K3.0	"	"	"	"	0.030	48.0	85.3	108.0	1.27	0.293	90.9	0.94	1.19
	K5.0	"	"	"	"	0.050	60.0	99.5	120.0	1.21	0.213	126.5	0.79	0.95

* Refer to Fig. 1 for positions of fork-lift load
\+ For panels TH1.25 and TH1.50, a margin strip of 500 mm width was thickened
x Load at the allowable bearing capacity according to Eq. 2, resulting from linear finite element analysis and neglecting the slab reinforcement

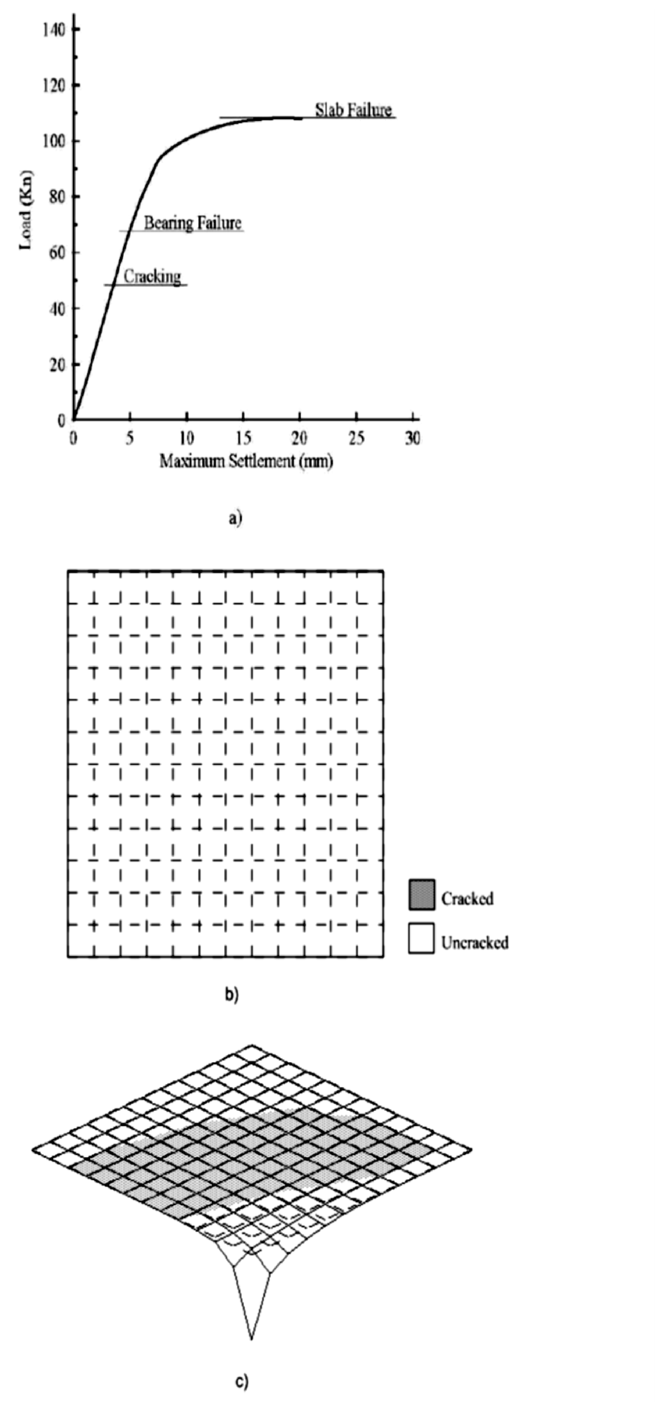

Figure 2 Typical slab panel, RP- a) Load-settlement response; b) Slab cracking at failure; c) Slab deformation at failure

