Reflection upon slope stabilization in mining regions using helical piles

Mehdi Dib & Chaouki Benabbas
Territory Planning Research Center, Constantine, Algeria

GeoCalgary 2022 October 2-5
Reflection on Resources

ABSTRACT
Vertically installed helical piles can be very advantageous to stabilize precarious slopes affected by mining activities, by reason of their installation process, which necessitates no excavation nor vibration, helical piles have a less risk of triggering the slide when installed. However, in practice, helical piles are generally used in case of axial and lateral loading. If a basically vibration free installation process is a key advantage regarding the reinforcement of unstable slopes, the structural efficiency is also very important. When installed properly, helical piles can offer both the structural and the installation advantages for an adequate reinforcement. A reflection upon using this technique in slope stabilization in mining regions is the subject of the present study.

RÉSUMÉ
Les pieux hélicoïdaux installés verticalement peuvent être très avantageux pour stabiliser les talus précaires affectées par les activités minières, en raison de leur méthode d'installation, qui ne nécessite ni excavation ni vibration, les pieux hélicoïdaux ont moins de risque de déclencher le glissement lors de leur installation. Cependant, dans la pratique, les pieux hélicoïdaux sont généralement utilisés en cas de chargement axial et latéral. Si un processus d'installation pratiquement sans vibrations est un avantage clé en ce qui concerne le renforcement des talus instables, l'efficacité structurelle est également très importante. Lorsqu'ils sont installés correctement, les pieux hélicoïdaux peuvent offrir à la fois les avantages structurels et ceux d'installation pour un renforcement adéquat. Une réflexion sur l'utilisation de cette technique dans la stabilisation des talus en régions minières fait l'objet de la présente étude.

1 INTRODUCTION

Worldwide, landslides are one of the most destructive calamities, a failure of a precarious slope can cause massive fatalities. A large variety of triggering factors can cause a slope to fail, it can be divided into natural factors: like earthquakes and rainfalls, and human activities related factors. Recently, the number of landslides caused by human activities is on the rise (Froude and Petley 2018).

The population growth, and the technological revolution lately caused the demand for underground resources to increase, which pushed mining activities to accelerate to cope with the growing demand. In regions that are already susceptible to landslides, underground mining operations can be the trigger to these calamities.

The precarious slopes located in the urbanized and strategic areas need to be reinforced. However, in slopes of a high unstability, the reinforcement operation itself can trigger the slide, for example: the vibration due to the installation of driven piles, or sheet pile walls, the excavation of a bored piles need to be considered as a potential triggering factor. Helical piles on the other hand have the advantage of a smooth installation process, which implies almost no vibration (Livneh and El Nagger 2008). Therefore, compared to driven, or board piles, helical piles installation process is less likely to trigger a slide. Nevertheless, Helical piles and high-capacity helical piles in general are used to resist to axial and lateral loading: (examples in literature: Prasad and Rao 1996, Livneh and El Naggar 2008, Perko 2009, Sakr 2012, Abdrabbo and Wakil 2016, Lanyi-Bennett and Deng 2019, Nowkandeh and Choobbasti 2021, Alwalan and Alnuaim 2022).

When subjected to ground movement, it was recently found that helical piles resist better to ground movement thanks to the additional resisting moment offered by the helices (Dib et al. 2019), which, in addition to the smooth installation process, it represents a structural advantage. The present paper represents a reflection upon slope stabilization in mining regions using helical piles.

2 BEHAVIOR OF HELICAL PILES WHEN USED FOR SLOPE STABILITY

This paper is a reflection inspired by the findings of (Dib et al. 2019) regarding the behavior of helical piles when used in slope stability. This reflection aims to open the door for further research in this field, because, both the installation and structural advantages offered by helical piles allow it to exceed the classic use to resist axial and lateral loading only, and to expand towards resisting ground movement.

3 LANDSLIDES AND MINING

In order to satisfy the growing demand on underground materials, legal and illegal mines were excavated in rich areas all around the word. Between 2004 and 2016, it was reported that landslides triggered by human activities are increasing (Froude and Petley 2018). As shown in figure 1,

among the non-seismic non-rainfall triggered landslides occurrence in the aforementioned time period, 38.6 % were caused by mining activities, in which the nature of these activities is legal, illegal and unknown in certain reported cases (Froude and Petley 2018).

