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# Consolidating existing road structures using self-drilling bars

## Consolidation des structures routières existantes à l'aide de barres autoperceuses

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**ABSTRACT**: The article presents design methods and execution technologies for consolidating geotechnical structures and roads in mountains areas of Romania, considering the specific conditions for each site. The design process took into consideration the difficult site conditions respectively , the working space - the consolidation and drainage works must be strictly performed within the road area (approximately 9m wide) and the execution phases – the works must be executed in such a way that traffic can proceed safely. The paper will present several situations encountered in different locations in Romania, with their respective geotechnical and hydrogeological characteristics and the specific technical solutions chosen at the design stage and implemented throughout the execution. Detailed solutions will be offered for the drainage system and the surface and underground water, as well as for the restoration of existing structures. The degradation over time of the road-associated structures is a widespread problem and it is influenced, among others, by geotechnical conditions and water action. Such deterioration compromises traffic safety leading to partial failure with impact to the usual traffic and even to complete failure. The pressing need for safety usually demands an emergency intervention plan, with technical solutions that can be quickly executed in the event of a major hazard. With this innovative approach, roads can be made safer and more resilient against future deterioration caused by changing geotechnical conditions or other environmental factors.

**RÉSUMÉ**: L'article présente des méthodes de conception et des technologies d'exécution pour consolider les structures géotechniques et les routes dans les zones montagneuses de Roumanie, en tenant compte des conditions spécifiques de chaque site. Le project a pris en considération les conditions difficiles du site, respectivement l'espace de travail - les travaux de consolidation et de drainage doivent être strictement effectués dans la zone routière (environ 9 m de largeur) et les phases d'exécution - les travaux doivent être exécutés de manière à ce que la circulation puisse se dérouler en toute sécurité. Le document présentera plusieurs situations rencontrées dans différents endroits de Roumanie, avec leurs caractéristiques géotechniques et hydrogéologiques respectives et les solutions techniques spécifiques choisies lors de la phase de conception et mises en œuvre tout au long de l'exécution. Des solutions détaillées seront proposées pour le système de drainage et l'eau de surface et souterraine, ainsi que pour la restauration des structures existantes. La dégradation au fil du temps des structures associées aux routes est un problème répandu et elle est influencée, entre autres, par les conditions géotechniques et l'action de l'eau. Une telle détérioration compromet la sécurité routière, entraînant une défaillance partielle avec un impact sur la circulation habituelle et même une défaillance complète. Le besoin urgent de sécurité exige généralement un plan d'intervention d'urgence, avec des solutions techniques qui peuvent être rapidement exécutées en cas de danger majeur. Avec cette approche innovante, les routes peuvent être rendues plus sûres et plus résistantes à la dégradation future causée par les changements des conditions géotechniques ou d'autres facteurs environnementaux.

**Keywords:** Self-drilling bars; micropile; anchors; consolidating structures.

## 1 INTRODUCTION

Recent changes in construction work sector and the creation of special, modern equipment have allowed the development of new solutions for applied geotechnics.

One of these relatively recent technologies is the self-drilling bars, used as soil anchors and also as micropiles for deep foundation works, which is successfully applied in Romania in projects for consolidation and foundation works for road construction, slope protection structures and landslide stabilization etc., in difficult soil and space conditions.

Consolidating existing road structures is a crucial aspect of infrastructure development, especially in mountainous regions. The challenging terrain and specific geological conditions in these areas require specialized design methods and execution technologies to ensure the stability and longevity of

the road structures. One approach to consolidating road structures in mountainous regions is using self-drilling bars. These self-drilling bars provide a cost-effective and efficient solution for reinforcing the geotechnical structures and stabilizing the road foundations. Consolidation significantly influences soil strength and the stability of structures. Accurate prediction of consolidation and settlement is essential for the construction, design, and safety of engineering projects in mountainous regions. Over the past ten years, many road construction projects in Romania encountered difficulties that heightened the vulnerability to landslides.

In every situation, it was needed to use small but strong equipment that could change according to work conditions.

## 2 CONSOLIDATION WORKS FOR EXISTING RETAINING WALLS IN THE MOUNTAIN AREA

The high traffic in the city of Brasov, situated in a mountain area in the center of Romania, led to the accentuated degradation of some structures and traffic restriction in the area.

The existing structures were made of raw stone and cyclopean concrete, with a poor strength plain concrete foundation. The walls dimensions were variable as follows: widths between 0.60 m and 3.00 m at the base of the wall, lengths between 40.00 m and 80.00 m and heights varying from 0.90 m up to 10.00 m.

