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Behaviour of Wall/Slab Joint Reinforced by Headed Studs

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Abstract: This paper deals with behaviour of headed studs which are used for reinforcing of concrete structures. Numerical simulations of wall/slab joints reinforced by headed studs were carried out to find if there was some increase of wall/slab joint capacity due to the compressive zone in the joint. It was found that there is an increase of capacity of headed studs due to the compressive zone and the coefficient of capacity increase was introduced.

Keywords: Anchorage; Concrete; Headed Studs; Tensile Capacity; Wall/Slab Joint.

1 Introduction

Continuity systems where reinforcement has to be bent out are usually used for continuous and non-interrupted concrete casting. Limitation of these systems is reinforcement diameter which varies up to 16 mm. The reason is simple, reinforcement has to be bent out in situ and larger diameter of reinforcement cannot be bent out manually. This problem can be solved by the anchorage systems which allow additional connection of the reinforcement to the casted headed studs (eg. KS ANCON Threaded Headed Studs). These systems are very suitable to attach the perpendicular structural members to the main casting direction. There exists so called Concrete Capacity Design (CCD) to design the capacity of headed studs in tension. This method presumes that concrete is broken out with the headed stud in the shape of pyramid. According to this method the capacity of joint between the wall and slab reinforced by headed studs can be designed. None the less this method does not take into account the influence of the compressed part of the slab which affects the shape of the breakout pyramid shape (Fig. 1). Main aim of this paper is to find if there is any influence of the compression on the anchorage capacity and if yes then quantify this influence.

2 Concrete Capacity Design Approach

Concrete Capacity Design (CCD) method was properly described by Fuchs et al. in 1995 [1]. This compact CCD method is based on 1200 test results from all-around the world and showed that it can predict failure of any type of anchorage member including group of anchors and close edge influence. CCD abandoned presumption of corrugated cone shaped failure surface and it was replaced by idealized pyramid breakout shape with the length of base equalled to $3h_{ef}$ (Fig. 2). The inclination between the concrete surface and failure surface is approximately 35 degrees. Concrete failure capacity in tension N is governed by Eq. 1:

$$N = k \cdot h_{ef}^{1,5} \sqrt{f_c} \tag{1}$$

where N is capacity of single anchor in tension [N], k is coefficient equalled to 15.5, h_{ef} is effective embedment depth [mm], f_c is compressive strength of concrete [MPa].

3 Numerical Analysis

There was simulated behaviour of wall/slab joint reinforced by headed studs. The motivation of this part was to examine the influence of compression zone on the concrete breakout capacity of the anchors. The compression zone is caused by bottom surface of the slab which is pushing against the concrete breakout cone.

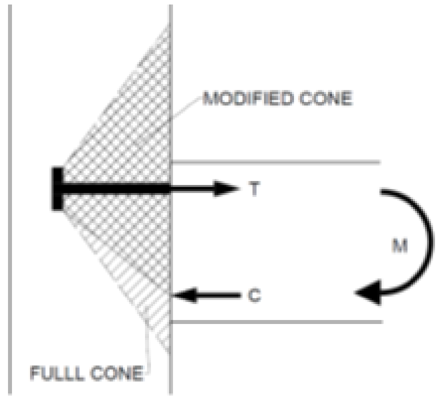

Fig. 1: Influence of the compression area on the shape of breakout cone.

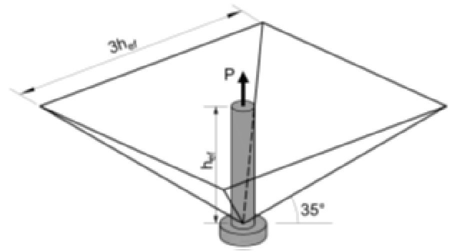

Fig. 2: Theoretical failure surface in shape of pyramid presented in CCD approach.

There exists presumption that the capacity can be assumed higher than analytically calculated because of this compression on the concrete breakout cone. This effect was investigated by only few researches with different quantification of the compression zone on the anchor capacity in wall/slab joint [2, 3]. However all of them confirmed some increase due to this effect. The capacity increase due to compressed area found by Zhao and Bruckner is presented in Fig. 3 in dependence on slab depth to embedment depth ratio.