Slope deformation and surface subsidence caused by mining is not a novel issue, however these phenomena are accelerating recently due to the increase of the use of long wall mining and the urban extensions towards abandons mines lands (Altun et al. 2010). The slope saturation, which is a key landslide triggering factor, can be caused by the increase of groundwater level (terrain surface depression) due to mining activities (Altun et al. 2010). It was also reported in a case of study in the Karviná part of the Ostrava–Karviná District (Czech Republic) that the underground mining of black coal has an influence on the changes in engineering-geological conditions, physical–mechanical properties of the rock material, the state of the stress in the slope, and the groundwater level regime (Marschalko et al. 2012). Furthermore, underground mining has a negative impact on the environment, and it can cause depression and reactivation of large slope deformation, which may endanger several villages, roads, railways, and other infrastructures (Malgot and Baliak 2004).

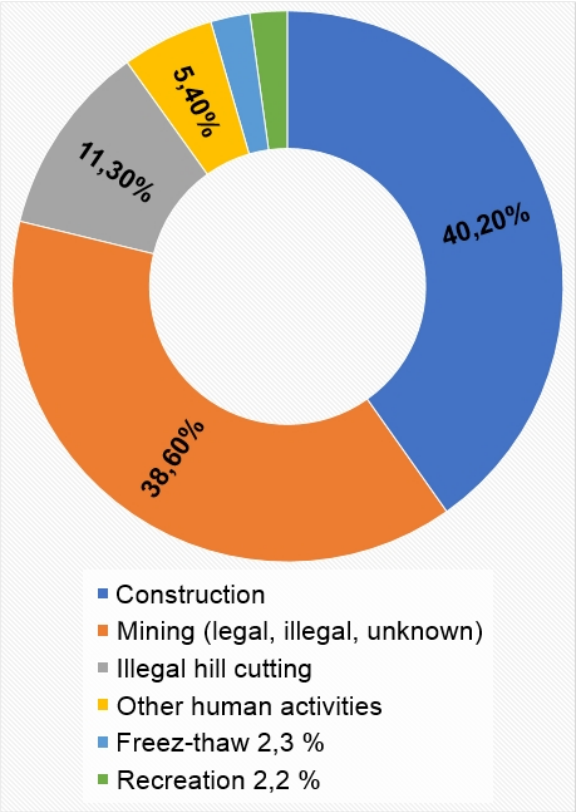

Figure 1. Triggers of non-seismic non-rainfall landslide events (770 events) (Froude and Petley 2018)

4 SLOPE STABILIZATION IN MINING REGIONS USING HELICAL PILES

In case of deep-seated landslides, the reinforcement is technically difficult, and the economic cost is enormous. On the other hand, shallow and medium slides can be reinforced when the affected area is urbanized or has a strategic value. Helical piles can be used to add more resisting force to precarious slopes without endangering it during the installation.

4.1 Helical piles: installation safety

Helical piles are installed into the ground by a slow rotation (figure 02), the helices are designed and manufactured to follow one unique path during the installation in order to minimize the soil disturbance. The installation of helical piles implies almost no vibration (Livneh and EL Naggar 2008), this key advantage makes it very suitable in case of reinforcing precarious slopes.

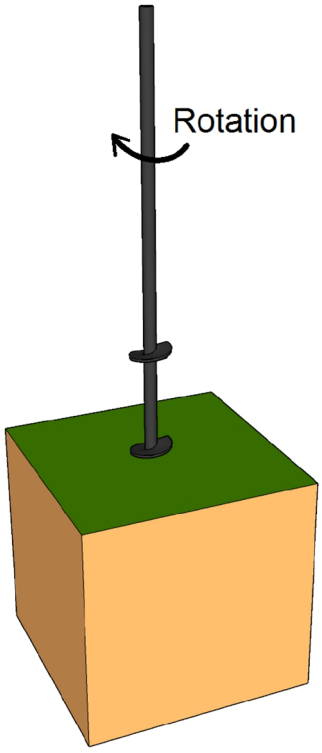

Figure 2. Schematic illustration of a helical pile installation process

4.2 Helical piles: structural efficiency

If a basically vibration free installation process is a key advantage regarding the reinforcement of unstable slopes, the structural efficiency is also very important. The numerical analysis of various high capacity helical piles in a clayey slope have shown that the presence of plates leads to an increase in the resisting force (Dib et al. 2019).

