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A new, durable micropile for the foundation of rockfall protection structures

Un nouveau micropieu durable pour la fondation d'ouvrages de protection contre les chutes de pierres

M.J. Rebhan*, H.-P. Daxer, R. Marte
Graz University of Technology, Institute of Soil Mechanics, Foundation Engineering and Computational Geotechnics, Graz, Austria

M. Schuch
ÖBB Infrastruktur AG, Vienna, Austria

S.L. Burtscher
burtscher consulting GmbH, Vienna, Austria

**rebhan@tugraz.at*

ABSTRACT: The erection of protective structures is necessary to ensure the safety of infrastructure facilities such as roads and railways as well as settlement areas. Especially for rockfall protection structures, foundations in the form of micropiles are often used to transfer dynamic or impact-like loads into the subsoil. In addition to the requirements regarding the installation, the demands for a durable and sustainable foundation design of such structures have increased in recent years. In the course of a research project, a micropile system that can meet these requirements has been developed. It consists of a hollow bar that can be installed in a self-drilling manner and additionally has a corresponding durability due to a factory-applied resin coating. The advantages of such a system are the simple and fast installation process, which can be carried out with a wide range of equipment. This allows the system to be installed in areas that are difficult to access, as it is the case with protective structures. In addition, the resin coating has a high wear resistance in order to withstand the rough installation process during rotary percussive drilling and ensures the required corrosion protection layer for a durable geotechnical element. On the one hand, this paper presents findings from investigations on current corrosion protection methods for micropiles. On the other hand, the developed micropile system is introduced, which has already been tested and validated in a series of field tests. In addition, ongoing developments such as spacers and post grouting possibilities are presented.

RÉSUMÉ: La mise en place d'ouvrages de protection est nécessaire pour assurer la sécurité des infrastructures telles que les routes et les voies ferrées, ainsi que des zones d'habitation. En particulier pour les ouvrages de protection contre les chutes de pierres, des fondations sous forme de micropieux sont souvent utilisées pour transférer des charges dynamiques ou des charges d'impact dans le sous-sol. Outre les exigences relatives à l'installation, les demandes de conception de fondations durables pour de telles structures ont augmenté ces dernières années. Dans le cadre d'un projet de recherche, un système de micropieux capable de répondre à ces exigences a été développé. Il s'agit d'une barre creuse qui peut être installée de manière autoperceuse et qui présente en outre une durabilité correspondante grâce à un revêtement en résine appliqué en usine. Les avantages d'un tel système sont la simplicité et la rapidité du processus d'installation, qui peut être réalisé à l'aide d'un large éventail d'équipements. Cela permet d'installer le système dans des zones difficiles d'accès, comme c'est le cas pour les structures de protection. En outre, le revêtement en résine présente une résistance élevée à l'usure afin de supporter le processus d'installation brutal pendant le forage rotatif à percussion et assure la couche de protection contre la corrosion requise pour un élément géotechnique durable. D'une part, cet article présente les résultats d'études sur les méthodes actuelles de protection contre la corrosion pour les micropieux. D'autre part, il présente le système de micropieux développé, qui a déjà été testé et validé dans une série d'essais sur le terrain. En outre, les développements en cours, tels que les entretoises et les possibilités de post-encastrement, sont présentés.

Keywords: Rockfall-protection, durability, micropiles, impact-like loads.

1 FOUNDATION OF ROCKFALL PROTECTION STRUCTURES

Protective structures such as rockfall protection nets are an essential part of Austrian railways and roads and along settlement areas. Due to the topography, such structures are necessary and are currently becoming more frequent due to the effects of climate change. Rockfall protection structures can be designed in different forms and variants (Bergmeister, 2009). In addition to dam structures (Mölk & Hofmann, 2018), rockfall protection nets are often erected, as shown in Figure 1. These consist of a superstructure formed by posts and a net placed in between.

Figure 1. Rockfall protection net next to a support road of a railway line.

The (inclined) posts are connected to an appropriate foundation (e.g. slab) and can also be supplemented – depending on the energy level – by an additional upstream and downstream cable. Therefore, next to counterweights, micropiles are necessary for the foundation of protective structures in order to transfer the cable forces into the subsoil and to ensure the load-bearing capacity of the post foundations. Consequently, these are to be installed in the surrounding subsoil along the axis of the protective structure, which means that they are installed in mostly inaccessible areas.

