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Punching Resistance of Flat Slabs

Ľudovít Fillo[a], Tomáš Augustín[b], Ján Hanzel[c], Veronika Dvoranová[d]

Faculty of Civil Engineering at SUT in Bratislava, Radlinskeho 11, 81368 Bratislava, Slovakia

[a]ludovit.fillo@stuba.sk, [b]tomas.augustin@stuba.sk,
[c]jan.hanzel@stuba.sk, [d]veronika.dvoranová@stuba.sk

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Abstract: Results of latest experiments have revealed that the maximum punching resistance defined from crushing of concrete struts at the perimeter of a column is an insufficient criterion for limitation of maximum shear forces at the vicinity of the columns. Therefore further limitation has been accepted.

Limits of punching resistance

There are two possible ways of structural failure due to the punching. The first one is strut diagonal failure (crushing of concrete) at control perimeter u_0 of the column. The second one is the shear-tension failure of concrete or transverse reinforcement in area surrounded by the basic control perimeter u_1.

The maximum shear force was limited by compressive capacity of the struts at the column perimeter. The new limit is based on the punching resistance of a member without shear reinforcement $v_{Rd,c}$, Eq. 1.

$$v_{Rd,cs} = 0.75 v_{Rd,c} + \left(\frac{1.5.d}{s_r}\right)\frac{A_{sw}.f_{ywd,ef}}{u_1.d} \leq k_{max}.v_{Rd,c}. \tag{1}$$

Punching failure depends also on a position of column in plan of a building [4]. There are several types of column - slab contacts illustrated on typical flat slab plan - Fig. 1. By taking into account the loading area of the column, there is a possibility to substitute the influence of imbalanced bending moments and taking the coefficient β=1. For this decisive loading area, column C, graphs of relation between the design uniform distributed load and the heights of flat slab were created.

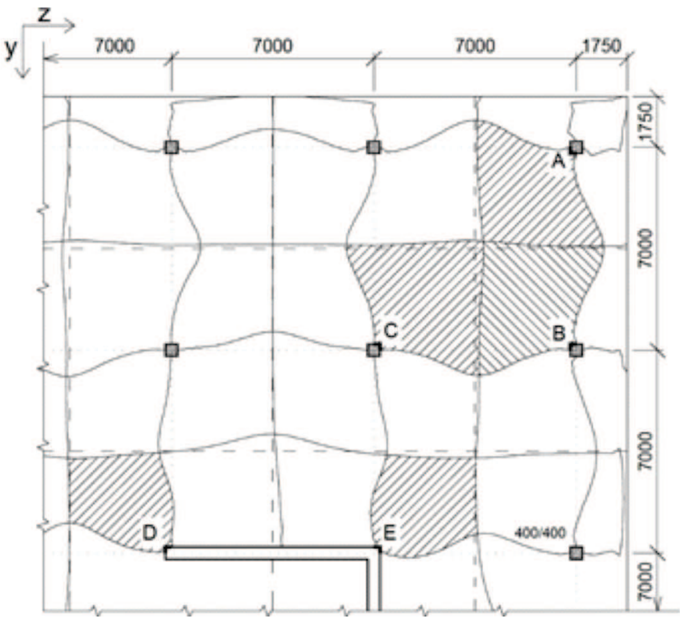

Fig. 1: Analyzed plan of flat slabs

Analysis of minimum flat slab height

The graph in Fig. 2 was created for typical floor of the building (Fig. 1) with flat slabs and column distance of 7 m. By design of flat slab height 175 mm the shear-tension failure arises by load 11.5 kN/m^2 - ρ = 0.005 and 14.5 kN/m^2 - ρ = 0.01. The shear-tension failure precedes the failure of diagonal struts, which should arise by 22.9 kN/m^2. Diameter of main slab bars was ϕ18 and concrete cover 28 mm. The maximum allowable deflection (1_y/250), was reached also by this thickness of slab 175 mm. The nonlinear deflection with cracks and creep of concrete was simulated according to the scheme of Fig. 1 using program Scia Engineer.

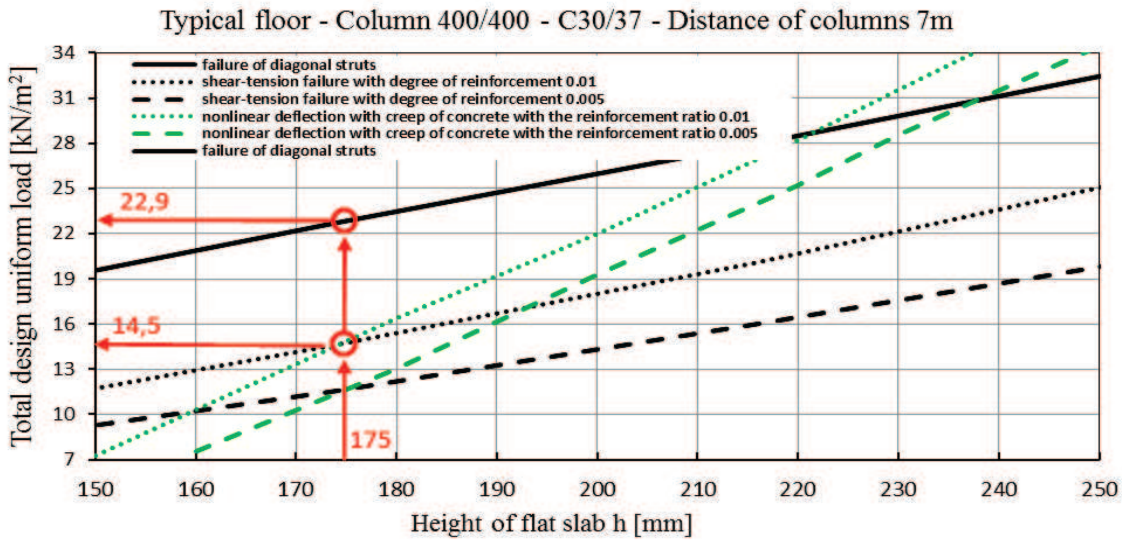

Fig. 2: Minimal flat slab heights for distance of columns 7 m, typical floor (column C-Fig. 1), C30/37, main horizontal reinforcement ϕ18, ρ = 0.01 a 0.005; k_{max} = 1.9.

Conclusions

The problem of flat slab punching was presented in the paper. Coming from limits of shear resistance by CEN TC250 SC2 there was an option to create graphs for control of minimal necessary height of flat slabs. The surrounding of central column C (Fig.1) was analysed for two grades of slab reinforcement ratio 0.01 and 0.005. The presented analyses were carried out with k_{max}=1.9 where shear reinforcement consists of double headed studs. By all analysed cases the shear-tension failure precedes the failure of diagonal struts and so decides about the height of flat slabs.

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