AN OVERVIEW OF POST INSTALLED MECHANICAL ANCHORING SYSTEMFOR USE IN CONCRETE

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***Abstract:*Post installed anchors are being increasingly useful in construction and civil engineering. Post installed connection allows greater flexibility for the design of new structural systems and strengthening of existing structure. There are some major consequences of failure of anchorage system due to improper design of connections. The accurate design of post installed connections should be done using relevant guidelines. In this research paper we have discussed design parameters of post installed mechanical anchors as well as working principle, failure modes. This paper includes illustrative design example which refers documents of EOTA publications such as European Technical Approval Guidelines (ETAG) and European Assessment Documents (EAD) and makes use of software.**

***Index Terms*- post installed, HST3, EOTA, design resistance, concrete.**

I. INTRODUCTION

Fastening technique is used in a wide range of the construction industry. By co- operation between industry and research more economical and safe fastening systems have been and will be developed, which work well in cracked and uncracked concrete. Engineers use special software for the selection of fastening systems and the design of fastenings.
In a sustainable society, structures and infrastructures must, from time to time, be adjusted to meet new demands. The capacity and/or service life of structures typically must be increased to comply with these new requirements, and this increase requires upgrading of both the structural components and the structural connections. Therefore, the structural connections can also be subjected to an increased load or extended service life.
Modern fastening systems are becoming more important in civil engineering constructions. Fastenings are used in all types of constructions. Because the failure of a fastening may lead to an endangerment of human life or major economic consequences, reliable fastenings are necessary. To ensure reliable fastenings a good co-operation of producer, engineer and user is needed.
The producer has to supply efficient and well-functioning fastening systems, the engineer must choose the optimal fastening system for the application in question and proof the adequate safety of the fastening by accurate design methods and the user has to ensure a correct installation of the fasteners.
From the structural connection point of view, the adequacy of existing fastenings in practice for the intended increased load or service life must be determined; inadequate fastenings must either be replaced or upgraded. Similarly, the reliability of current design methods for fastening systems should be evaluated particularly for geometrical, loading, and boundary conditions differing from those considered in the development of the design models.

II. LITERATURE REVIEW

Werner Funch,Rolf Eligehausen andJohn E. Breen(1995)
Concrete capacity design (CCD) method is briefly explained in this paper for design of fastening system. The method is compared with the provisions of ACI 349-85.Various tests are performed under shear and tension loading to compare design parameters like effective depth, edge distance, and concrete failure pattern. As given in the paper the angle of concrete cone failure varies as the per design methods. The comparison demonstrates that the CCD method can correctly predict the concrete fastening failure load for the complete spectrum of applications investigated.CCD is more user-friendly for design.

Marcela Karmazínová , Jindrich Melcher and ZdenekKala
States in his paper the new construction as well as in repair and strengthening works the anchor behaviour can be rather complicated considering the influence of concentrated loads. In this paper the brief information on analysis of results of the experimental research program directed to problems of actual behaviour of torque-controlled expansion anchors is presented. Within the frame of the realized experimental program the expansion anchors under tension static loading and also tension cyclic loading and under shear static loading were tested. Using the formulas taking into account not only the effective embedment depth and the concrete strength but also the sleeve diameter *D*, more exact expressions for the load- carrying capacity can be obtained but these ones are not so transparent for the practical use.

Sang-Yun Kima,, Chul-Soo Yu , Young-Soo Yoon

States in his paper Expansion anchors are fasteners designed for use in masonry base material that provides holding power through expansion. This paper shows the static behavior, and the seismic and fatigue resistance capability of sleeve-type expansion anchors in cracked concrete which is type of expansion anchor. These are the most versatile of the masonry anchors because they can be used in most masonry base material, such as concrete, brick or block. A test was performed to investigate the effect of concrete cracks on the static behavior of sleeve-type expansion anchors, and to confirm the seismic and fatigue resistance capability in cracked concrete .Testing was conducted on the sleeve-type expansion anchors, M10, M16 and M24, which have 10, 16 and 24mm anchor bolt diameter and 69, 101 and 148mm effective embedment depth, respectively. The types of failure, the static strength and displacement behavior of the anchors in untracked and cracked concrete were compared to evaluate the effect of the cracks. The results conclude that effects of concrete cracks on the tensile capacity reduction of a single anchor are mostly below 25% and decrease to below 10% with the increase of the anchor diameter. The anchor capacity reduces abruptly with the decrease of the amount of the displacement as failure criteria.