A visual inspection of the retaining walls was performed prior to the consolidation works design which revealed existing degradations such as cracks, displacements, settlements, that endangered the stability and resistance of these structures, the degradations being mostly still an active process. Some of the retaining walls had drainage systems, but due to the degradation of the roadway water infiltration took place and led to the collapse of one part of the walls and road, and also affected some houses downstream. These situations with degraded structures and signs of loss of stability have led to the restriction or even stop of road traffic, requiring immediate interventions to ensure stability of the area. The lithology in the site consisted of conglomerate layers that represent the bedrock, and on top of the bedrock, the soil was formed by soft reddish-brown, yellowish-brown clayey silt or silty clay representing the Quaternary age alteration blanket and contains fragments of rocks in variable percentages.

Consolidation works (Figure 1) consisted of micropiles executed by drilling vertically into the body of the structure, with two stage injection, which were connected at the top by a reinforced concrete beam. In addition, the walls were supported by inclined micropiles executed on two levels, respectively at the top and center of each wall height, with 45º inclination and lengths of 12.00 – 15.00 m. Furthermore, the consolidation works involved the restoration of the drainage system, where existing, or otherwise, execution of a new drainage system.

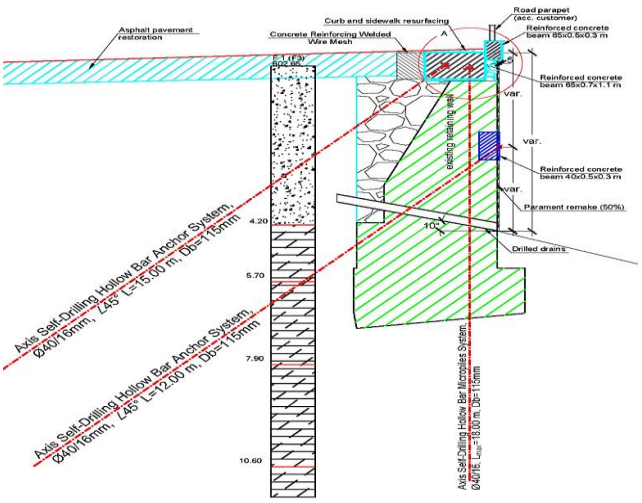


*Figure 1. Characteristic section - designed solution for consolidation of the retaining wall.*

The works were executed in well-defined steps as the consolidation of the retaining walls had to be done under traffic, on narrow streets and without changing the specific architectural aspect of the area (Figure 2). The geotechnical design of the structures rehabilitation was carried out in accordance with the requirements of European and Romanian standards.

*Figure 2. Picture from the site during execution.*

The structure was modeled in 2D design software, using both the limit equilibrium method and the reaction coefficient method, and verifications were

performed at the ultimate limit states: structural (STR) and geotechnical (GEO), considering normal and seismic design situations.

The geotechnical design was verified for the following ultimate limit states:

- internal failure or excessive deformation of the structural elements, in which the material strength contributes significantly to ensuring the resistance (STR);
- failure or excessive deformation of the soil, in which the foundation soil parameters contribute significantly to ensuring the resistance and global stability (GEO);

The main consolidation elements were the self-drilling bars. Their sizing was done preliminarily with the formula (1) below, then by automatic calculation the influence of these as a group effect on consolidation and displacement reduction was verified.

$$L = \frac{T_w * F_s}{\pi * D * T_{ult}} + l \qquad (1)$$

where $T_w$ is the design force (kN); $F_s$ is the safety factor equal to 2, dimensionless; D is the design diameter of the anchor/micropile (m); $T_{ult}$ is the lateral friction resistance of the injected micropile (kPa); l is the free length (m).

The equilibrium conditions were verified in the first step, through which the dimensions and geometry of the micropiles were determinate to ensure the stability of the system under the action of the soil pressures and other external loads. Then, in the second step, the structural design, the necessary sectional strength characteristics were established for the new system to be able to safely take all the loads and stresses (bending moments, shear and axial forces).

## 3 CONSOLIDATION WORKS FOR LANDSLIDES ON A NATIONAL ROAD

On a national road in Romania, in the mountain area, with high traffic accentuated degradation and instabilities were discovered with fast evolution accentuated by the rainy condition. Thus, from day to day, the degree of damage was greater, which endangers road traffic without taking urgent rehabilitation measures (Figure 3).

*Figure 3. Photo of the affected road area*

The geotechnical investigation, including inclinometer measurements (Figure 4), showed a first layer of soft sandy clay and loose sand to a depth of approx. 6.00 m over a layer of consolidated marl clay. Groundwater was intercepted at depths between 0.40-4.10 m, sometimes having a under presure character, due to clay intercalations in the first layer that locally block groundwater flow and generate springs locally.