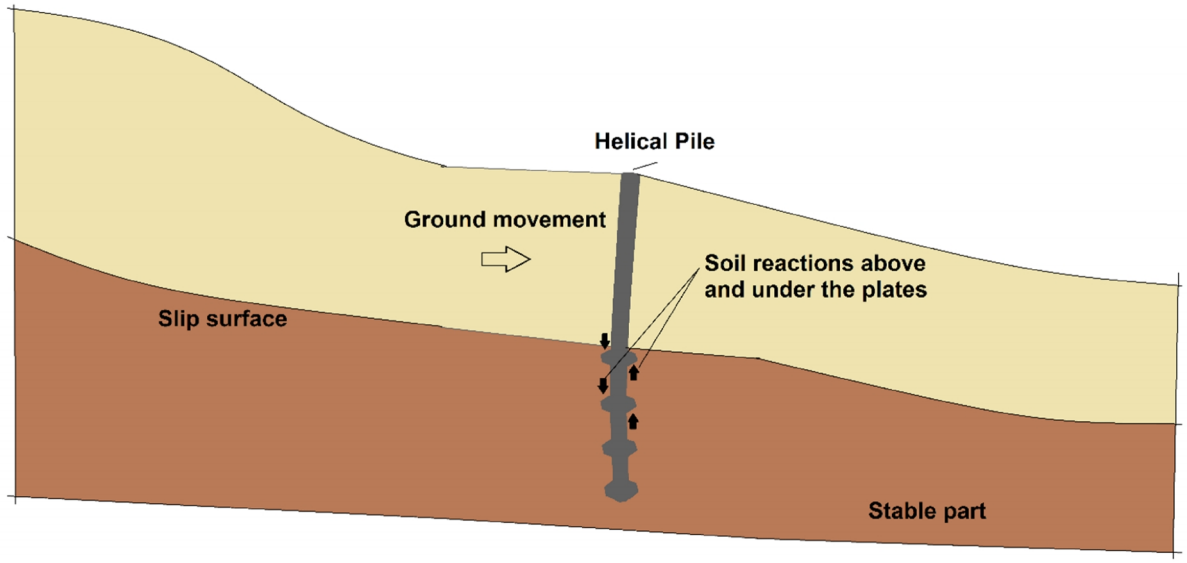

Figure 3. Schematic illustration of a four plates helical pile subjected to ground movement (according to Dib et al. 2019)

The numerical analyses were conducted on straight pile shaft without plates (P0), and high-capacity helical piles with one plate (P1), tow plates (P2), four plates (P4), and six plates (P6) (Dib et al. 2019).

Figure 03 shows a schematic illustration of a four plates helical pile subjected to ground movement. When subjected to ground movement, the plates of the helical pile positioned near the sliding plan move with the pile due to the ground movement, this movement mobilizes soil reactions underneath and above the plates, which add a resisting moment to the pile (Dib et al. 2019).

The pile head deflection on the other hand is also reduced for helical piles compared to the straight pile shafts without the plates. Figure 4 illustrates the gain in the resisting force (Rf) and the piles head deflection of P4 compared to P0 with respect to pile to pile spacing (D: is the pile shaft diameter) (Dib et al. 2019).

5 REFLECTION AND CONCLUSIONS

This research represents a reflection upon slope stabilization in mining regions using helical piles. Starting from the premise that an adequate reinforcement for a precarious slope must: (1) Have a smooth, vibration free installation process, (2) have a high structural performance, helical piles seem very appropriate for the reinforcement of unstable slopes.

Figure 05 illustrates the idea behind this research. For landslides of a medium and shallow slide depth, when installed properly, helical piles can offer both the structural and the installation advantages for an adequate reinforcement.

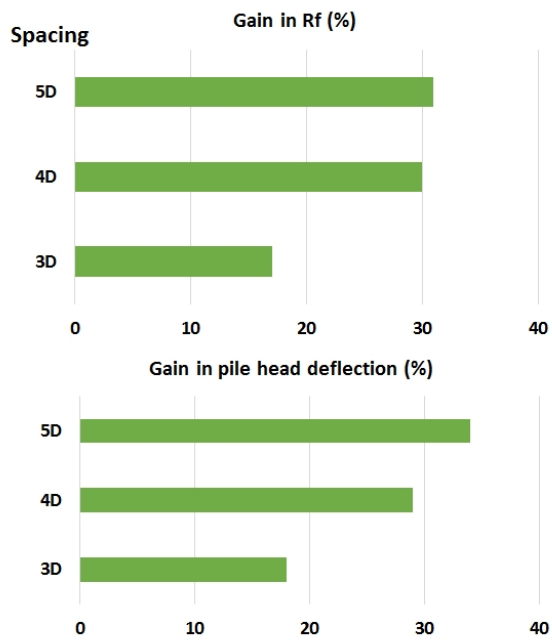

Figure 4. The gain in the resisting force (Rf) and the pile head deflection of P4 compared to P0 with respect to pile to pile spacing (according to Dib et al. 2019)

