Modern technologies for engineering protection in landslide areas

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Abstract

Today, engineered protection of infrastructure, investment objects for social and economic development, as well as objects of strategic importance are some of the most challenging tasks of construction in mountainous areas around the world. Difficult geological, unique climatic conditions and a high level of seismicity pose special challenges for construction in these regions. Construction if the facilities is a concern as well as to ensure the safety of their long-term use. The main threats to the safety of these objects are landslides, rockfalls, mudflows and snow avalanches caused by climatic or seismic influences. This paper presents the TITAN self-drilling system and shows some of its applications in slope stabilization.

1 INTRODUCTION

The TITAN self-drilling system was developed by Friedr. Ischebeck GmbH more than 35 years ago. Over the long period of its existence, countless projects have been realized all over the world, a huge experience has been accumulated in various geological conditions and under very difficult circumstances, which is continuously used to improve the system and develop new applications.

The TITAN self-drilling system consist of a ribbed steel tube and a grout body made from cement suspension. The system is permanently interlocked with the existing soil and is suitable for tensile, compressive and cyclic loads in permanent and temporary applications according to the National Technical Approval Z-34.14-209 issued by the German Institute of Building Technology (DIBt).

Figure 1. Rockfall, Krasnaya Polyana, Sochi, Russia.

2 TITAN SELF-DRILLING SYSTEM

TITAN self-drilling micropiles are one of the fastest, easiest and most reliable ways to build pile foundations. The essence of the technology is that the prefabricated structure of steel elements simultaneously performs three functions.

1. The hollow bar itself, equipped with a suitable drill bit for the present soil conditions is a drilling tool. For its drilling, it is not necessary to involve additional drilling tools like auger, casing pipes or any other equipment. Further, it is not necessary to remove it from the borehole after drilling.
2. TITAN hollow bars and drill bits with holes allow for the simultaneous flushing with cement grout while drilling, automatically and continuous filling the borehole from the bottom. No other additional injection hoses are required.
3. The steel structure of the micropile can be extended from the surface by means of coupling with additional bars to the required length and remains in the borehole as the reinforcing element of the pile.

Drilling without casing and the simultaneous injection of cement grout through the hollow bars significantly speeds up and simplifies the process of installing TITAN micropiles.

In general, the installation of TITAN micropiles, anchor piles, and soil nails consists only in their direct drilling and flushing with thin cement grout (w / c = 0.7 - 1.0) and successive injection of thick cement grout (w / c = 0.4 - 0.6). Flushing cement slurry removes soil particles from the borehole, penetrates the soil surrounding the pile body, improves its characteristics, stabilizes the borehole and creates an interlink transition between the pile body and the soil around. In this way, depending on the properties of the soil, it is possible to increase the diameter of the drilled pile up to a double diameter of the drill bit. The surface of the TITAN piles is very uneven and this ensures their good adhesion to the ground.

After the calculated depth of the pile is reached, the drill bar continues to rotate and we start to inject the thick cement grout, which displaces the flushing grout. This secondary injection achieves a higher pressure up to 80 bars, which in soft soils contributes to their compaction, as well as the expansion of the pile diameter.

Due the lightweight nature of the system the installation can be made by small installation equipment. It facilitates drilling works in difficult access areas, such as steep slopes or mountains without existing infrastructure.

Small deformations in TITAN self-drilling micropiles encourages their use as foundations of buildings, bridges, overpasses and more complex structures. Micropile groups can withstand a wide range of loads and load combinations, such as pressure, tension, lateral loads, torque and torsional moments and even dynamic loading. Especially in seismically active zones, groups of several “root” micropiles are a more efficient and reliable solution compared to massive pile foundations.

3 SOIL NAILING

In hilly and mountainous areas stabilization of natural and cut slopes by soil nailing is a widespread method. The working principle is firstly stabilization of the local soil area by soil nails, and secondly, the combination of all installed nails, creating a reinforced stable geocomposite wall, which increases the global stability of the slope.

Figure 2. Slope failure, highway A1 in Poland.

