Denis Popovski
PhD, Associate Professor
University "Ss. Cyril and Methodius"
Faculty of Civil Engineering – Skopje
popovski@gf.ukim.edu.mk

Mile Partikov
PhD, Assistant Professor
University "Ss. Cyril and Methodius"
Faculty of Civil Engineering – Skopje
partikov@gf.ukim.edu.mk

Ivan Micevski
MSc, Civil Engineer
micevskivan@gmail.com

PULL-OUT TEST FOR CHEMICAL ANCHORS

The task of connecting building components is as old as building itself. Modern technology for fastenings is getting more applied worldwide. Fastenings must be designed in such a way that they do the job for which they are intended, are durable, robust and exposed to external loads. This study deals with the identification of chemical anchors embedded in reinforced concrete slab under tension load. The anchors are embedded according to rules and recommendations given from anchor manufacturer. The axial load capacity and the failure mode are observed for each test. Results from conducted tests are given in form of load – displacement diagram curves which defines the type of anchor failure. Conducted tests in this paper are basis for further experimental researches for chemical anchors under tension load while changing the parameters of concrete, reinforcement, edge and axis distances, embedment depth and other parameters that define the behavior of chemical anchors and ultimate failure loads.

Keywords: chemical anchors, post-installed anchors, pull–out test, load-displacement, ultimate failure loads.

1. INTRODUCTION

Design of construction and construction elements have to comply with the current norms and standards. In case when the design of structure or detail cannot be in accordance to national norms and standards, then technical approvals should be used. Every type of anchor is designed for use in special conditions such as different type of concrete, different type of load, frequency of load, position of installment, etc.

The technical approvals are based on results from qualifications tests conducted by independent laboratories. Modern technology for fastenings is more applied worldwide and every type of anchor is designed for use in special (individual) conditions, such as different type of concrete, load, frequency of load, position of installment etc. If the anchor is not properly installed in conditions which is suitable for, then the safety of the detail is suspected, even the safety of the whole structure. Due to the complexity and diversity of post – installed anchors, all attempts to standardize anchor products have failed.

In the countries in the European Union, calculation of load capacity of anchors is carried out according to Annex C of ETAG001 (Guidelines for European Technical Approval of Metal Anchors for use in concrete) until implementation of CEN/TS 1992-4 (2009) as part of Eurocode 2 (2005) – Part 4. In United States calculation for load capacity of anchors is regulated from 2002 in Appendix D from ACI318 (2002), revised and supplemented in 2011. Recommendations given in guidelines strictly defines the conditions and the manner in which tests for approval of anchors will be carried out.

2. EXPECTED BEHAVIOR AND TYPES OF FAILURE FOR ANCHORS LOADED WITH TENSION FORCE

Several failure modes are possible for post – installed adhesive anchors loaded in tension and all of the failure modes are characterized with different load – displacement curve in function of different types of factors.

Expected types of failures under external tension load are:

- Steel failure,
- Concrete cone failure,
- Splitting failure,
- Pull – out failure (concrete/adhesive interface),
- Pull – out failure (adhesive/anchor interface)
- Pull – out failure (mixed interface)

Apart from the type of the anchor, the failure and behavior also depend on cleanliness of the drilled hole, adhesive type, embedment depth, concrete class, cracked or non – cracked concrete and the way force is applied. Total measured displacement (extraction) of the anchor is compiled of the slip of the anchor, local deformation in concrete zone where the transfer of the friction load occurs, and the deformation of the anchor itself.Every type of failure occurs after characteristic tension force is reached.

