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Paper:

The Helical Anchor Type with Application as a Horizontal Drainage Equipment for Slope Protection

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Helical anchors, sometimes referred to as screw anchors, screw piles, and helical piles, are a steel screw-in piling and ground anchoring system used for building deep foundations. Screw piles are manufactured using varying sizes of tubular hollow sections for the pile or anchor shaft. This paper presents an innovation of the helical anchor for horizontal drains, a form of subsurface drainage systems for slope protection. To address the adverse effect of groundwater, an expansion of the application of the helical anchor structure in civil engineering is needed, and new drainage solutions are being considered. The features of the helical anchor type for horizontal drainage equipment, analyses of some of its advantages, and conditions of application are presented. Generally, a helical anchor for horizontal drainage is convenient for installation, maintenance, or removal, and is effective for both horizontal drainage and for anchoring the revetment. It is also a typical construction in drainage works, generally performed by a cranking handle or a rotary-percussion-type drilling machine. The helical anchor pipe for horizontal drainage has many segments with joints using a cranking hand for installation and is quite effective where the installation space is narrow or there is no machine. In particular, the installation of this equipment differs significantly from other drilling methods because it can be driven into a sand layer without a hole wall.

Keywords: helical anchor, horizontal drainage, groundwater, new drainage solution, subsurface drainage

1. Introduction

Groundwater has long been recognized as contributing to distress in various types of structures, and this is certainly true of slopes. A slope is more likely to fail during or after prolonged wet weather, and if the slope fails, the wet condition of the material within the slope is obvious [1]. In recent years, groundwater removal works have become more important than ever because of many instances of slope collapse due to increases in rainfall intensity and the local concentrations of heavy rain. There are many measures against the adverse effect of groundwater such as horizontal drains. For drain placement, horizontal drilling is a possible construction method, but it is not suitable for sand, where the hole wall is not self-supporting [2].

Until now, screw structures have often been used in the form of screw piles or helical anchors in applications such as screw anchors of plate load tests and helical anchors for excavation. Although the size of the helix is not large, the pull-out bearing capacity of the helical anchor is quite high. In addition, the greatest advantage of the screw pile is its ease of installation, as it can even be installed by hand. For calculations regarding screw piles, there have been many formulae for pull-out bearing capacity depending on the number of helices and soil characteristics [3]. Recently, some researchers in Vietnam have investigated extensions of the screw structure and applications to protect sea-dike slopes such as a screw anchor for overlapping block revetments [4]. The pull-out bearing capacity of a screw anchor provides higher resistance against uplift and reduces both horizontal and vertical displacements of placed block revetments. The screw anchor of the placed blocks has three essential parts: the anchor head, tendon, and fixed connection. The anchor head is made from plastic with a twisted slot. High-tensile plastic cable is used for the tendon. A fixed anchor is connected to concrete blocks at the center of the concrete block. Another application for the protection of slope canal [5] uses a plate revetment made from polymer or composite with a screw anchor to maintain stability. This paper discusses the screw pile as horizontal drainage equipment, which is an innovation in horizontal drains, as it is easily installed in all kinds of soil. It has functions both of horizontal drainage and to anchor a placed block revetment on the slope surface. Additionally, within such a confined space, it is quite difficult to place horizontal drains. The helical anchor type therefore would resolve these technical shortcomings. The segment structure of the helical anchor supports ease of placement and withdrawal. This paper also focuses on the principles of this system of drainage.

Fig. 1. Cement mortar pump designed for slope protection at a site along the Noibai-Laocai Expressway.

Fig. 2. Cement mortar layer with PVC pipe for drainage.

2. Technical Conditions of Existing Works for Which Horizontal Drainage Equipment Needs to Be Installed

In Vietnam, there are many ways to protect a cut slope, such as a concrete grid beam with grass, placed blocks of concrete, and placed stone and grass, but the most popular is a cement mortar pump, which fights erosion of the surface and weathering of the soil with plants (**Fig. 1**).

This is designed for dealing with aggregate whose maximum size is 10 millimeters. For drainage, a PVC pipe of 20 mm diameter is usually used (**Fig. 2**).