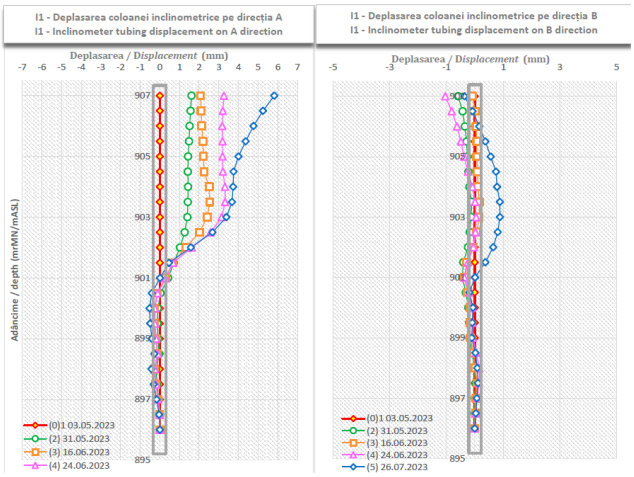


*Figure 4. Inclinometer measurement that show the evolution of displacement at different time intervals*

Following the stability analyzes performed, it resulted that the soil is stable in dynamic and static conditions only when the soil layer is not saturated.

Thus, through the project, works were foreseen to ensure the controlled flow of surface water and groundwater, the consolidation of soft ground and ensuring the general and local stability of the site.

The engaging was the condition that the consolidation and drainage works must be strictly performed within the road area (approximately 9m wide) and the execution phases – the works must be executed in such a way that traffic can proceed safely.

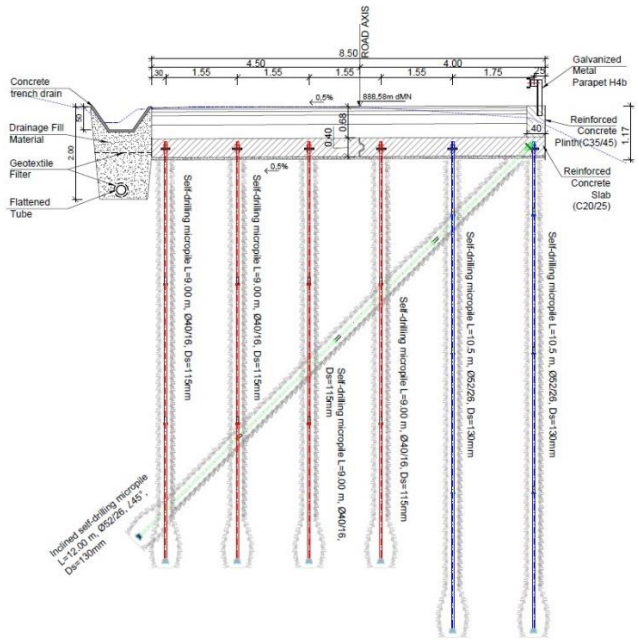


*Figure 5. Section with the designed solution*

In this case it was designed a complex solution with self-drilling micropiles, vertical and inclined, that ensures the soil improvement where difficult soil conditions were encountered and load transfer to the deeper layers and also the stability of the area (Figure 5).

The advantage of this solution is that it is based on a fast and efficient execution technology because the self-drilling bars allow dynamic grouting during drilling. In addition to significantly reducing execution time, it also allows efficient injection of soil near the micropiles.

The execution of the proposed works will eliminate the need to occupy surfaces outside the road and through the proposed execution solution, does not require closing traffic, because the equipment involved in the implementation of the works has small size an weight and the time required for execution is very reduced, reducing the inconvenience caused by single-wire traffic.

For groundwater drainage, an infiltration water collection system was provided consisting of a perforated rifled tube, wrapped in a geotextile filter, mounted at about 2.00m depth and drainage filling, on the route of the concrete channel projected on the left side of the road, in the direction of increasing mileage.

## 4 CONCLUSIONS

According to the specific conditions of the site, it is important to choose the consolidation solution for both structural damage of structure and soil degradation that appears due to the actions of natural or anthropic factors, it is very important to be minimally invasive and highly effective. Dynamic grouting during drilling process offers the advantage of improving the near soil by injection, also the execution can be performed with modern small dimensions equipment. The use of self-drilling bars for consolidation and foundation works it is a modern and efficient solution that which can be applied in cases.

The possibility of execution of both inclined and vertical self-drilling bars can ensure the soil improvement and also the stability of the area.

The solution was successfully applied in many projects in Romania associated with drainage works.

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