As an installation method either solid rod systems or self-drilling systems can be used. The first are installed by means of a cased drilling with the advantage of a wide range of usability and the disadvantage of low performance in installation and correspondingly high costs. The second type can be installed easier and therefore offers a quite high performance under the constraints of the location of these structures.

2 CORROSION PROTECTION MEASURES & MICROPILE DCP-SBZ

In order to ensure the necessary (or expected) durability and the planned service life (ÖNORM B 1997-1-, 2021 & ONR 24810, 2017), appropriate corrosion protection of the micropiles is required. This generally applies to all buildings and structures, although protective structures usually have a shorter service life. A large part of the structural elements can be examined for damage of degradation in the course of visual tests and inspections. The foundation elements, however, are installed within the subsoil and therefore cannot be inspected visually. For this reason, attention must be paid to the corrosion protection of the tension elements.

Typical corrosion protection measures for micropiles are defined in the respective regulations (e.g. ÖNORM EN 14199, 2015) and have recently been specified more comprehensively in ÖNORM B 4456 (2021). Within this Austrian standard, a distinction is made between single corrosion protection (SCP), double corrosion protection (DCP see Figure 2 bottom) and material related corrosion protection (MCP). The first – and most frequently used SCP – can be further subdivided into sacrificial corrosion allowance (STA), coating corrosion protection (CCP), zinc corrosion protection (ZCP see Figure 2 top right) and grout cover protection (GCP see Figure 2 top left).

Figure 2. Types of corrosion protection, top left: grout cover protection (GCP), top right: uinc corrosion protection (ZCP) and double corrosion protection (DCP).

In the course of a research project (DAT, 2022), improvements on the corrosion protection of micropiles used as a foundation of protective structures has been investigated. The results of this project are described below and show a first basic concept while the field testing and application if given in chapter 3.

The basic concept was to develop a permanent and durable micropile, that fulfils both the requirements for durability and load-bearing capacity and also offers easy installation. A system based on a self-drilling tensile element was used as the basis for this, which was supplemented by an appropriate coating to ensure durability. This corrosion protection system is based on the DCP, which is widely used for pre-stressed anchors (ÖNORM EN 1537, 2015) and other tensile elements, but is not yet used for self-drilling elements such as micropiles and soil nails. A schematic structure of an initial prototype is shown in Figure 3.

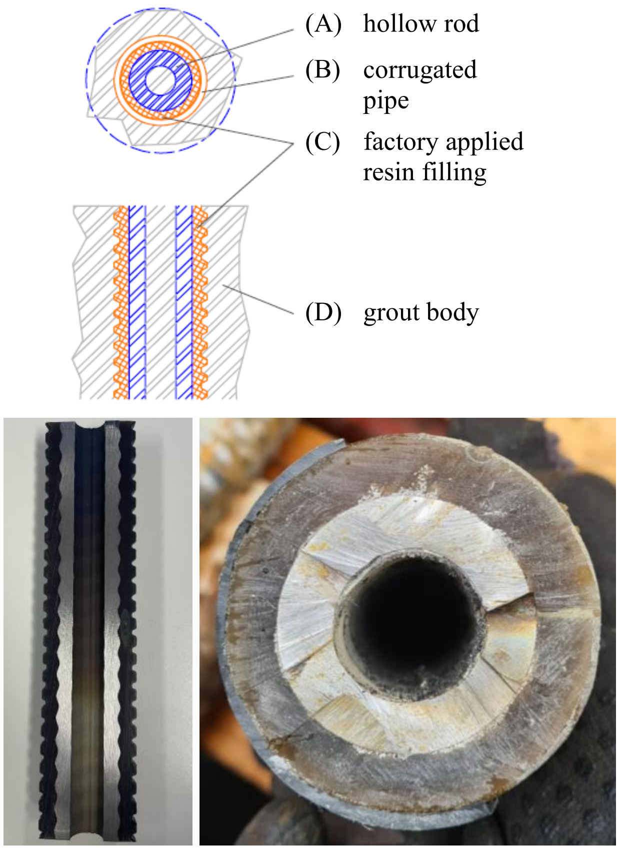

Figure 3. Developed double-corrosion-protection self-drilling tension element (DCP-SBZ), top: schematic, bottom: longitudinal and sectional cross section.