Usually a soft surface facing like a steel mesh is used or shotcrete is necessary to avoid surface sliding and the erosion processes of soil. This modern and smart solution often replaces the construction of heavy and bulky concrete retaining walls. It saves not only time and money, but also preserves the natural appearance of the landscape. Soil nailing structures contain often hundreds of nails which are installed on steep slopes with difficult access. Selfdrilling systems such as provided Ischebeck TITAN are very suitable due to high installation speed and requirement of very small, light and flexible equipment.

Figure 3. Slope stabilization by Ischebeck TITAN soil nails combined with a Geobrugg TECCO steel mesh, Alpika Service, Sochi, Russia

4 ROCKFALL PROTECTION

In instances of possible rockfalls, two types of engineering protection are commonly used. The first solution involves a complete covering the danger zone with a suitable steel mesh, fixed by nails or rock bolts depending on the geological conditions and loads. This option prevents collapses, but it is more appropriate for locally securing relatively small danger zones (Figure 4).

Figure 4. Option 1. Rockfall protection by the Geobrugg TECCO mesh and Ischebeck TITAN rock bolts, Poland.

If there are large areas of possible rockfall hazards, for example along a road or railway track, the more efficient protection option is a rockfall barrier (Figure 5). Such barriers do not prevent the rockfalls, but they provide the necessary protection for infrastructure against falling stones and boulders. Small TITAN micropiles can be used as a foundation for these structures and as anchor piles to secure the cable braces. Similar looking barriers are used in combination with TITAN micropiles and anchors to protect against mudflows and snow avalanches.

Figure 5. Option 2. Rockfall barriers along railway tracks, founded on TITAN micropiles, Germany

5 ANCHORED RETAINING WALLS

One of the classic, but nonetheless popular methods of stabilizing slopes and landslide hazard zones is the protection with anchored retaining walls (Figure 6). An innovative point here is the use of selfdrilling TITAN anchor piles instead of conservative strand anchors or solid bars. The system is known for its high rigidity and low deformations before being fully activated in the ground, compared to strand anchors where the prestression and its continuously monitoring during the working life of the structure are required to avoid big deformations. Using the self-drilling system, the head construction can be completely sealed in the concrete wall or beam and thus protected against corrosion.

Figure 6. Retaining wall anchored by TITAN anchor piles in Sochi Russia

The installation method (Figure 7) of self-drilling TITAN anchor piles and geometric thread configuration provides simple, but permanent corrosion protection through the designed grout cover. Therefore, the use of TITAN anchor piles is especially beneficial in permanent structures, in which steel elements of alternative anchors require additional anti-corrosion protection.

Figure 7. Installation of TITAN anchor piles on top of a retaining wall.

Engineered protection are often geared toward permanent applications such as retaining walls along roads or railways. TITAN anchor piles have advantages in easy installation, operational reliability and maintenance free when compared to that of other anchor solutions. Increased experience in this application aims at developing more practical and efficient methods of slope retention.

Figure 8. Testing of TITAN anchor piles infrastructure objects in Sochi Russia

6 ROAD RECONSTRUCTION AFTER A LANDSLIDE

Linear road transport infrastructures together with rail transport, are probably the projects in which geotechnical works represent a very significant percentage of the actions. If we exclude the structures and therefore their foundations (sometimes also complex to design and execute) as well as the tunnels, the linear works are a succession of embankments and land clearance whose analysis and design is purely geotechnical, and in the 2nd case a portion of the ground is removed from its location to generate new slopes.

The execution of these new slopes affects the stability conditions of the adjacent lands, they could be mobilized if the new geometry does not have an adequate factor against landslide.

This may occur during the execution of the construction work of a road, with its corresponding economic and term repercussion for the project but can be corrected as an additional item or extension of the existing ones, or worse, after the commissioning of the infrastructure, due to a change in boundary conditions, such as an earthquake, the coronation load, a change in the water table level or the mere evolutionary character and the variable resistance of the affected lands (processes of progressive degradation over time, erosion, creep / creep or drop in resistance to residual values). In these cases, the consequences on the road in operation may become temporarily useless (Figure 9), with the high damages and costs that this entails.

