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Proposed Way of Calculating the Value of the Failure Load in the Span Zone of Slab-Column Structures

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Abstract: In a properly designed slab-column structure the failure of the floor should be signalled by scratches and significant and visible deflections of the floor in the spans. The paper presents two proposed ways of calculating a uniform loading causing the destruction of the central field of a typical slab-column structure. The values obtained in the ultimate state were compared with the value of the load obtained during the experimental research.

Introduction

One of the main factors causing the failure of the slab-column structures is the phenomenon of punching. The threat of such failure can occur in the case of a support zone lacking a transverse reinforcement. The stronger reinforcement over the support is, the higher becomes the threat of a brittle destruction. To be able to utilize the load capacity of the slab reinforcement, the construction must have a guaranteed protection of the structure against a brittle destruction by punching among the columns. In order to determine the limit of the load capacity of a flat slab, two mechanisms of its destruction have to be considered. The first assumes that the destruction of the area of the floor slab can occur in the course of unidirectional fracture (Fig. 1a). In the second mechanism it is assumed that individual slabs can be destroyed independently (Fig. 1b). The first destruction model (Fig. 1a) assumes the following conditions of equilibrium:

$$0{,}125 \cdot q \cdot l_y \cdot (l_x - c_x)^2 \le f_{yd}\left(A_{s,prz} \cdot z_{prz} + 0{,}5 \cdot A^P_{s,pod} \cdot z^P_{pod} + 0{,}5 \cdot A^L_{s,pod} \cdot z^L_{pod}\right) \tag{1}$$

c_x, c_y – the width of the support,

$A_{s,prz}$ – the cross section area of the bottom reinforcement of the central part of the span along its width;

$A^P_{s,pod}, A^L_{s,pod}$ – the cross section area of the upper reinforcement above the left and right support;

$z_{prz}, z^P_{pod}, z^L_{pod}$ – the arm of internal forces in the centre of the span, and above the right and left support.

The second destruction model (Fig. 1b) assumes the following conditions of equilibrium:

$$\frac{q \cdot l_x \cdot l_y}{8}\left(\frac{l_x + l_y}{2} - 2c + \frac{4}{3}\frac{c^3}{l_x \cdot l_y}\right) \le \frac{f_{yd}}{2}\left(z_{prz} \cdot \left(A_{s,prz,x} + A_{s,prz,y}\right) + \left(A_{s,pod,x} + A_{s,pod,y}\right) \cdot z^P_{pod}\right) \tag{2}$$

$A_{s,prz,x}, A_{s,prz,y}$ – the cross section area of the bottom span reinforcement in the central part of the span, working in directions x and y and summarized from the entire width of the span;

$A_{s,pod,x}, A_{s,pod,y}$ – the cross section area of the average upper support reinforcement of two supports for directions x and y and summarized from the entire width of the span;

z_{prz}, z_{pod} – average arm of internal forces for the span and support respectively.

Description of the experimental model

In order to verify the presented formulas the laboratory research of the central part of a slab-column floor with the dimensions 3000×3000×100 mm has been conducted (Fig. 2). The model loading was induced with a set of hydraulic actuators of the load range up to 4.0 T. The substitute value of the uniform variable load was 69.76 kN/m^2 above the dead load of the investigated element. In the initial phase of the conducted research two distinct directions of scratches in the bottom surface of the investigated element were observed:

- latitudinal scratches propagating in the form of concentric circles relative to the centre of the model,
- meridional scratches propagating in the form of straights lines beginning in the centre of the model.

From the value of load equal to ca. 60% of the maximum load on the lower and upper surface of the model an image of a scratch consistent with Fig. 1b started to emerge.

a) b)

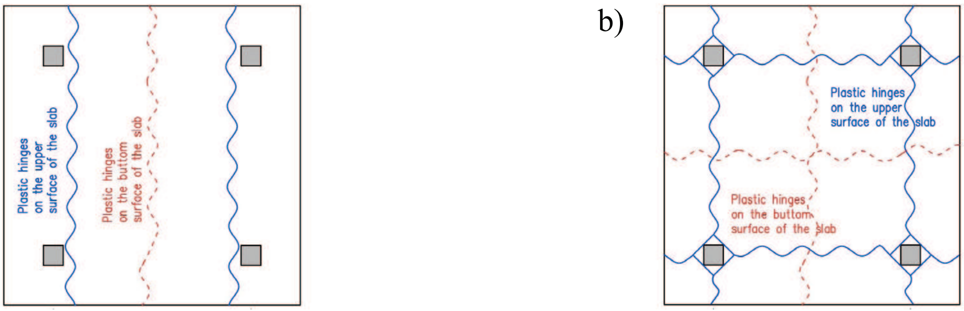

Fig. 1: Patterns of destruction of the internal area of a continuous slab (described in the text)

a) b)

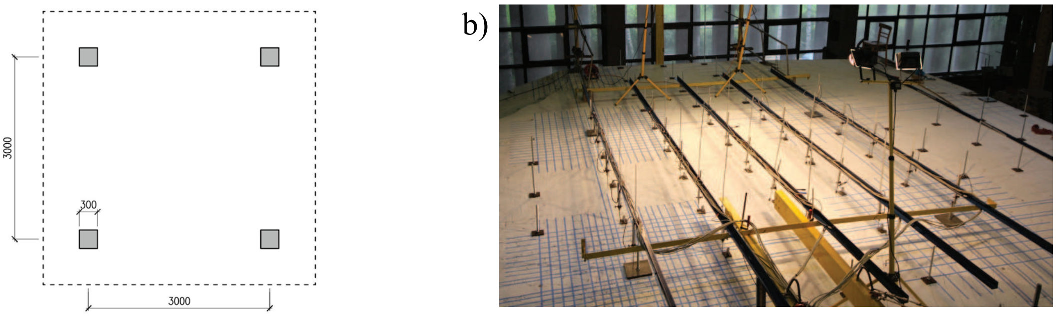

Fig. 2: Test model: a) the dimensions of the model, b) view of the model

Summary

Reinforced concrete slab-column structures are very often used in municipal, industrial and service buildings. Their improper utilization or improper way of building can lead to their destruction through the emergence of punching in support zones or rupturing of the reinforcing bars in the centre of the slab. The value obtained in the course of the loading was significantly higher than the value of loading obtained on the basis of the presented formulas. Such considerable difference results from the change of the behaviour of the test element. At zero or a small deflection of the central area of the tested element in cross-section only bending moment occurs (flexural work of element). With the increase of deflection in cross-section an additional membrane forces also appear (tension work of element).

References

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