Rotary driven micropiles – using a hollow rod (A in Figure 3 top) – represent one of the cheapest installation methods in terms of equipment, making this system particularly suitable for the use in inaccessible areas. To prevent corrosion and furthermore fulfil the requirements of a planned service-life of more than 30 years, the metal rod was supplemented with a corrosion protection similar to a double corrosion protection DCP. However, this could not be achieved by using a cement-filled corrugated pipe (B in Figure 3 top), as it would not withstand the impact and abrasiveness due to the rotary percussive installation process. Consequently, the cement was replaced by a resin body (C in Figure 3 top) with a thickness of 4 to 7 mm depending on the shape of the rod.

The first results of this development have shown that a uniform and full-surface coating of the metal rod (see Figure 3 bottom) can be achieved during manufacturing, providing a continuous corrosion protection barrier.

3 FIELD TESTING, APPLICATION AND FURTHER DEVELOPMENT

In a series of field tests (DAT, 2022), investigations were carried out to determine whether the applied resin layer can withstand the installation process of rotary percussive drilling. These were carried out under a wide range of geological boundary conditions, from compact rock to soft, uncompacted fills and boulder dumps. The aim was to determine the applicability of the system and the influence of the subsoil on the installation. Figure 4 shows the installation process of aforementioned micropiles in a slope using a mounting carriage on an excavator.

Figure 4. Installation of DCP-SBZ (self-boring tensile element) micropiles for testing purposes.

These tests and a subsequent deinstallation of the micropiles showed, that over a large part of the pile length both the resin body and the corrugated pipe were still intact. On the one hand, micropiles installed were pulled out of the subsoil before the grout body hardened (Figure 5 left) and, on the other hand, the micropiles were uncovered after hardening (Figure 5 rigth) and the performance of tensile load tests.

In addition to the condition of the corrosion protection, a comparison of the load-bearing capacity with classic micropiles was also carried out. This showed no significant difference in either the load-deformation behaviour or the load-bearing capacity.

With respect to the corrosion protection only the head area near the drilling bit and in the area of fittings and joints small damages were observed when test bodies in (gravely and sandy) soil were exhumed after installation. These damages can be attributed to entrapment of coarse-grained fractions. However, such damage can be eliminated by further developing drill bits and also coupling devices, which provide protection for the transition zones.

Figure 5. Examples for exhumed micropiles.

The concept described and tested shows the development of a new type of micropile, which has considerable advantages due to the resin-based corrosion protection barrier and the simple self-drilling installation process. These range from the low installation effort to ensuring the required durability due to the double corrosion protection. The disadvantages at present are the high costs – due to the expensive resin that has to be used – and the fact that the application of the corrosion protection layer results in a significant increase in weight, which limits the handling by the site personnel.

Furthermore, the concept of this micropile additionally offers the possibility of post grouting (due to the core of the hollow rod), which can lead to an increase in the load bearing capacity and subsequently to a reduction in the required pile lengths. In addition to cost savings, this can result in a reduction in installation time, which can be a clear advantage given the difficult installation conditions for protective structures, as mentioned above.

Furthermore, this micropile system can also be used in other areas of geotechnics in addition to rockfall protection nets. Particularly in the construction and installation of soil nailing, the use of this type of system can create a permanent and therefore sustainable form of construction for cuttings and slope stabilisation.

4 CONCLUSIONS

This paper gives a brief insight into developments in the field of the foundation of protective structures through the use of micropiles.

A new type of micropile was presented, which is based on the application of a corrosion protection barrier to self-drilling tensile elements. The required corrosion protection can be ensured by a resin coating, which is factory-applied to the metal rod and therefore offers an easy and well-known installation process. This layer offers sufficient strength and abrasiveness to allow rotary percussive installation even in coarse-grained soils.

This article shows that there is a comprehensive potential for optimisation and improvement in the field of protective structures. Such developments are necessary to ensure the requirements for durability and thus a sustainable operation of the infrastructure, while still guaranteeing sufficient safety of the structures. Taking into account the increase in climate change-related effects, it can be assumed that there will be an increased need for such constructions in the future.

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