III. OBJECTIVES

To achieve the objectives of this research, the following tasks will be executed:

1. Understand and learn the design methodology given in the Guideline for European Technical Approval of Metal Anchors for Use in Concrete (ETAG 001).
2. Understand and learn various design parameters, installation techniques and product detail for HST3 anchor using European Technical Assessment (ETA-98/0001).
3. Summarize current knowledge of the behavior of post- installed anchors embedded in concrete
4. To analyze and design post installed mechanical fastening system as per European codes and guidelines required to analyze and design the selected product.
5. Providing knowledge for developing improved methods of designing new fastening System using PROFIS software.

IV. METODOLGY

To achieve the objectives of this research, the following tasks will be executed:

1. Review previous papers related to post installed mechanical fastening system.
2. Study and understand European codes and guidelines required to analyse and design the selected product.
3. Demonstration of product installation.
4. Understanding the importance of assessment and approval.
5. Learn software PROFIS ANCHOR.
6. Understanding installation of product and tools to be use for installation.
7. Design and analyse post installation of mechanical anchors onsite by manual calculations and software.
8. Find out benefits, accuracy, advantages and drawbacks, industrial scope of the process.

V. THEROTICAL CONTENT

- **Expansion Anchors**

Expansion anchors attach inside the drilled hole by mechanical means. For most expansion anchors, load is transferred from the anchor to the concrete by friction between the bottom end of the anchor and the wall of the hole. Two distinct methods are used to expand the anchor to bear against the wall of the hole, as shown in Figure. The first method is to apply torque to the anchor. Anchors installed in this manner are known as torque controlled anchors. The second method is to expand the anchor either by hammering it over an end cone or by hammering a cone into the anchor. Anchors installed by this method have two forms and are known as deformation-controlled anchors.

Fig.1. Expansion Anchor

- **Anchors Working Principle**

Friction

Friction is the load-transfer mechanism employed by expansion anchors. During the installation process, an expansion force is generated which give rise to a friction force between the anchors and side of the drilled hole. This friction force is in equilibrium with the external tensile force.

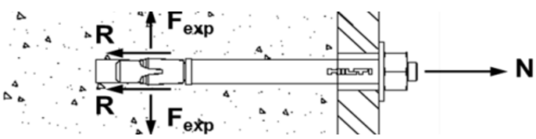

Fig.2.Friction

- **Applied Loads**

Static Loads

A typical static load could be a combination of the dead load (weight of fixture) and the live load a fixture must support .Basic static load conditions are tension, shear, or a combination of both. To determine the allowable static working load, the industry practice is to reduce the ultimate load capacity of an anchor by a minimum safety factor. In cases of combined load, other reduction factors may be required.

Tension Load

A tension load is applied directly in line with the axis of the anchor

Shear Load

A shear load is applied perpendicularly across the anchor directly at the surface of the base material.

Combined Load

Most anchor installations are subjected to a combination of shear and tension loads

Bending Load

One often overlooked result of static load is bending. It is frequently necessary to place shims or spacers between the fixture and the material for alignment or leveling. When this occurs, it is often the strength of the anchor material or bolt material that determines the capacity of the connection. The load is applied at a distance from the surface of the base material creating a lever-type action on the anchor.

- **Dynamic And Shock Load**

Dynamic Loads

Dynamic loads are intermittent and varying loads such as those imposed by central air conditioning units, manufacturing machinery or earthquakes. They are normally the alternating or pulsating loads associated with vibration.

