On the Load-Carrying Capacity of Concrete Pavements

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The load-carrying capacity of concrete pavement under central load is investigated. The pavement is treated as a rigid-plastic slab of infinitely large size resting on an elastic subgrade. Under the action of a concentrated load over a small circular area the subgrade reaction is represented by a conical diagram and its variation with displacement is neglected. The same problem was solved by G. G. Meyerhof in the early 60's when he was studying the carrying capacity of concrete pavement under wheel loads. His formulae for central loads are actually upper bound solutions. The exact solution under the above mentioned assumptions is obtained in which the position of the circular yield line is somewhere inside the circle of zero subgrade reaction.

The ultimate load can be expressed as follows

$$P_0 = \frac{4\pi M_0}{1 - \frac{2}{3}\frac{a}{b}\left(\frac{b}{c}\right) - \left(\frac{c}{b}\right)^2 + \frac{1}{2}\left(\frac{c}{b}\right)^3}$$

in which the value of $\frac{c}{b}$ can be determined from the equation

$$4\frac{a}{b} - 12\left(\frac{c}{b}\right)^3 + 9\left(\frac{c}{b}\right)^4 = 0$$

M_0 is the ultimate moment of the slab section, a, b and c being the radius of the circle of the loaded area, of zero subgrade reaction and of the circular yield line respectively.

Ultimate loads for dual, triple and quadriple circular loads and a strip load are also investigated.

The moment curvature relation of a plain concrete section is deduced by considering the existance of horizontal axial thrust in the slab and the gradual cracking of the section. It is interesting to note that the moment curvature relation thus obtained is practically of elasto-plastic type.

The theoretical analysis is simple, and it explains why full redistribution of internal forces to form a collapse mechanism is possible in a large plain concrete pavement as has been observed in the experiments carried out in China in recent years.

DEFORMATION CAPACITY IN REINFORCED CONCRETE SLABS

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Summary

In reinforced concrete slabs at yielding not only the load bearing capacity but the deformations and the cracking process too are greatly influenced by the level of orthotropy and by the divergence in the principal directions of the resistance of the slab and of the external moments. The theoretical and experimental investigations proved that this fact should in some cases be taken into account.

Experimental investigations

Rectangular slabs with fixed corners and with different levels of orthotropy were tested in the Laboratory of the Hungarian Institute for Building Science (ÉTI, Budapest). The details of the test specimens are given in Fig. 3.

The difference in the amounts of reinforcement and in the level of orthotropy altered the load bearing capacity and the yield pattern in the corners of the slabs. Of course in the middle part of the slabs the angle Ψ was equal to zero, but in the corners Ψ differed considerably from zero.

Due to these differences, the behaviour of the slabs during the transition process, the deformations and the crack pattern at the maximum load (at yielding) were different (Fig. 4).

References

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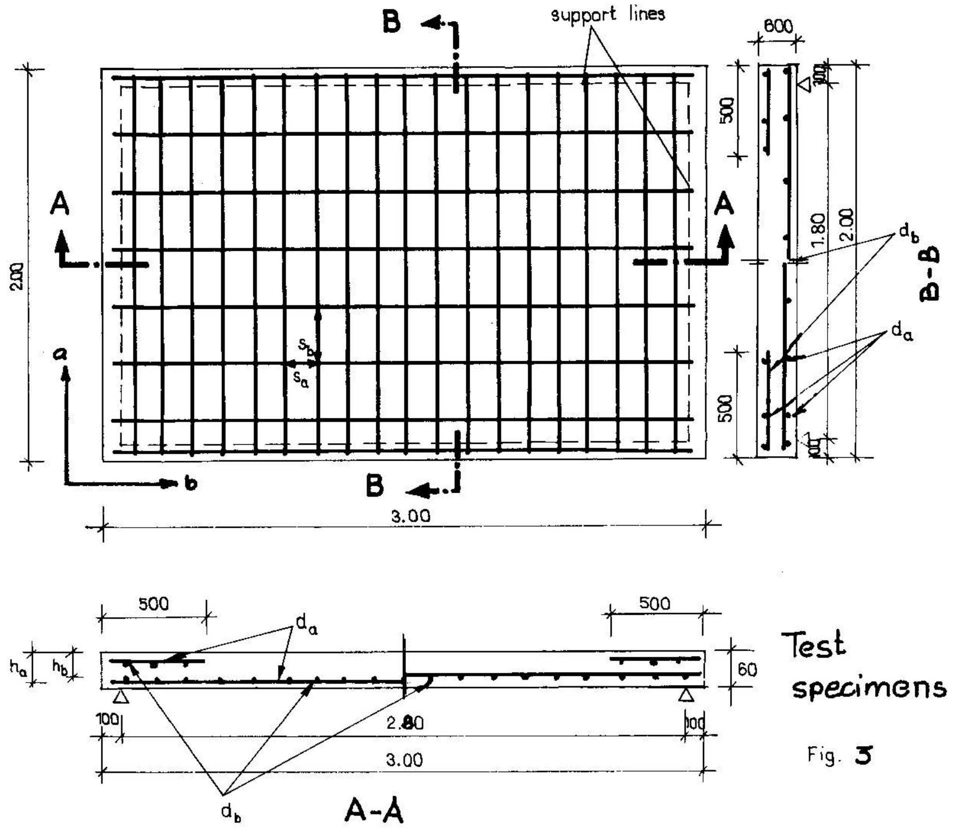