Figure 9. Original situation of route 228 (courtesy GSS Titan)

As an example, we could mention Route 228 Costa Rica, this site had failed numerous times and was done with a gabion wall. The gabion walls are heavy and collapsed typically every 3 years. As an alternate solution it was carried out the installation of self-drilling TITAN micropiles for the footing (40/16) and then a reinforced block wall with two layers of tieback anchors (40/20). Figure 10 shows the installation process.

Figure 10. Micropile installation (courtesy GSS Titan)

Figure 11 shows the final state of the wall and figure 12 the repaired route

Figure 11. Final state of the wall (courtesy GSS Titan)

Figure 12. Repaired route 228 Colpachi - Cartago (courtesy GSS Titan)

7 CONCLUSION

Mastering modern technologies in the field of engineering protection allows us to cope with existing challenges economically, quickly and reliably. In conditions of rapid growth and the need for engineered protection systems, it is important to make a choice, in priority of reliable high-quality systems. Investments in infrastructure and other facilities are incomparably higher than the cost of engineering protection. Cost savings should be realized by effective long-term solutions and innovative technologies, not only on the quality of materials but on consumer safety.

The TITAN self-drilling system is applicable for soil nailing, anchor and micropile projects in an efficient way. Protection against corrosion and the steel characteristics provide a high degree of safety for any application, allowing to consider the TITAN self-drilling system as a permanent solution.

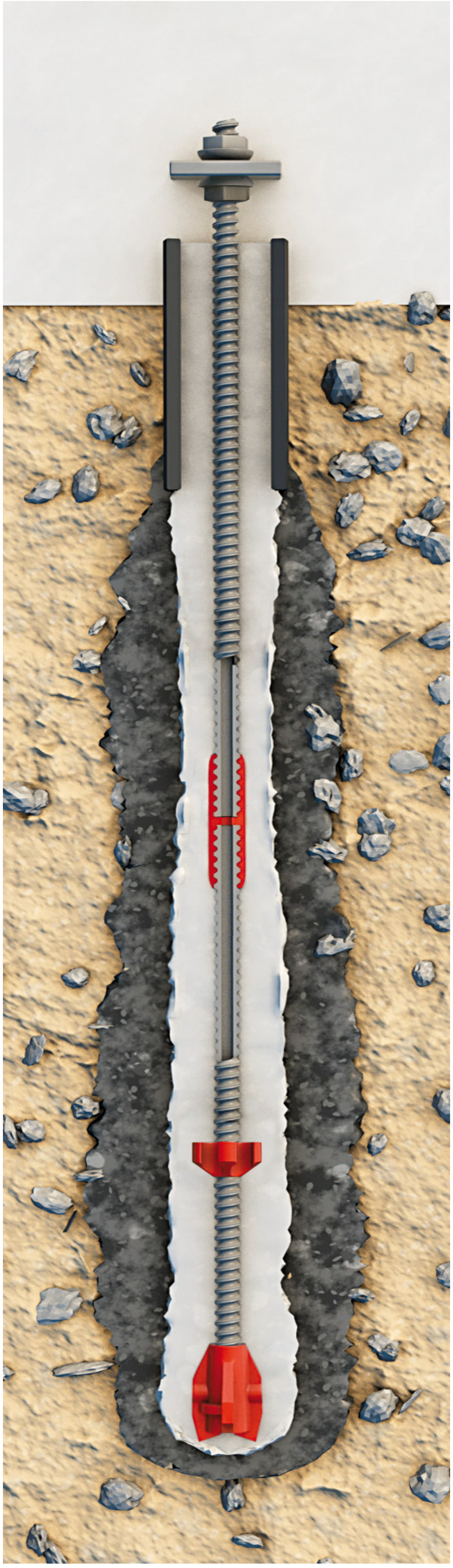

Figure 13. TITAN micropile

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