In principle, this PVC pipe plays a role in the horizontal drainage of the slope, but in fact it is not installed in deep soil and is not effective at drainage. During the rainy season, a part of the water runs out over the cement surface and the other runs out under the cement layer and can break through any part of it (**Fig. 3**), leading to the collapse of the cement cover protection.

As the existing drains are ineffective, a new drainage solution is being considered.

Fig. 3. Water breaks in cement cover.

Furthermore, in the high mountain areas in Vietnam, there are many difficulties such as transportation difficulties and a lack of budget, and insufficient construction equipment. Resources of local authorities are not sufficient to apply model technology, especially for horizontal drainage for slope protection, inspiring our suggestion of the simplified technology of a helical pile for horizontal drainage. This equipment can be installed by hand or machine. It acts as a helical pile and functions both for drainage and as an anchor for the plates of the revetment for slope protection.

In other situations, horizontal drainage is needed for the reduction of the top flow line in an earth dam with stuck drainage. The Da Bac earth dam is a typical case with serious seepage out of the downstream slope. The Da Bac reservoir is located in Hong Linh Town, Ha Tinh Province. Its basic parameters are as follows:

- Structure of dam: Homogeneous dam with rock toe
- Length: 605 m
- Height of dam: 25.75 m
- Capacity: 3×10^6 m^3
- Current technical situation: As the rock toe does not work for drainage, the top flow line exits on the downstream slope of the dam. The water has leaked out of the downstream slope in an area of about 20 m^2 at that site. There are many sites with such bad leakage as to reduce the water level to half. **Fig. 4** shows the Da Bac earth dam with half the planned water level in the reservoir.

Figure 5 is a clear picture of a leaked-out site on the downstream slope. The soil has become softer, wet, and undulating.

Several solutions have been offered, such as a rebuilt rock toe for drainage, jet-grouting cement mortar into the soil body of the dam, and installing horizontal drainage, but it would be too difficult to drill in incohesive soil without a hole wall. As the soil body of Da Bac Dam is sandy soil, helical piles can be used as horizontal drainage.

Fig. 4. Headwork at Da Bac reservoir.

Fig. 5. Typical leaked-out site on the downstream slope of Da Bac dam.

3. Features of Horizontal Drainage Helical Anchor Equipment

Helical anchors, sometimes referred to as screw anchors, screw piles, and helical piles, are a steel screw-in piling and ground anchoring system used for building deep foundations. Screw piles are manufactured using varying sizes of tubular hollow sections for the pile or anchor shaft.

The pile shaft transfers a structure's load into the pile. Helical steel plates are welded to the pile shaft in accordance with the intended ground conditions. Helices can be press-formed to a specified pitch or simply consist of flat plates welded at a specified pitch to the pile shaft. The number of helices and their diameters and positions on the pile shaft as well as steel plate thickness are all determined by a combination of: The combined structure design and load requirement, the geotechnical parameters, environmental corrosion parameters, and the minimum design life of the structure being supported or restrained.

Screw pile foundations are still used extensively in a wide range of structures from lighthouses to rail, telecommunications, roads, and numerous other industries where fast installation is required or building work is taking place close to existing structures.

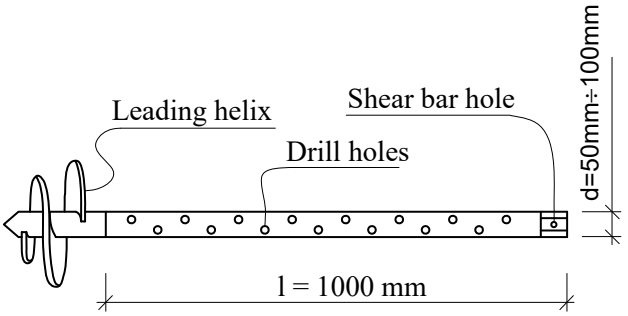

Fig. 6. Features of the first segment.