At small embedment depths ($h_{ef} \approx 3d$ *to* $5d$) concrete cone failure is characterized by a cone – shaped concrete breakout originating at the base of the anchor. It occurs when full tensile capacity of the concrete is utilized. Splitting failure is characteristic failure when anchor is installed near the edge of the concrete embedment or when dimensions concrete cone is limited. For greater embedment depths, the concrete failure mode usually transitions toa a mixed – mode (bond/concrete breakout) type of failure. A concrete cone with a depth of approximately *2d* to *3d* forms at the top end of the anchor and the bond fails over the balance of the embedment depth. Bond failure occurs either at the boundary between concrete and mortar or at the boundary between the mortar and anchor rod. Often a failure between concrete and mortar occurs in the upper part of the embedment, with the failure of the bond between mortar and anchor rod confined to the deeper end. For large embedment depths the bond resistance developed over the length of the anchor can exceed the rupture strength of the steel rod, leading to steel failure. The minimum embedment depth of a single anchor rod depends on the grade of the steel, the concrete mechanical properties and the properties of the mortar.

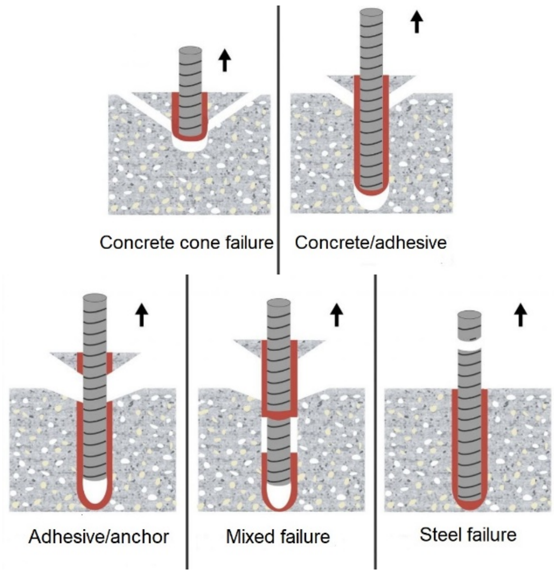

Figure 1. Types of failure due to tension load

3. TEST PREPARATION

3.1 PREPARATION, DRILLING AND INSTALLATION OF ANCHORS

In the foundation slab 4 types of anchors from same manufacturer were installed with different type of chemical injection.

All parameters for installation of anchors are previously measured and approved. After drilling of the holes, before installation of the anchors, every hole was cleaned from drilling dust. Scheme of the procedure for installation of chemical anchors is shown in figure 2 and figure 3.