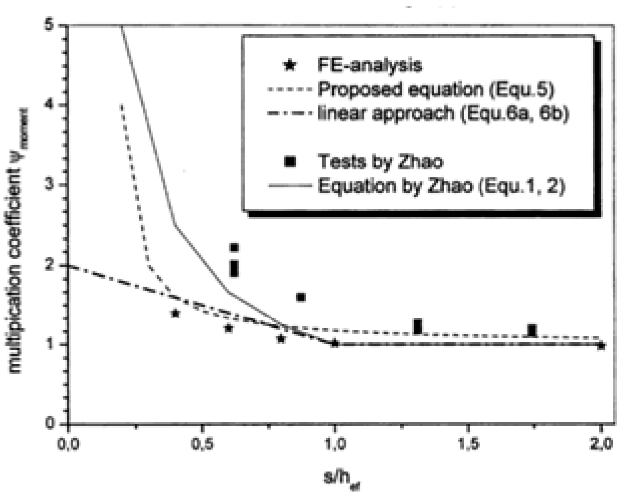

Fig. 3: Multiplication coefficient ψ_{moment} as function s/h_{ef} proposed by Bruckner and compared to results of Zhao [3].

ATENA software was used for the simulations of wall/slab joint behaviour. Wall/slab joints with three embedment depths of the anchors h_{ef} = 100, 125 and 150 mm were created and loaded by displacement at the end of the slab (Fig. 4). The head was rectangular with the side length 60 mm (30 mm for h_{ef} = 125 mm). Displacement was applied in the distance 1 mm from the face of the wall so the theoretical moment in connection was equalled to the loading force or vertical reaction R_y, respectively. Depth of the slab varied from 75 mm (h_{ef} = 100 mm) to 400 mm (h_{ef} = 150 mm). Distance between top of the slab and top reaction R_x varied to ensure $h \geq 2.5h_{ef}$ so the influence of the top R_x on the concrete breakout cone capacity was diminished. Two different approaches were used for the simulations of wall/slab joints. Joints reinforced by anchors with embedment depth equalled to 100 and 150 mm were simulated as single anchors with minimal distance from the edge $1.5h_{ef}$ and joints reinforced by anchors with h_{ef} = 125 mm were simulated with four anchors with horizontal spacing s = 150 mm and distance from the edge c = 75 mm.

Concrete material model used for all models was Microplane 4 (MP4) with the compressive strength f_c = 30 MPa. Von Mises steel material model with hardening and yield strength f_y = 550 MPa was used for the support and load transfer plates. Reinforcement was modelled as discrete bars with the yield strength 550 MPa and 12 mm in diameter of bottom reinforcement in all cases and diameter 16 mm or 20 mm for h_{ef} = 125 mm or h_{ef} = 100, 150 mm, respectively.

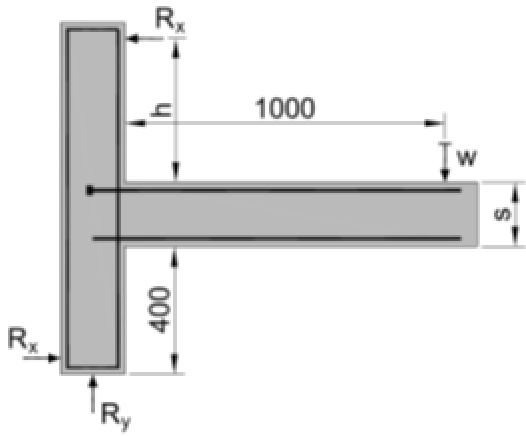

Fig. 4: Geometry of wall/slab joint reinforced by headed studs – side view.