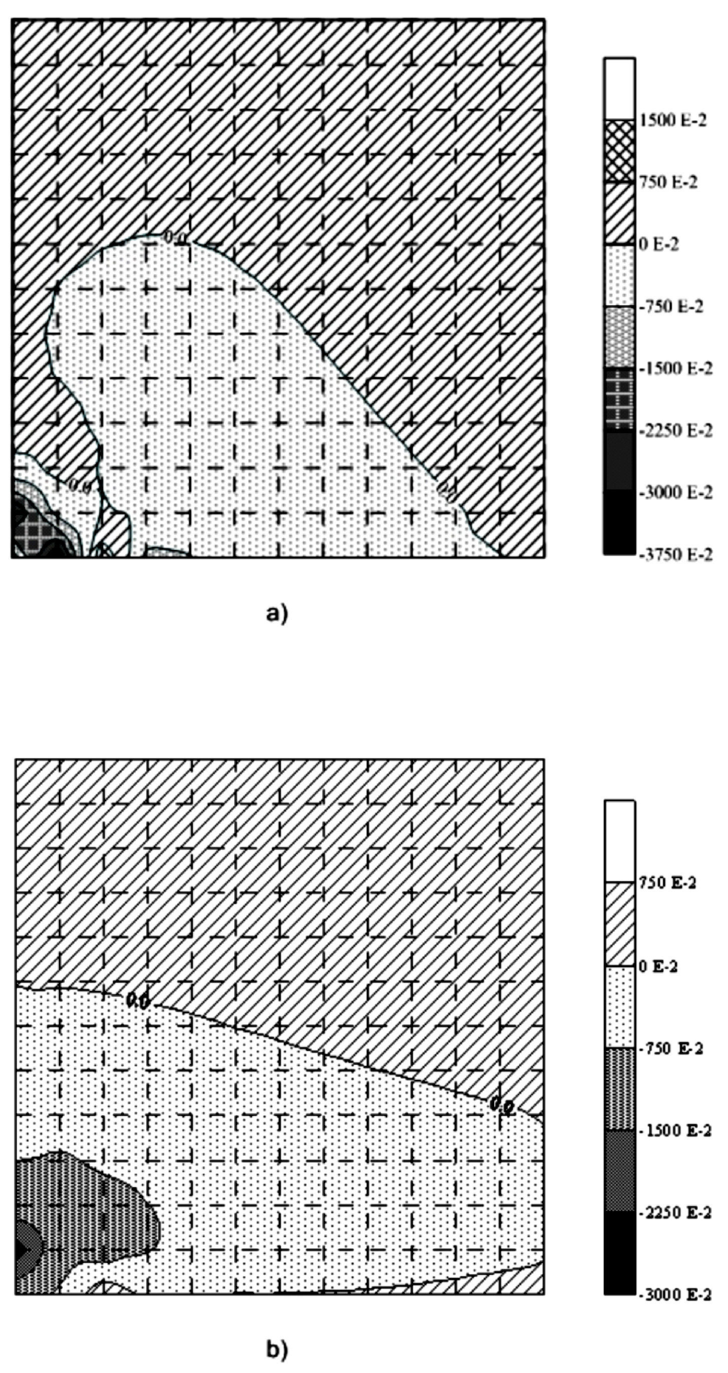

Figure 3 Bending moments at failure- a) moment M_x; b) moment M_y

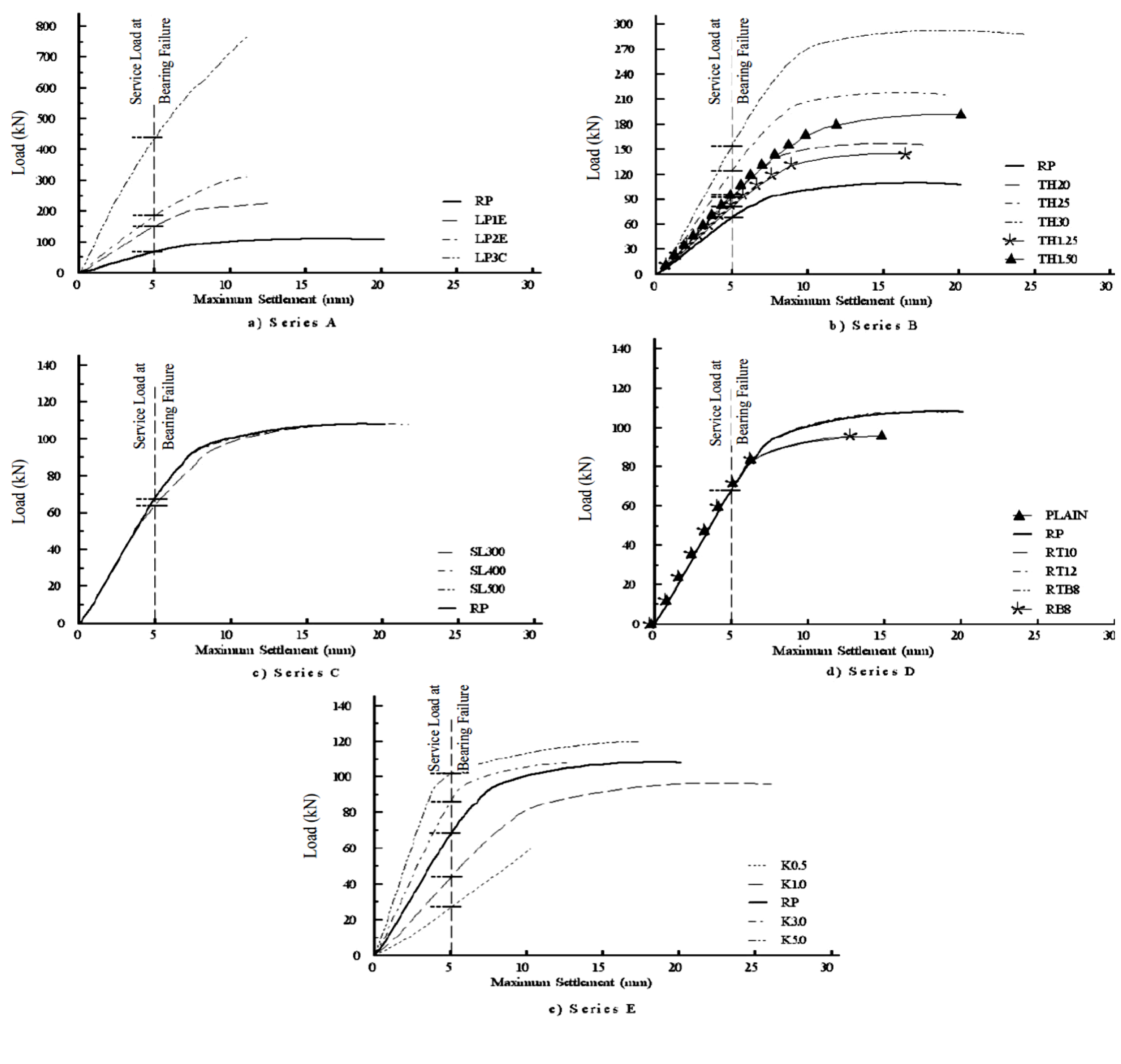

Figure 4 Load-settlement response of the slab panels

Conclusion

Based on the study presented herein, the following conclusions can be drawn:

1- In the practical range of subgrade modulus, adequate results are expected in case the safety factor of bearing capacity is assigned a value close to 7.

2- Slab thickness has a dominant effect on the results of load-carrying capacity.

3- Reinforcement has an insignificant influence on the structural response. It is sufficient to provide the steel reinforcement on the basis of serviceability requirements.

4- Linear finite element analysis yields acceptable load-carrying capacities as compared to the results of NLFEA. Essentially, a typical load-settlement response lasts linear beyond the bearing failure criterion set by Equation 2.