Shock Loads

Shock loads are instantaneous, periodic loads of high intensity such as those applied by an automobile striking a guard rail support or a truck hitting a dock bumper. Standard industry practice with regard to safety factors varies depending upon the frequency and intensity of the load. Safety factors for critical loads may be 10:1 or higher. Determination of the appropriate safety factor should be made by the design professional in charge of the actual product installation.

- **Failure Modes:**

Typical Failure Modes Considered In Tension

Spiltting failure

Splitting failure is a failure mode where the concrete component splits completely or the concrete fractures along the fastening and the edge of the concrete element. If the edge distance is adequate, splitting cracks might develop between closely spaced anchor bolts during installation.

Concrete failure

Concrete cone failure occurs when a cone-shaped break-out body is separated from the base concrete. As an engineering practice, a dispersion angle of approximately between 30degree and 40degree is commonly assumed.

Steel failure

Steel failure is the most straightforward failure mode. It is observed by fracture in the shaft or the thread area. Steel failure can be avoided by increasing the number of fixing point or selecting a higher steel strength for the anchor or increasing anchor size.

Anchor pull out failure

Pull out mainly depend on the anchor quality, the cracked condition of the concrete and concrete class

Typical Failure Modes Considered In Shear

Steel failure

Failure might be occur if the anchor size is too small, the number of fixing points is not enough or simply due to steel strenght capacity.

Concrete pry out

The concrete can also break out far from the edge,especially with shallow embedement. The resistance to this failure can be enhanced by increasing the depth of embedding or the volume of engaged concrete.

Concrete edge breakout

A lateral concrete break-out might occur under shear load,when the anchors are close to the edges.

VI. DESIGN METHODOLOGY F POST INSTALLED MECHANICAL ANCHOR

For anchors for use in concrete having a **European Technical Approval (ETA)** the partial safety factor concept according to the **European Technical Approval GuidelinesETAG 001** shall be applied. It has to be shown, that the value of design actions does not exceed the value of the design resistance.

$$S_d \leq R_d \quad (1)$$

S_d = value of design action

R_d = value of design resistance

Resistance for tension and shear loads:

A] Tension load

Table .1 Resistance for tension load

Single anchor	Group of anchors
Steel failure	
$N_{sd} \leq N_{Rk,s} / \gamma_{MS}$	$N^h_{sd} \leq N_{Rk,s} / \gamma_{Ms}$
Pull- out failure	
$N_{sd} \leq N_{Rk,p} / \gamma_{Mp}$	$N^h_{sd} \leq N_{Rk,p} / \gamma_{Mp}$
Concrete cone failure	
$N_{sd} \leq N_{Rk,c} / \gamma_{Mc}$	$N^g_{sd} \leq N_{Rk,c} / \gamma_{Mc}$
Splitting failure	
$N_{sd} \leq N_{Rk,sp} / \gamma_{Msp}$	$N^g_{sd} \leq N_{Rk,sp} / \gamma_{Msp}$

B] Shear load

Table 2. Resistance for shear load

Single anchor	Group of anchor
Steel failure, shear load without lever arm	
$V_{sd} \leq V_{Rk,s} / \gamma_{MS}$	$V^h_{sd} \leq V_{Rk,s} / \gamma_{Ms}$
Pull–out failure, shear load with lever arm	
$V_{sd} \leq V_{Rk,s} / \gamma_{MS}$	$V^h_{sd} \leq V_{Rk,s} / \gamma_{Ms}$
Concrete pry-out failure	
$V_{sd} \leq V_{Rk,cp} / \gamma_{Mc}$	$V^g_{sd} \leq V_{Rk,cp} / \gamma_{Mc}$
Concrete edge failure	
$V_{sd} \leq V_{Rk,c} / \gamma_{Mc}$	$V^g_{sd} \leq V_{Rk,c} / \gamma_{Mc}$

C] Combined shear and tension

$$(\beta_N)^\alpha + (\beta_V)^\alpha \leq 1$$

α = 2.0
α = 1.5

VII. DESIGNEXAMPLE

Design 2✕2 anchor group subjected to design tension force 20 KN and design shear force of 6 KN as shown in fig.