Test specimens

Fig. 3

Reinforcement data (design values)

Slab type and number		s_a mm	s_b mm	d_a mm	d_b mm	A_a mm^2/m	A_b mm^2/m	h_a mm	h_b mm	ρ_a %	ρ_b %	$\lambda = \rho_a / \rho_b$
1	1/1, 1/2	150	200	4,2	4,2	69	92	47,9	43,7	0,144	0,210	0,686
2	2/1, 2/3	150	300	4,2	4,2	46	92	47,9	43,7	0,096	0,210	0,457
3	3/1	200	200	4,2	4,2	69	69	43,7	47,9	0,158	0,144	1,097
	3/2, 3/3							47,9	43,7	0,144	0,158	0,911
4	4/2	100	300	4,2	7,6	46	454	40,3	46,2	0,114	0,987	0,116
5	5/1, 5/2, 5/3	100	150	4,2	7,6	92	454	40,3	46,2	0,228	0,987	0,231

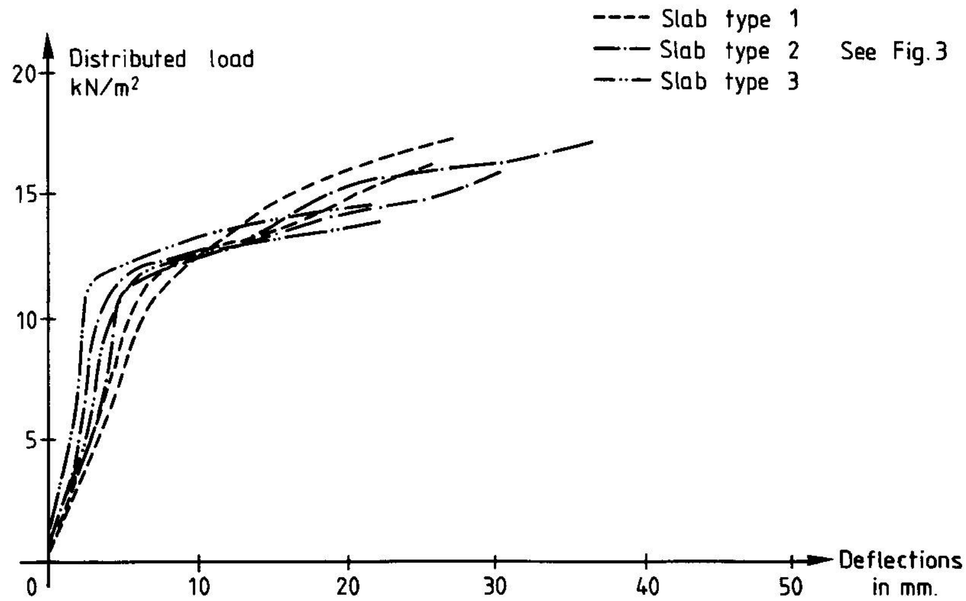

Fig. 4. Deformations of Slabs

Punching of Slabs subjected to In-plane Biaxial Tension

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The punching shear strength of slabs subjected to in-plane biaxial tension is of interest to designers, because this situation can occur in continuous composite steel-concrete bridge decks in regions where a cantilever cross girder intersects a main girder near an internal support, and the neutral axes for bending of the two composite members lie many slab thicknesses below the deck.