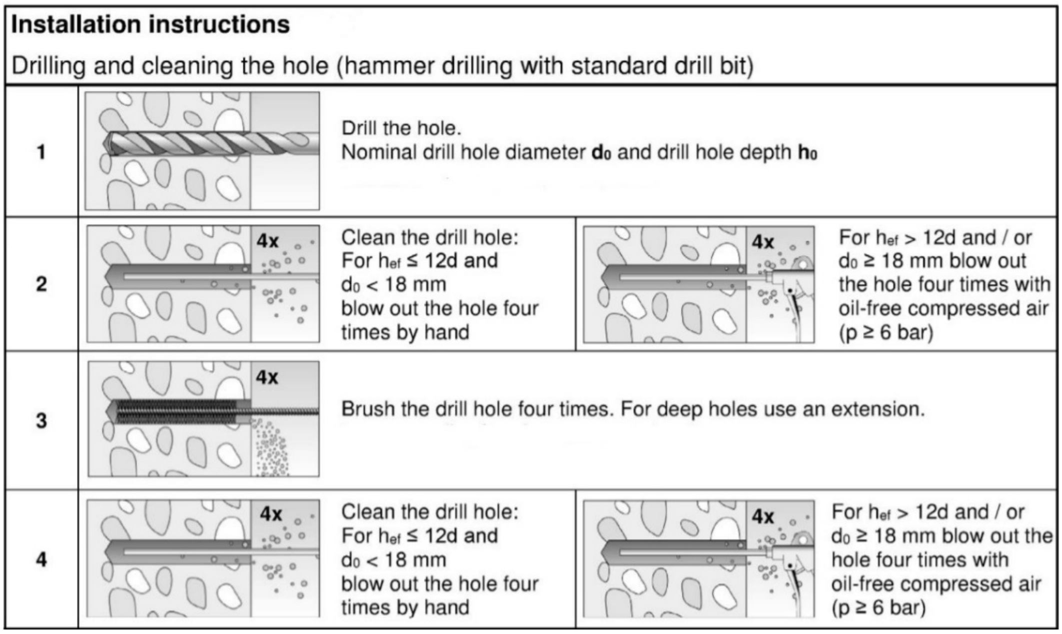

Figure 2. Drilling and cleaning the hole

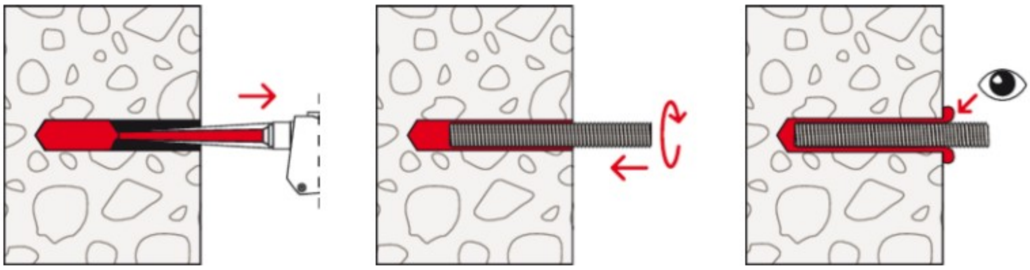

Figure 3. Application of adhesive and installation of anchor

3.2 QUALITY CONTROL OF CONCRETE

As mentioned before, the pull-out test conducted for chemical anchors embedded in non-reinforced concrete, presented in this paper, is not standard procedure, which differs from procedures stated in ETAG. To control the quality of concrete from which foundation slab is made, samples from concrete in phase of concreting are taken for further laboratory tests. Samples are taken for cubes with standard dimensions 15/15/15cm in accordance with EN12390-1 (Testing hardened concrete – Part1: Shape, dimensions and other requirements for specimens and molds). According to recommendations, many samples are taken in phase of concreting. Samples were stored in controlled laboratory conditions in accordance with EN12930-2 (Testing hardened concrete – Part2: making and curing specimens for strength tests). To determine the class of concrete and compressive strength, all of the cubes were tested after 28 days from concreting the foundation slab. Obtained results from concrete tests are processed in accordance with EN 13791. From measured results concrete class C25/30 was achieved.

3.3 EQUIPMENT FOR MEASURING TEST RESULTS

The electronic equipment is connected to HBM Quantum data acquisition system amplifier, directly connected to computer, with measuring in real time. Results are given in form of vertical deformation of anchor (extraction) in proportion to the applied tension force. Scheme for installation of measuring equipment is shown in Figure 4.

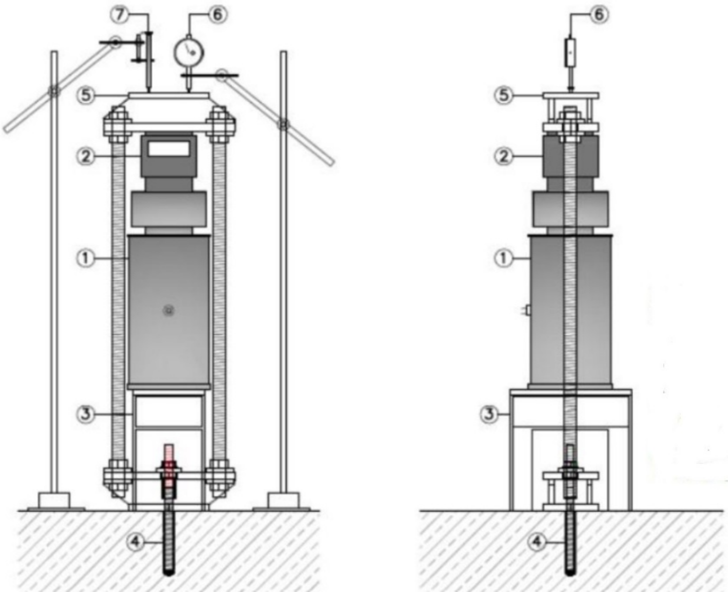

Figure 4. Scheme for installation of the equipment

Where,

1) Hydraulic press
2) Dynamometer
3) Concrete cone support construction
4) Installed chemical anchor
5) Tension load construction
6) Inductive deformeter (comparator)
7) Electronic deformeter (comparator)

All of the selected anchors were with similar installation procedure, steel quality, equal diameter and same thread M16, but with different load capacity defined by the manufacturer as a result of different type of adhesive.

