21st International Conference **ENGINEERING MECHANICS 2015**
Svratka, Czech Republic, May 11 –14, 2015
Paper **#025, pp. 82–83**

Statistical Safety Evaluation of EC2 and MC 2010 – Model for Assessment of Punching Resistance of Footings

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Keywords: reinforced concrete, foundation footings, punching, shear resistance.

Abstract: Assessment of punching resistance according to EC2 is based on the empirical model which was introduced in the Model Code 1990. In the current Model Code 2010 is presented a new physical model which is based on the *"Critical Shear Crack Theory"* by Muttoni and Schwartz [1]. Calculation of punching resistance of foundation slabs and footings was derived in both models using the principles which are valid for flat slabs. In addressing this issue it opens a space for discussion and analysis of possibilities to update, these models in a case of foundation members.

Introduction

The assessment of punching resistance of foundation members without shear reinforcement in EC2 is based on iterative process where the critical control perimeter u_{crit} has to be found. Distance of this perimeter measured from the face of a column is a_{crit}. For each size and type of the foundation footing is the distance a_{crit} different. In Tab.1 are introduced distances a_{crit} which were derived for footings with different shear slenderness and effective depth. For intermediate values the linear interpolation can be used.

Tab. 1: Dependence $a_{i.crit}/d_i$ on the shear-span-depth-ration a_i/d_i for effective depth d_i

$d_{i.\text{footing}}$	a_i/d_i	0,8	0,9	1,0	1,2	1,3	1,4	1,5	1,6	1,7	1,8	2,0	2,1	2,2	2,4	2,5
200	$a_{i.\text{crit}}/d_i$	0,40	0,45	0,49	0,57	0,62	0,66	0,70	0,74	0,79	0,83	0,91	0,96	1,00	1,08	1,13
400	$a_{i.\text{crit}}/d_i$	0,38	0,41	0,45	0,52	0,56	0,60	0,63	0,67	0,71	0,74	0,82	0,85	0,89	0,96	1,00
750	$a_{i.\text{crit}}/d_i$	0,36	0,39	0,42	0,48	0,52	0,55	0,58	0,61	0,64	0,68	0,74	0,77	0,80	0,87	0,90
1100	$a_{i.\text{crit}}/d_i$	0,34	0,37	0,39	0,45	0,48	0,51	0,54	0,56	0,59	0,62	0,68	0,71	0,73	0,79	0,82
1450	$a_{i.\text{crit}}/d_i$	0,33	0,36	0,38	0,43	0,46	0,49	0,51	0,54	0,57	0,59	0,64	0,67	0,70	0,75	0,78

