Developments in the field of removable anchors

M. J. Rebhan¹, R. Marte¹, F. Tschuchnigg¹, A. S. Eder¹, H. Fuschelberger², B. Meyerhans³
¹Graz University of Technology, Institute of Soil Mechanics, Foundation Engineering and Computational Geotechnics, Rechbauerstraße 12, 8010 Graz, Austria
²ANP-Systems GmbH, Christopherusstraße 12, 5061 Elsbethen, Austria
³KUBATEC BMT AG, Widaustraße 3, 9491 Ruggell, Liechtenstein

rebhan@tugraz.at

Abstract. The design of inner-city building pits is a challenging task in geotechnical engineering. Due to rising property prices and the limited vacant plots in urban areas, the installation of building pit support measures is often constrained. Besides rigid systems, struts or anchors are often used to support such building pits. On the one hand, this support is required to come up with an economical design and on the other hand, it is necessary to keep the deformations of adjacent structures within certain limits. In this paper a new approach for the design and the (de-)installation process of removable anchors is presented. By using a non-explosive cracking agent, a fully removeable anchor has been developed. Laboratory test results have shown, that by filling a pre-installed injection tube with the non-explosive cracking agent, a partial destruction of the grout body and consequently a reduction of the bond along the cement body and the steel tendon can be achieved. As a result, an extraction of the steel tendon is possible.

1. Inner-city building pit design and removable anchor systems

The growth of cities worldwide implies the construction of new buildings and infrastructure which leads to smaller building pits and an influence of these structures on adjacent buildings. Additional measures are often necessary to comply with the limitations of the building pit support (e.g. sheet pile walls, bored pile walls or diaphragm walls) given by standards (e.g. [1] & [2]) or with the design regulations of the customer.

Figure 1. Building pits; left: strutted diaphragm wall [3]; right: diaphragm wall with anchors
Due to the limitations (bearing capacity and deformation) of rigid systems they are generally limited to shallow building pits. Therefore, this topic is not further addressed within this contribution.

The usage of struts to support a building pit is shown in Figure 1a. As one can see, the installation of struts in multiple levels can lead to restrictions regarding the construction process. This is especially the case, when the construction process of the building inside the pit advances and struts (or strut levels) have to be removed. Furthermore, these construction elements are pressure rods which can be affected by buckling, which often leads to additional measures (e.g. bracing). Due to these limitations, anchors are widely used, as a building pit support system.

Anchors are tensile elements that are capable of increasing the bearing capacity of a structure (e.g. against the acting earth pressure). In addition, if pre-stressed anchors are installed, a reduction of the deformations of the building pit support and its influence on adjacent structures can be achieved. Although anchors have no influence on the inside of the building pit (compared to struts), the surrounding soil body is affected due to their installation. Besides to geotechnical boundaries such as rinsing of fine particles or heave due to post-grouting, the impact on third-party properties for the installation of the tendon is of major interest. The installed anchors and tendons cause an obstruction, which can be a handicap concerning the subsequent installation of other underground structures such as tunnels, diaphragm walls, bored piles or sheet pile walls. Due to these restraints, removeable anchor systems are used for the construction of (temporary) building pits in vacant plots in urban areas.

2. State-of-the-art removable anchor systems

As briefly described in chapter 1, the usage of removable anchors is often necessary, when adjacent and third-party properties should not be (permanently) influenced by the installation of anchored structures. Such systems have been used in the last three decades, but recently a series of developments took place, especially regarding improvements in the method and the tendon material.