Such a region has been studied at the University of Warwick in tests on cruciform specimens composed of two intersecting composite girders, supported at the centre of the cross and subjected to downwards point forces at the ends of the arms. Control of these forces enabled known biaxial tensile strains to be maintained at the top surface of the slab, which was 90 mm thick. There were four layers of reinforcement (8 and 12 mm bars at 150 or 200 mm pitch). The tensile strains at the underside of the slab were about 80% of those at the top surface.

Punching shear tests were done on three quadrants of the same cruciform slab, while the mean tensile strains in the top two layers of reinforcement were 0, 860 and 1730 microstrain, respectively. The corresponding punching loads were 164, 162, and 163 kN. The punch diameter was 120 mm, and the maximum diameter of the punched-out area was about 850 mm (limited by the flanges of the steel girders), giving a mean slope of 14° for the surfaces on which failure occurred.

These results confirm what can be deduced from the upper bound analysis presented by M.P. Braestrup: that membrane tensile strain in a slab has no effect on its strength in punching shear, in the range of strains likely to occur in practice.

DISCUSSION ON POST-PLASTIC BEHAVIOUR OF RESTRAINED SLABS

by I. KANITAKIS, Research Fellow, N.T.U.- Athens

Prof. T.P. Tassios and myself would like to present some very first results of a theoretical investigation related to the problem of post plastic behaviour of Reinforced Concrete slabs, rigidly connected at their ends.

Each span is assumed to be fixed-ended and without any lateral displacement. The slab has equal compression and tension reinforcement along its length. The gradual modification of the bearing mechanisms of the slab are considered qualitatively, through three consecutive models.

The first model is the conventional elastoplastic model. Here, moment redistribution is also considered and the values of the stiffness along the span are variable. There is no axial force in the slab.

The second model is the post plastic one (fig.1). The slab geometry has significantly changed (compressive membrane) contributing to a considerable increase of the ultimate load capacity of the slab. (Negative axial force N).

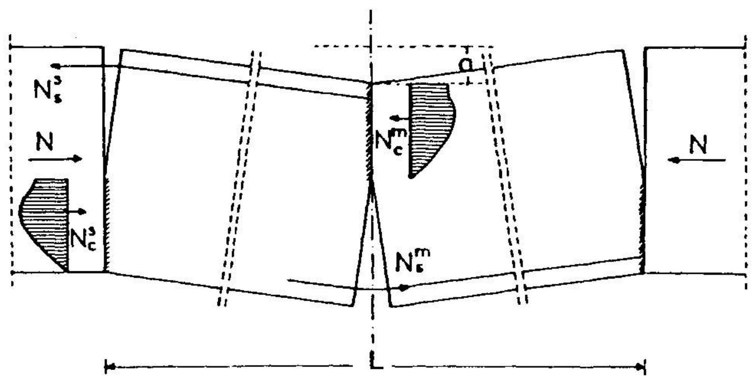

fig.1

The third model is the catenary one, where concrete in critical sections is destroyed and only the steel can carry some load. (Positive axial force N).

The load versus mid-span deflection curve for a slab 120 mm thick and with a percentage of reinforcement of 0.318% is shown in Fig.2. Branch OA is due to the elastoplastic model. Branch AB is due to the post plastic model and branch BC is due to the catenary model. The dotted line in fig.2 shows a more smooth transition curve which should be worked out and theoretically located.

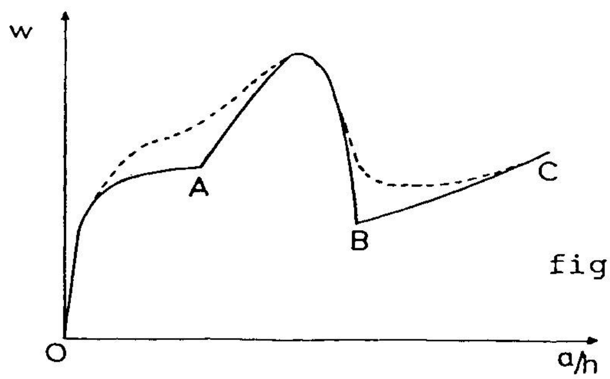

fig.2

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