4 Results of Numerical Simulations

There was observed slight increase of the capacity due to the compressive zone when the lever arm z was shorter than 2.0 h_{ef} (Fig. 3). This effect is raised when horizontal spacing between the anchors was lower than $3h_{ef}$ (Fig. 4). The coefficient of the increase due to the compressive area influence in the wall/slab joint was based on the results of the simulations. It is modified coefficient presented by Bruckner and also includes the effect of horizontal spacing:

$$\psi_{\mathrm{moment}} = \left(\frac{1}{1.05 - 0.1\frac{h_{\mathrm{ef}}}{z}} \right)^{\frac{3h_{\mathrm{ef}}}{s}} \quad \text{for} \quad \frac{h_{\mathrm{ef}}}{z} \leq 2.0, \tag{2}$$

$$\psi_{\mathrm{moment}} = 1.0 \;\; \text{for} \;\; \frac{h_{\mathrm{ef}}}{z} \geq 2.0, \tag{3}$$

where s is horizontal spacing of anchors [mm], z is lever arm of tensile and compressive force considered [mm].

The coefficient considered that the influence of the compressive area can be observed at the value $z/h_{ef} \leq$ 2.0. The value 2.0 was set based on the previous research of the influence of distance of the support ring on the capacity of anchor. It was found that the support can affect the capacity of the anchor if it had been closer than approximately $2h_{ef}$.

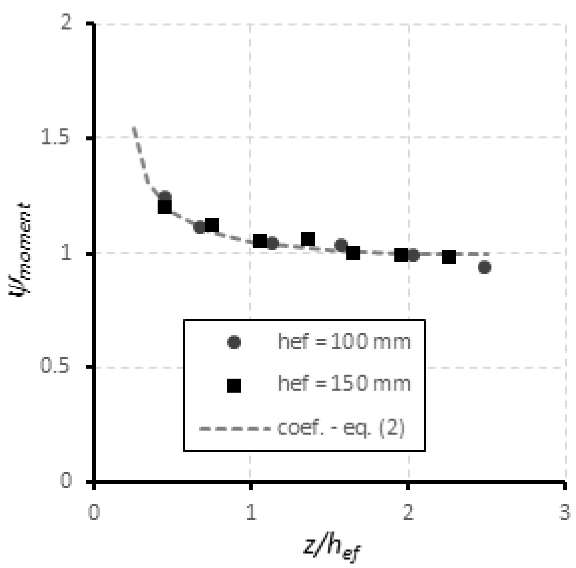

Fig. 5: Moment capacity increase due to compression zone effect (single anchors).

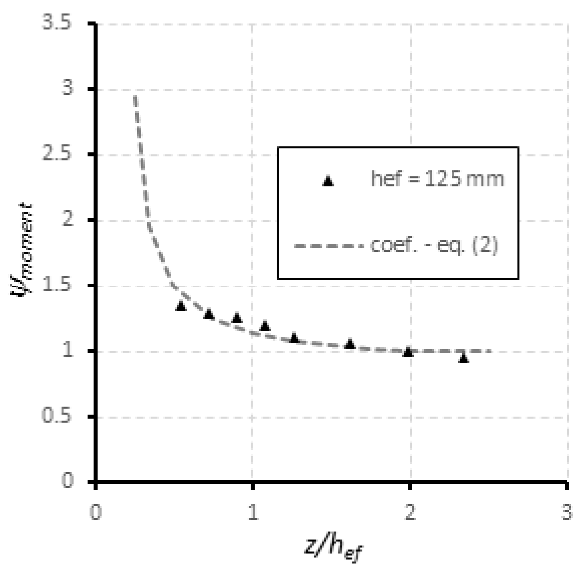

Fig. 6: Moment capacity increase due to compression zone effect (four anchors).

5 Conclusion

The simulation of wall/slab joint reinforced by headed studs' behaviour is presented in this paper. The motivation of this research was to examine the influence of compression zone on the concrete cone capacity of the anchors. The compression zone is caused by bottom surface of the slab which is pushing against the concrete breakout cone. There exists presumption that the capacity can be assumed higher than analytically calculated because of this compression on the concrete breakout cone. This effect was investigated by only few researches with different quantification of the compression zone on the anchor capacity in wall/slab joint. However all of them confirmed some increase due to this effect. Three different numerical models with different embedment depths, each with variable slab thickness were created. There was observed slight increase of the capacity due to the compressive zone when the lever arm z was shorter than $2.0h_{ef}$. This effect is raised when horizontal spacing between the anchors was lower than $3h_{ef}$. The coefficient of capacity increase due to the short lever arm was introduced in this paper.

Acknowledgement

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