In Figure 2 some examples of removeable anchor systems are shown. Figure 2a) illustrates the usage of a predetermined breaking point along the transition zone from free length to bond length of the anchor. This breaking point is induced by inductive warming of the material which reduces the material strength. In this system, the free length of the anchor can be removed, only leaving the bond length (and its metallic components) behind. To improve this system and to accomplish a system where both, the free length and the bond length can be removed, different approaches have been made, e.g. an anchor system with a loop can be used. As shown in Figure 2b), a pulley is installed at the end of the bond length, at

![Figure 2. Examples for removeable anchors; a) anchor with a predetermined breaking point [4]; b) anchor with loop [5]; c) tube anchor with removable tendon [4]; d) fibre reinforced tendons [6]](image-url)
which every tendon is deflected back to the anchor head, which allows it to remove all the tendons. A similar system can be used, within a tube anchor, where at the end of the tube, a box (Figure 2c) is installed. In this box, the tendons are screwed in, making it possible to remove them after use. Due to the fact, that the pulley and the tube can be made out of cast iron (or other brittle materials), these systems are machinable and have consequently only a minor effect on subsequent construction measures such as the installation of sheet pile walls. Recent developments also include new materials such as glass reinforced plastic (GPR), which is used for bars as well as tendons (Figure 2d).

Nevertheless, none of the systems available, offers the possibility to be “fully” removed from the underground, and therefore has (at least a minor) impact on the soil body in which they are installed.

3. Development of a new removable anchor system

Due to the described limitations of available removable anchor systems, a new type of removable anchor system was developed and tested at Graz University of Technology. The concept behind this new method is to reduce the bonding between the anchor tendon and the surrounding cement, offering the possibility to pull the tendon out of the grout body. Therefore, all metallic parts of an anchor could be removed, leaving only a weak and brittle cement body in the ground, which is no obstruction for subsequent construction measures.

For the realization of this concept, a non-explosive cracking agent (see [7]) is used. This product consists of lime (calcium oxide) and portland cement which reacts to calcium hydroxide when mixed with water. This exothermal reaction, produces heat and leads to an expansion of the material. The amount of expansion depends on the diameter of the drilling or pipe, in which the non-explosive cracking agent is filled. This technique is currently mainly used to demolish footings (Figure 3a) or to destroy boulders within a building pit or next to road constructions. Due to its “non-explosive” operating principle, a blasting permission is not required, making it ideal to be used on site.

Figure 3. Non-explosive cracking agent; a) used for the demolition of a footing; b) preliminary study for the usage in grout bodies of anchors

As one can see in Figure 3b) the same principle can also be applied, to destroy (or demolish) the grout body of anchors. In this preliminary study, a pipe (PVC) has been used to simulate the borders of a drill hole, in which a grout body (in this case dry concrete) with a tendon (bar DN 36, SAS 950 [8]) was installed. Additionally, a hole was prepared along the tendon, using a tube (DN 30) which was removed after a curing time (app. 2h) of the concrete.

This preliminary test indicates, that a destruction due to exceeding the tensile resistance of a grout body, by applying a non-explosive cracking agent next to a tendon is generally possible. Nevertheless, it is necessary for the system to provide a hole (or drilling) in the grout body, which is, from a practical point of view, not feasible for anchors installed within a soil body. Therefore, a new concept had to be developed. This concept is schematically shown in Figure 4. A (standard) grouting tube, with a diameter of 20 to 30 mm, is mounted next to the tendon (see Figure 4a). Although the tube is installed with the tendon in the soil (see Figure 4b) it is neither used for grouting nor for post grouting.
Figure 4. Concept for removeable anchors using a non-explosive cracking agent

This system enables the injection of the non-explosive cracking agent (see Figure 4c) after the operation period of the anchor, which allows to destroy the grout body due to expansion (by reducing the bonding between the tendon and the grout body). Subsequently the anchor can be removed by applying tensile forces using hydraulic jacks or heavy equipment, as shown in Figure 6.

4. Laboratory and Field Testing

Based on the results of the preliminary studies and additionally laboratory tests [9], a field-testing campaign on this removeable anchor system (using a non-explosive cracking agent) is currently in progress. For these investigations, the demolishing of the grout body will be tested under realistic conditions. Figure 5 shows a series of test anchors installed on site. Due to site-specific boundaries, 6.00 m long soil nails, representing the bond length of an anchor were installed in a shotcrete wall.