Tension force for the anchor was applied through special designed system with hydraulic press positioned on steel construction which does not affect the concrete cone failure. Application of tension load on anchors was continuously monitored through the electronic dynamometer. Installed anchors were loaded in one phase until failure occurs. Measurement of vertical displacement of the anchors was carried out by two positioned deformeters (electronic and inductive).

4. RESULTS FROM CONDUCTED PULL-OUT TEST FOR CHEMICAL ANCHORS

With the conducted experimental tests of the chemical anchors installed in foundation slab, the obtained data was used for the analysis of the behaviour of the anchors. All gathered data was processed in form of load – displacement diagrams. The following are the results for each anchor group from the experimental research. The anchors were loaded until the failure occurs. During the experimental examination maximum force that was occurred was 108.8 kN and maximum vertical deformation of the anchor was 10.8 mm.

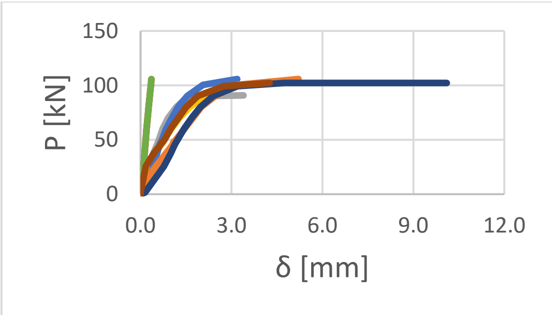

Figure 5. P-δ diagram for anchor type 1

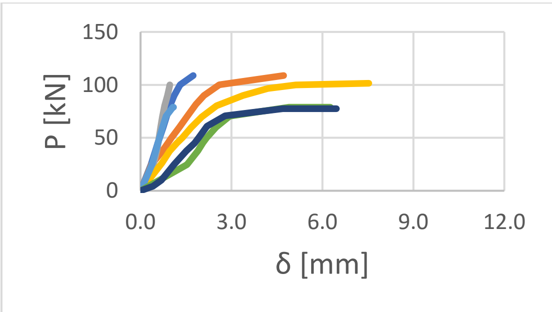

Figure 6. P-δ diagram for anchor type 2

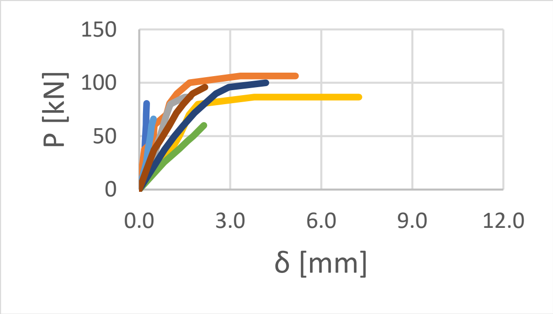

Figure 7. P-δ diagram for anchor type 3

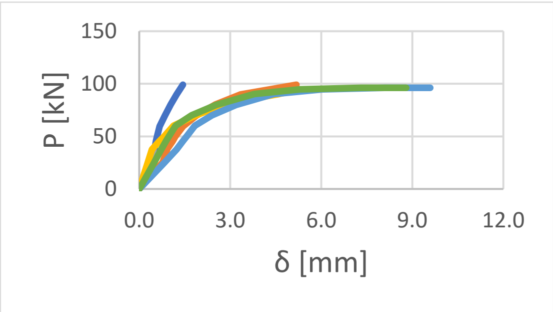

Figure 8. P-δ diagram for anchor type 4

In all cases of the tested anchors, the failure was different. There was concrete cone failure in most of the cases, but there were also steel failure and mixed failure (failure between concrete/adhesive/anchor).