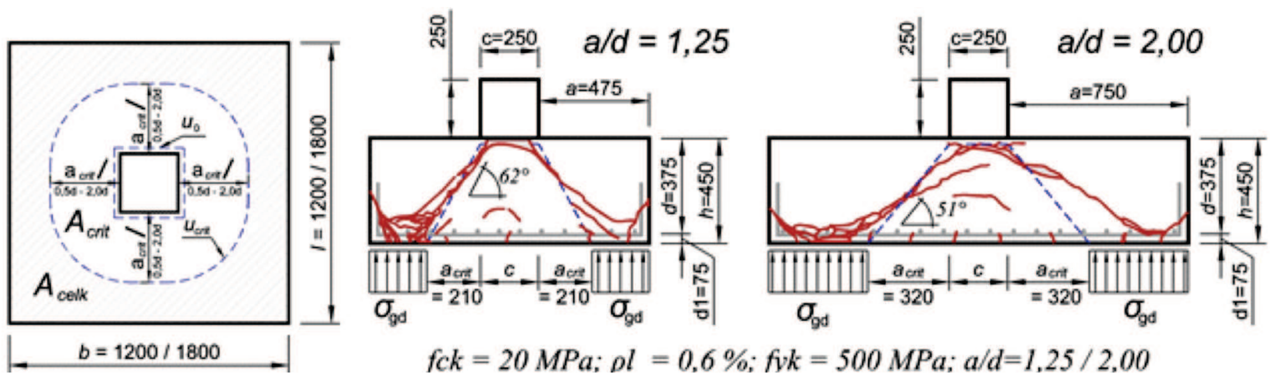

Fig. 1: Influence of shear slenderness a/d on the position of a_{crit}

Punching resistance V_{Rdc} [MN] can be determined according to the (1) as the product of shear strength v_{Rdc} [MPa] and the area surrounded by the critical control perimeter over the effective depth d [m]. The punching resistance then can be expressed as:

$$V_{Rd,c} = v_{Rd,c} * u_{crit} * d \text{ [MN]} \quad (1)$$

$$v_{Rd,c} = C_{Rd,c} * k_h * (100 * \rho_l * f_{ck})^{1/3} * (2d / a_{crit}) \geq v_{min} * (2d / a_{crit}) \text{ [MPa]} \quad (2)$$

The ratio $2d/a_{crit}$ [-] represents the favorable effect of concrete struts to shear resistance.

MC2010 model determines punching resistance without shear reinforcement V_{Rdc} depending on the development of the critical shear crack. The critical shear crack development depends mainly on the slab rotation ψ at the support. The shear resistance of structure without shear reinforcement can be determined as:

$$V_{Rd,c} = k_\psi * (f_{ck})^{1/2} / \gamma_C * b_0 * d_v \geq V_{Ed,red} \text{ [MN]} \quad (3)$$

Rotation of the structure ψ is expressed by factor k_ψ, which takes into account size effect, shear slenderness, aggregate size, and strains in the main reinforcement, e.g. bigger diameter of the aggregates increases the wedge effect of grain in a shear crack and increases resistance V_{Rdc} [MN]. It has to be noted that the model was primarily derived from the tests of the flat slabs [2], [3], [4] and then extrapolated to massive structures such as footings, foundations strips and slabs.

Both models were exposed to statistical evaluation of the safety using results of 48 experimental tests performed on the foundation footings with different shear slenderness and effective depth. The statistical analysis has shown that the EC2 model is pretty safe because $P_{k,0.05}$ is significantly higher than 1. Opposite current MC2010 model seems to be better calibrated with $P_{k,0.05}$ approaching to 1. Update of MC2010 improved precision of the model but due to the high value of COV the safety of the model descended deep below 1.

Tab. 2: Statistical evaluation of safety models EC2 a MC2010

Model	$C_{Rk,c}$ [MPa]	Factor k_ψ	Number of experiments [n]	The average value of [m_x]	Coefficient of variation [V_x]	The characteristic value [$P_{k,0.05}$]
EC2	0,180	-	48	2,408	0,2448	1,388
EC2[1)]	0,240	-	48	1,806	0,2448	1,041
MC2010	-	MC2010	48	1,566	0,2226	0,955
-	-	CCST EC2	48	1,284	0,2181	0,800

[1)] Update of the EC2 model by different value of $C_{Rk,c}$

References

[1] A. Muttoni, J. Schwartz, Behaviour of Beams and Punching in Slabs without Shear Reinforcement, In: IABSE Colloquium, Vol. 62, Zurich, Switzerland, 1991, pp. 703-708.

[2] A. Muttoni, M. Fernández Ruiz, Shear strength of members without transverse reinforcement as function of critical shear crack width, ACI Structural Journal, 105 (2008) 163-172.

[3] A. Muttoni, M. Fernández Ruiz, The levels of approximation approach in MC 2010: applications to punching shear provisions, Structural Concrete, Ernst&Sohn, Germany, 13 (2012) 32-41.

[4] C. Siburg, M. Ricker, J. Hegger, Punching shear design of footings: critical review of different code provisions, Structural Concrete, Ernst&Sohn, Germany, 3 (2014) 1-27.