Most industries use screw pile foundations due to cost efficiencies and, increasingly, their reduced environmental impact. "Screwing" the foundations in the ground entails less soil displacement, so excess soil does not need to be transported from the site, saving on transportation costs and reducing the carbon footprint of the project.

The main benefits of screw pile foundations include shorter project times, ease of installation, ease of access, reduction of the carbon footprint, ease of removal when the foundations are no longer required, reduced risk to the workforce, and reduced costs.

Being suitable for both tensile and compression loads, they are also used for masts, signs, and retaining structures, and now, screw piles or helical anchors are being used as horizontal drainage equipment for slope protection.

The horizontal drainage helical anchor equipment is divided into many steel pipe segments. Each segment is about 1 m long and 50–100 mm in diameter or larger. The first steel pipe segment has the leading helix at the tip of the pipe, with drill holes for drainage about 600 mm along the pipe. The other tip of the pipe (without the helix) is made to form a square shape with a shear bar hole so as to connect to a swivel arm for the installation of the second segment (**Fig. 6**). The filter is inserted inside steel pipe correlative drill holes in a position that allows groundwater entry into the steel pipe but excludes solid material. A permeable geotextile filter is perhaps better than a ceramic or combined filter. Because the horizontal drainage screw pile can pass through several soil layers with different grain sizes, it is divided into many steel pipe segments to allow insertion of a conformable filter, as well as ease of removal and ease of installation in a narrow space or in case of insufficiency of the machine.

The length of the first segment is 1000 mm minimum. The diameter is 100 mm or larger. The dimensions of the pipe should be designed so that it can carry a volume flow rate equal to the expected rate, multiplied by a safety factor.

The second segment with two tips has a square shape but different sizes [6] (**Fig. 7**).

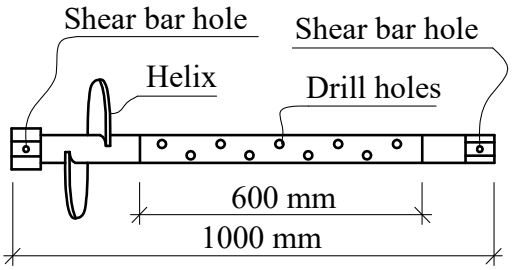

Fig. 7. Feature of extension segment with one helix.

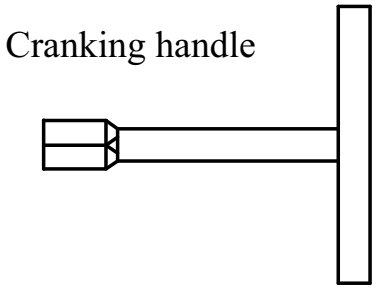

Fig. 8. Cranking handle for installation.

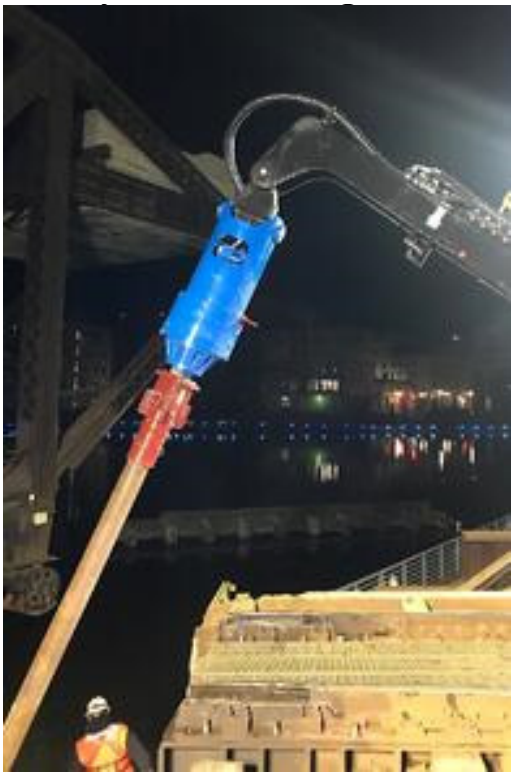

Fig. 9. Typical machine for installation of a helical anchor [8].