Figure 9. Failure of anchor type 1

Figure 10. Failure of anchor type 2

Figure 11. Failure of anchor type 3

Figure 12. Failure of anchor type 4

This paper gives the results from the tested anchors that are embedded in accordance to the manufacturer recommendations. The testing was conducted so at least four anchors of each type fully developed failure occurs.

Anchor type 1, with double component epoxy injection, average value of the tested anchors 101.12kN. Anchor type 2, with epoxy resin injection, average value of the tested anchors 91.67kN. Anchor type 3, with mortar-based injection, average value of the tested anchors 89.80kN. Anchor type 4, with double component mortar injection, average value of the tested anchors 96.47kN. Manufacturer tension load for all 4 anchor types 55.19kN.

5. CONCLUSION

From the occured data for this experimental research can be concluded that the behavior of the chemical anchors depends on many different factors, which always vary for each situation.

By obtaining the results and creating the load – displacement diagrams, the behavior of the mechanical anchors as elements for connection gives opportunity for ease of analayzis. Conclusions from conducted pull-out test of mechanical anchors are that:

- The load-bearing capacity obtained from the experimental test is much higher than the calculated design load-bearing capacity of the anchors. The difference between the design and tested loads of tension anchors is not only due to the revised global and partial reliability coefficients, but additionally the design loads are reduced due to a number of parameters that in practice can not be precisely defined. With further analysis of the results and comparison with the given design and allowed tension loads from the manufacturers for each type anchor, can be concluded that maximum bearing capacity of the anchors is underestimated (62-83%).

- Different based injection filler (epoxy-based or mortar-based), during static loads, have similar bearing capacity, with maximum difference around 12%.

- Double component injection filler (epoxy-based or mortar based), during static loading, gives higher bearing capacity than the single component injection, with diference around 7-10%.

- The type of chemical used as adhesive has little effect on the tensile strength of the anchor. While the process of drilling, cleaning the opening and the way of installing the anchor has a huge impact on the load capacity of the chemical anchor.

REFERENCES

[1] Australian Engineered Fasteners and Anchor Council (2015): „Test and Evaluation Procedure for Concrete Screw Anchors “.

[2] Cannon R.W. (1981): „Guide to the Design of Anchor Bolts and Other Steel Embedments “, Concrete International.

[3] Damjanovski Vladimir (2015): „Testing the extraction of anchors in existing concrete slab“, MASE16 proceedings.

[4] Denkovski Damjan (2019): „Experimental and analytical research of behavior of mechanical anchors“, master thesis, Skopje.

[5] Dr. S.S.H Cho, „Guide on Design of post-installed anchor bolt systems in Hong Kong “, The Hong Kong Institute of Steel Construction

[6] European Organization for Technical Approvals (2013): „ETAG 001-Guideline for European Technical Approval of Metal anchors for use in concrete, Part one: Anchors in general “.

[7] European Organization for Technical Approvals (2012): „ETAG 001-Guideline for European Technical Approval of Metal anchors for use in concrete, Part two: Torque-controlled expansion anchors “.

[8] European Organization for Technical Approvals (2012): „ETAG 001-Guideline for European Technical Approval of Metal anchors for use in concrete, Part three: Undercut anchors “.

[9] European Organization for Technical Approvals (2012): „ETAG 001-Guideline for European Technical Approval of Metal anchors for use in concrete, Part four: Deformation-controlled expansion anchors “.

[10] European Organization for Technical Approvals (2012): „ETAG 001-Guideline for European Technical Approval of Metal anchors for use in concrete, Part five: Bonded anchors “.

[11] European Organization for Technical Approvals (2012): „ETAG 001-Guideline for European Technical Approval of Metal anchors for use in concrete, Annex A: Details of tests “.

[12] European Organization for Technical Approvals (2012): „ETAG 001-Guideline for European Technical Approval of Metal anchors for use in concrete, Annex B: Tests for admissible service conditions detailed information “.

[13] European Organization for Technical Approvals (2012): „ETAG 001-Guideline for European Technical Approval of Metal anchors for use in concrete, Annex C: Design methods for anchorages “.