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Headed fastenings acting in cooperation with supplementary steel reinforcement

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Abstract

Composite and precast concrete structural systems are becoming the first choice for many construction designers. Headed fastenings are currently a relatively common technique to create joints in such types of structures. Performance of fastenings usually depends on load capacity of the concrete surrounding the fastening. The resistance of the fastening may be increased by using supplementary reinforcement designed in order to prevent concrete cone failure. The background of current design methods and experimental research is discussed in the paper.

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Keywords: headed fastening; design methods; supplementary reinforcement.

1. Introduction

The appropriate design and performance of structural joints are very important preconditions for durability and effectiveness of structures. In current practice, there are many types of fastening systems using in building structures as part of joints. But requirements of high load capacity present preferable advantage especially for cast-in-place anchorage systems. Headed fastenings made of rebar or smooth steel appertain presently to the attractive solution. This type of anchors currently represents a relatively popular technique to create joints in composite structures because it is more compact than other available systems. The proper design and detailing of anchors and joints may be quite complex in some cases. Due to a gap between the design of fastenings in concrete and steel design and missing concerted standardised joint solutions it may lead to unnecessarily conservative results. For designing of anchors could be used available approaches, namely CEN/TS 1992-4[1], fib Bulletin No. 58 2011[2], INFASO [3]. The research and studies focused on headed fastening have been executed at the Faculty of Civil Engineering of the Žilina University.

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2. Scope of research

The aim of our research should be a better understanding of the headed fastening behaviour subjected to tension load and identification of some the factors influencing the fastening capacity. In this part of work we try to compare interim results with current methodologies that describe the behaviour of anchors. Interim tests are essential for preparing and calibrating future experimental more ample testing programme. Performance of fastenings usually depends on load capacity of the concrete surrounding the fastening. The resistance of the fastening may be increased by using supplementary reinforcement designed in order to prevent or delay the formation of concrete cone. The supplementary hanger reinforcement can be used in form of hooks, loops or stirrups. The study is focusing on determination of this type of reinforcement contribution that can be generally taken into account too conservatively.

3. Failure modes of individual headed anchor subjected to tension load

3.1. CEN/TS 1992-4-2 [1]

The design of headed fastenings is regulated by the technical specification CEN/TS 1992-4-2[1] that defines a set of verifications for different failure modes of headed fasteners loaded in tension. The load capacity of a fastener is governed by its geometry, position in concrete member and materials properties of concrete and steel. Non-reinforced anchorage typically exhibit five possible failure modes in the case of tension loading. These consist of following: pull-out failure (Fig. 1(a)); concrete cone failure (Fig. 1(b)); steel failure (Fig. 1(c)); splitting failure (Fig. 1(d)); blow-out failure (Fig. 1(e)).

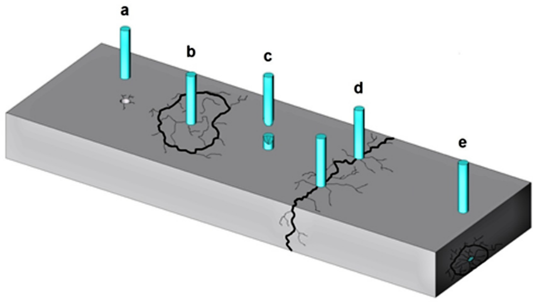

Fig. 1. Failure modes of headed anchors.

The resistance of an anchorage system is due to concrete cone failure obtained from the capacity of one anchor without influence of concrete member edges. In such conditions, the characteristic resistance of this anchor according to CEN/TS 1992-4-2 [1], is

$$N^0_{Rk,c} = k_{cr} \cdot \sqrt{f_{ck,cube}} \cdot h^{1.5}_{ef} \tag{1}$$

where k_{cr} - factor taking into account the influence of load transfer mechanisms for applications in concrete as a function of concrete situation, especially concrete with or without cracks; $f_{ck,cube}$ – characteristic compressive cubic strength of concrete; h_{ef} -effective embedment depth of fastening in concrete.

In order to increase the resistance of the fastening against concrete cone failure, a common practice is the use of supplementary reinforcement around the fastening. After the concrete cone crack surface is formed, the reinforcement acts on keeping the concrete cone and member together. In such conditions not only the resistance of the anchorage is increased but also the ductility. So, the supplementary reinforcement delays or prevents the formation of a concrete cone, and therefore two new failure modes may occur:

- Steel failure of the supplementary reinforcement (Fig. 2(a))
- Anchorage failure of the supplementary reinforcement in the concrete cone (Fig. 2(b))