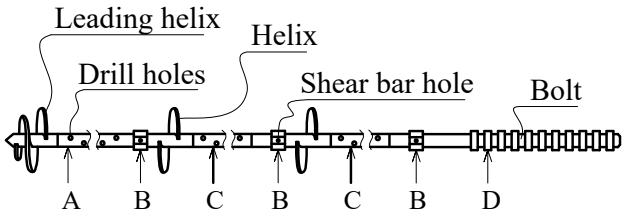

Fig. 10. Typical configuration for a multi-helix screw pile using horizontal drainage. A – lead section with one helix or several helices; B – joint; C – extension with one helix; D – the last segment with bolt.

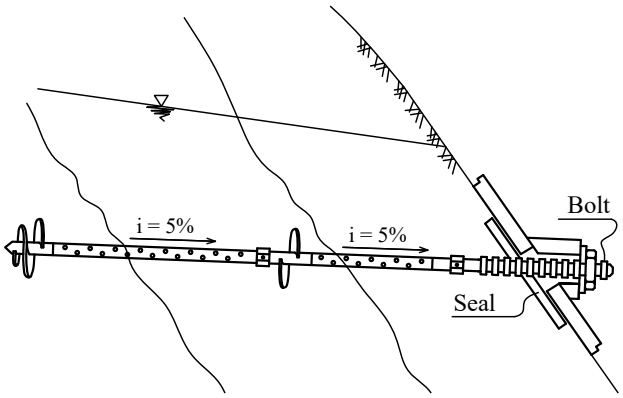

Fig. 11. General sketch line of the horizontal drainage screw pile in an earth slope.

A swivel arm (**Fig. 8**) or a machine can be used to install the screw pile.

In some cases, for instance, in mountainous areas, there is no machinery or equipment for installation. The helical pipe for horizontal drainage will then be installed using the swivel arm [7].

For a large helical pipe, using a machine (**Fig. 9**) allows the installation of many extension segments. **Fig. 10** shows typical configuration for a multi-helix screw pile with many segments.

The last segment has a tip for connection to the previous segment, while the other tip is made with a bolt to hold the plate of the revetment [6]. At the position of the steel pipe, the soil of the surface slope should be sealed by tamping clay or a similar impermeable material for 0.5–1.0 m into the annular space around the drainpipe before placement of the revetment (**Fig. 11**).

4. Remarks on Design and Installation

Helical piles for horizontal drainage may also be driven into an aquifer by hand or machine, the same as horizontal drains. There are many calculation methods for horizontal drains, such as horizontal drains in unconfined aquifers, using flow nets and finite-element methods. The design procedure and design parameters are the same as for a horizontal drain [9].

Some of the criteria for the filter and drill holes on the helical pile also follow the same criteria as horizontal drains for slope protection.

In case a horizontal drainage helical pile is used to anchor a revetment, the dimension of the helixes should be determined for the resistance of the anchor. The calcula-

tion is followed by the helical pile procedure.

The length of the horizontal drainage screw pile that can be installed by hand is less than 4 m. If longer than 4 m, it should be driven by a machine and more helices should of course be put on the extension segment.

Instead of a female socket connection, a bar is used to connect the steel pipe segments. A multi-segmental structure makes it easy to insert and extricate filters inside the pipe.

5. Conclusion

The horizontal drainage screw pile is an innovation of horizontal drains, a form of subsurface drainage systems for slope stabilization. It can be installed without drilling in advance.

Generally, this solution is characterized by ease of installation and maintenance and is an effective measure for both horizontal drainage and anchoring a plate revetment.

The design parameters such as the filters and drilled holes on the pipe follow the existing standards of horizontal drains.

When installed as an anchor for revetment, the calculations are the same as for a helical pile of steel pipe.

The horizontal drainage helical pile is also a typical structure in drainage works that is generally installed with a cranking handle or a rotary-percussion-type drilling machine. This is quite effective in places where the installation space is narrow or suitable machinery is lacking. In particular, this equipment has a major difference from existing drilling methods in that it can be driven into a sand layer without a hole wall.

Acknowledgements

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