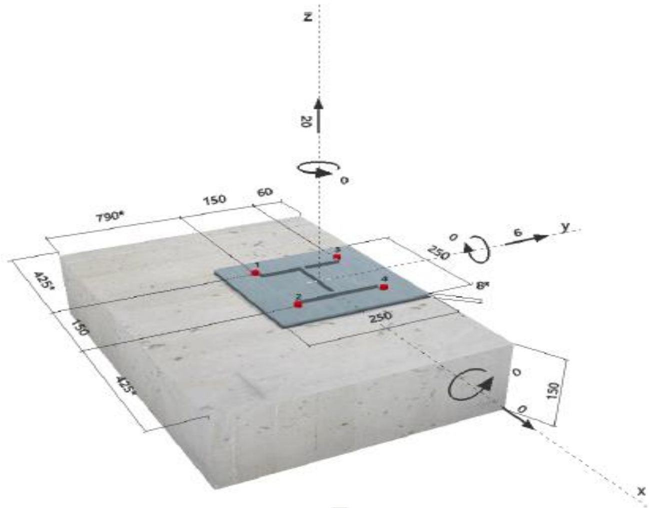

Fig .3 Anchorage system with tension and shear load

Table 3. Design parameters

Concrete	
Concrete Grade = M30 Concrete condition – cracked Reinforcement spacing – 150 mm	
Anchor bolt	**Specifications**
Anchor bolt type: Hilti HST3 Bolt size Characteristic ultimate strength fuk = 800N/mm^2 Characteristic yield strength fyk = 640 N/mm^2 Stressed cross-sectional area As = 84.3 mm^2 Nominal diameter of drill bit = 12 mm External diameter of anchor dnom = 18 mm Effective anchorage depth hef = 70 mm	1. Minimum thickness of concrete Member = 150 mm 2. Minimum spacing s_{min} = 50 mm 3. Minimum edge distance ,c_{min} = 55 mm 4. Critical spacing for concrete cone Failure, $s_{cr,N}$ = 210 mm 5. Critical edge distance for concrete cone ,failure =105 mm 6. Critical spacing for splitting failure $s_{cr,sp}$ = 210mm 7. Critical edge distance for splitting failure $c_{cr,sp}$ = 105mm

VIII. RESULT AND DISCUSSION

We get similar results for given problem statement from PROFIS software and manual design using European code ETAG 001

Table .4.Design Resistance

Description	**Design according to ETAG-001 ANNEX C**	**Design using PROFIS software**
Calculation for tension resistance		
$N_{Rd,s}$	32.21 KN	32.21 KN
$N_{Rk,p}$	14.606 KN	14.606 KN
$N_{Rd,c}$	34.43 KN	34.503 KN
Calculation for shear resistance		
$V_{Rd,s}$	26.98 KN	28.32 KN
$V_{Rd,cp}$	95.91 KN	95.91 KN
$V_{Rd,c}$	9.21 KN	9.41KN
Combined tension and shear resistance		
utilization	96%	96%

IX.CONCLUSION

The following conclusions could be made using present study.

- The results from PROFIS software and manual calculations using European guidelinesfromEuropean Technical Approval of Metal Anchors for Use in Concrete (ETAG 001) ANNEX C, are similar.
- Software designs are a simple, precise and less time-consuming technique that also enables us to use optimum alternatives to design issues.
- Cracked concrete condition used during design improves anchorage system efficiency under real circumstances at the site.
- PROFIS software can be used efficiently under different loads for seismic, fatigue and fire design of anchorage system.
- In order to achieve maximum system effectiveness, the installation parameters for the product in the appropriate ETA should be followed correctly on site.

ACKNOWLEDGMENT

I sincerely thank Prof. Dr. Sudhir P. Patil who guided me throughout the research work and suggested the correct means to carry out the work in every aspect.

I, also thank Dr. Prashant Sathe; Hilti.Inda.Pvt.Ltd for supporting me and providing me with the research head start.

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