Figure 5. Field testing, test series installed in a shotcrete wall using representative soil nails

These tests are ongoing at the moment and represent the feasibility study for the concept described above. The anchor bars consist of a micro-pile-rod (SAS 950 [8]) with a diameter of 36 mm. To investigate the influence of the expansion process, different configurations of the tube (diameter and application along the rod) have been used. Furthermore, the influence of the strength of the grout body will be evaluated by deinstalling the anchors at different curing periods of the concrete.
The first tests have been conducted after a curing period of 7 days. The results are shown in Figure 6. As one can see, it was possible to remove the anchor rods. Furthermore, a destruction of the grout body could be achieved by using a non-explosive cracking agent.

However, for a practical application of this method, further investigations are necessary. On the one hand, this method must be tested for different soil types and different load levels (e.g. overburden). But it also has to be mentioned that this method could be used on strands, instead of anchor bars as shown in the laboratory and field tests, which can enlarge the field of application of this method.

5. Conclusions & Summary
This paper describes a new concept for removeable anchors which is based on the usage of a non-explosive cracking agent which is filled in a pre-installed tube along the tendon of an anchor. Due to the expansion of this material a cracking of the cement body can be achieved, which leads to a reduction of the bonding between the anchor tendon and the grout body. The concept has been validated in small scale tests under laboratory conditions and is currently tested under practical conditions in field tests.

The method described can lead to profound changes in the anchor design especially for inner-city building pits. Due to the quite simple setup of the anchors, which do not use any specially designed or engineered elements, a significant reduction of costs can be achieved. Nevertheless, further developments and improvements of the method, e.g. considering different soil types or the applicability on strand anchors, are necessary before the system is applicable to a wide range of boundary value problems.

Acknowledgments
The conduction of the laboratory and field tests was possible due to the provision of the necessary material from the companies ANP-Systems and KUBATEC BMT. Furthermore, the field tests performed where enabled by Keller Grundbau which installed the test anchors and the Austrian autobahn operator ASFINAG which allowed these tests on the construction site along the new traffic line S7. Additionally, a funding of the Austrian Research Promotion Agency FFG and the Amt für Volkswirtschaft AVW of the Principality of Liechtenstein.
References

[1] Eurocode 7: Geotechnical design Part 1: General rules (consolidated version) ICS 93.020
    01.010.30 Committee 023 Geotechnics Austrian Standards Edition: 2014-1–15
[2] EAB Recommendations on Excavations Deutsche Gesellschaft für Geotechnik e.V. (Hrsg.) 2.
    Edition, 2008, 978-433-01855-2
[3] Bauer Spezialtiefbau 2019. Girsch Erwin Teil der Vorlesung ASMFE im SS 2019 Technische
    Universität Graz Institut für Bodenmechanik, Grundbau und Numerische Geotechnik Graz
[4] Dedic D and Wörle P 2017 Vollständig rückbaubare Litzenanker: Innovationen und Erkenntnisse
    Beiträge zum 32. Christian Veder Kolloquium Gruppe Geotechnik Graz Technische
    Universität Graz 20. und 21. April 2017
[5] Gipperich C and Triantafyllidis T 1997 Entwicklung eines rückbaubaren Verpreßankers
    Bauingenieur Heft 72 Seite 221-234 Springer VDI-Verlag
[6] Buchacher P and Gutsche R 2017 Ausbaubare Temporäranker und eine mögliche Alternative
    Beiträge zum 32. Christian Veder Kolloquium Gruppe Geotechnik Graz Technische
    Universität Graz 20. und 21. April 2017
[7] Betonamit 2018 Gebrauchsanweisung Betonamit® Homepage Betonamit Zugriff am
    08.01.2020, https://www.betonamit.com/wp-content/uploads/2018/11/BETONAMIT-
    Gebrauchsanweisung-und-Sicherheitsbestimmungen-2018.pdf
[8] ANP-Systems 2019 ANP-Einstabanker SAS 950 aus Spannstahl Y1050H Zulassung BMVIT-
    327.120/0003-IV/IVVS2/2019 Bundesministerium Verkehr, Innovation und Technologie
    Wien
[9] Eder A ongoing Master Thesis Graz Univeristy of Technology