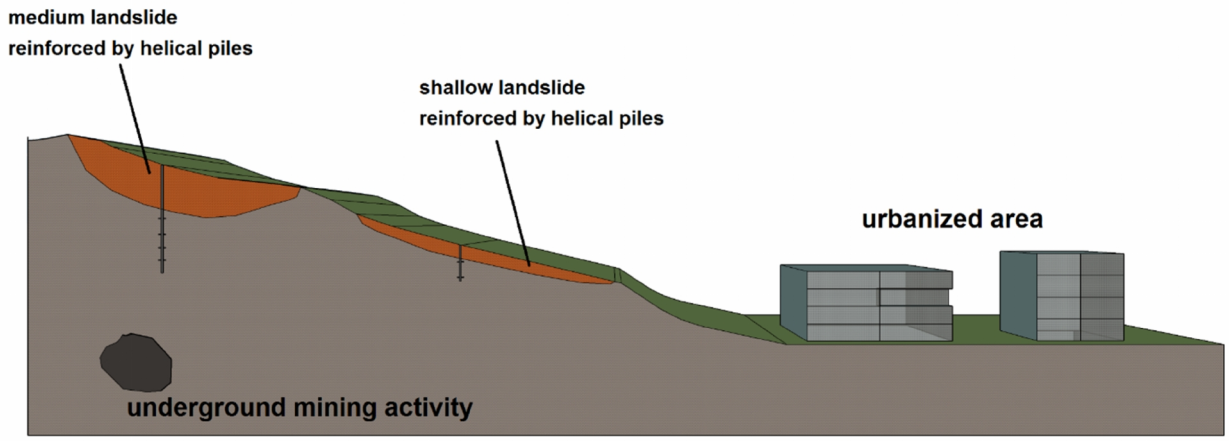

Figure 5. Illustration of slope reinforcement using helical piles in mining regions

6 REFERENCES

Abdrabbo, F.M. and Wakil, A. 2016. Laterally loaded helical piles in sand, *Alexandria Engineering Journal*, 55:3239–3245.

Altun, A.O. Yilmaz, I. and Yildirim, M. 2010. A short review on the surficial impacts of underground mining, *Scientific Research & Essays*, 5 (21): 3206-3212.

Alwalan, M. and Alnuaim, A. 2022. Axial Loading Effect on the Behavior of Large Helical Pile Groups in Sandy Soil, *Arabian Journal for Science and Engineering*, 47: 5017–5031.

Dib, M. Kouloughli, S. and Hecini, M. 2019, Numerical analysis of high capacity helical piles subjected to ground movement in weathered unstable clayey slope, *Computers and Geotechnics*, 110:319–25.

Froude, M. and Petley, D. 2018. Global fatal landslide occurrence from 2004 to 2016, *Natural Hazards and Earth System Sciences*, 18(8):2161–2181.

Lanyi-Bennett, S.A. and Deng, L. 2019. Effects of inter-helix spacing and short-term soil setup on the behaviour of axially loaded helical piles in cohesive soil, *Soils and Foundations*, 59: 337–350.

Livneh, B. and El Nagger, M.H. 2008. Axial testing and numerical modeling of square shaft helical piles under compressive and tensile loading, *Canadian Geotechnical Journal,* 45(8): 1142–1155.

Malgot, J. and Baliak, F. 2004. Influence of underground coal mining on the environment in Horna nitra deposits in Slovakia, *Engineering geology for infrastructure planning in Europe. Lecture Notes in Earth Sciences,* 104:694–700.

Marschalko, M. Yilmaz, I. Bednarik, and M. Kubecka, K. 2012. Influence of mining activities on the slope deformation genesis: Doubrava Vrchovec, Doubrava Ujala and Staric case studies from Czech Republic, *Engineering Geology*,147–148:37–51.

Sakr, M. 2012. Installation and performance characteristics of high capacity helical piles in cohesive soils, *DFI Journal - The Journal of the Deep Foundations Institute*, 6(1): 41-57.

Nowkandeh, M.J. and Choobbasti, A.J. 2021. Numerical study of single helical piles and helical pile groups under compressive loading in cohesive and cohesionless soils, *Bulletin of Engineering Geology and the Environment*, 80: 4001–4023.

Perko, H. A. 2009. *Helical Piles: a Practical Guide to Design and Installation*, J. Wiley, Hoboken, N.J.

Prasad, Y.V.S.N., and Rao, S.N. 1996. Lateral capacity of helical piles in clays, *Journal of Geotechnical Engineering*, 122 (11): 938–941.