

SOLUTIONS TO STABILIZE THE EMBANKMENT OF A ROAD LOCATED IN THE STREAM BED OF A FLOWING MOUNTAIN WATER

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Abstract: *The location of the road embankment in the proximity of a flowing mountain stream caused the road to collapse. The embankment collapse occurred as a result of erosion and scouring phenomenon. The scouring phenomena have caused the destruction of the existing support structures and the loss of the river bank stability and the erosion phenomena have caused increase of the quantity of dislocated soil from under the road structure. The article presents the root cause of the collapse and analyzes and proposes solutions to stabilize the embankments.*

Key words: *stabilization, embankment, road, flowing stream*

1. Introduction

The continuous development of human settlements determined different constructions to be built on difficult terrains in terms of foundation, in zones with high potential to sliding, in the minor and major bed of the flowing streams. For the most of the cases, the geotechnical engineer encounters in current practice locations where one or more of the factors mentioned above are present. This study covers the problem of a landslide located in the minor bed of a flowing mountain stream by determining the causes that led to this situation and is analyzing and proposing intervention strategies.

The slide process includes three phases [1]:

- the preparation phase, of slow sliding, incipient (before threshold processes)
- the actual sliding (passing over the geomorphic threshold);
- natural stabilization (balancing, post-threshold processes)

The occurrence or reactivation of landslides is controlled by two categories of factors: natural and anthropogenic [2]. Natural factors are represented by the change of the natural water level, torrential rains, seismic movement, erosion and/or land dredging. Anthropogenic factors are represented by the out of control constructions on slopes with a highly chance of sliding and the deforestation / decaying of the vegetation on the same slopes.

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2. Aspects Related with the Situation on the Field

The targeted site is located in Zemeş commune area, in Bacău County, in the minor bed of Tazlăul Sărat river, an area known for its high risk of landsliding.

During the visit on site we found the following:

- The Tazlăul Sărat riverbed was clogged in a percentage of 50-60% with large boulders and tree trunks and vegetation residue.
- We identified residues of old retaining walls made from simple concrete and gabions;



Fig. 1. Overall view of the site

- the road embankment has been affected by a fall type landslide of the shore [3]. The landsliding occurred due to deterioration of the foot-slope on which the DC 130 is located caused by the erosion produced by the Tazlăul Sărat river.

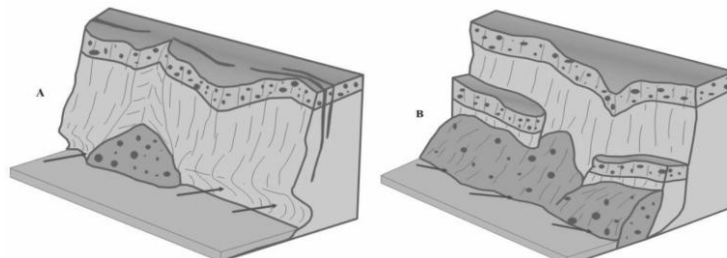


Fig. 2. The typical representation of a shore fall, after [3]
A) Before; B) After;

- In the proximity of the landslide, downstream, in the Tazlăul Sărat river stream bed there is a retaining wall made by simple concrete, a wall that supports the road embankment; after a visual inspection of the wall we noticed that the first section, near the zone that we have analyzed, has suffered a type GEO failure at the horizontal translation; the rest of the seen sections are showing structural degradation as well and there is a high risk for a future type GEO rotational failure as a result of the erosion of their foundation ground, the foundations being at present on an area of about 30-40% in the console (Figure 3).

During the geotechnical prospecting works we found the following geological stratification starting from the top of the drilling to the bottom: 60 cm of blocks, 230 cm

of sand mixed with a small amount of clay, with gravel and blocks, 90 cm of gravel mixed with blocks and boulders, 100 cm of gray marl clay and the base layer consisting of a compact gray sandstone.



Fig. 3. Existing retaining walls proposed actions to be taken

3. Proposed Actions to be Taken

After analyzing the physico-mechanical characteristics of site layering and the site topography, it was concluded that the site landslides are activated by the following factors:

- Tazlăul Sărat River waters eroded by time the foot of the slopes on which the road DC130 is located, which led to its failure by collapse;
- the dismantling of the existing structural and geotechnical support walls due to the erosion of their base by the waters of Tazlăul Sărat river.
- the small percentage of afforestation, compared with the surrounding areas;
- stagnation over long periods of the surface waters due to the existence of reverse slope area in upstream of the road, have influenced the local physico-mechanical characteristics of the site.

Taking into consideration the facts mentioned above, the following three possible solutions for the road embankment intervention have been considered:

- Sloping of the road embankment without the support elements
 - it's being proposed the sloping of the road embankment with a gentle slope, according to the term of STAS 2914-1984;
 - the riverbed on the analyzed area it will be purged;
- The maximal solution with support elements
 - it is proposed to support the embankment of the road by the provision of a support structure of pushed pilots with interspaces, dimensioned according to the technical regulations in force; it is proposed to place supporting structures at the edge of the carriageway towards the river Tazlăul Sărat;
 - It will be realized clogging works of the bed river on the analyzed zone with arrange of the slope in front of the supporting wall.
 - It's being proposed suport of the embankment of the road by arrangement a reinforced concrete support wall, cornier type, dimensioned according to the actual technical norms;

It's being proposed to place this wall at base of the embankment of the road to the Tazlău Sărat river bed; the suport wall will have a depth which will take into account the

maximum river wash depth.

- It will be realized clogging works of the river bed on the analyzed area with arrange of the slope in front of the support wall ; is recomandated to put the boulders in the downstream of the support wall, creating on this way a non-erosional protection for foundation.

For this three intervention solutions was made stability calculations using the program Plaxis 2D, using constitutive model Mohr-Column and computational algorithm „ Phi-c reduction”.

In table 1 are presented the value of stability factors for stability analyzes performed. In figure 1, 2, and 3 are presented the glissade surface shape for calculation model I.1, I.2, II.2, II.4, III.2 și III.4.

Table 1

Proposed solution	Calcul situation	Stability factor
I. Stability factor	1. Without load	1.48
	2. With load	1.29
II. Minimal solution	1. Wall without load	1.30
	2. Wall with laod	1.19
	3. Erosion without load	1.27
	4. Erosion with laod	1.16
III. Maximal solution	1. Pilots wall without load	1.75
	2. Pilots wall with load	1.75
	3. Erosion without load	2.02
	4. Erosion with load	2.15

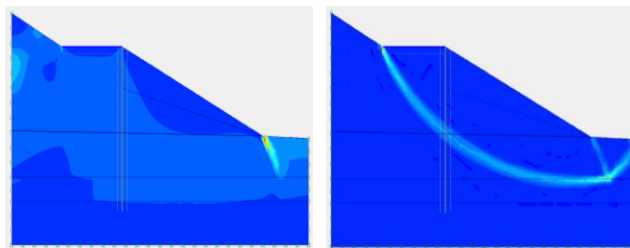


Fig. 4. Surfaces to yield calculation models I.1 (left) and I.2 (right)

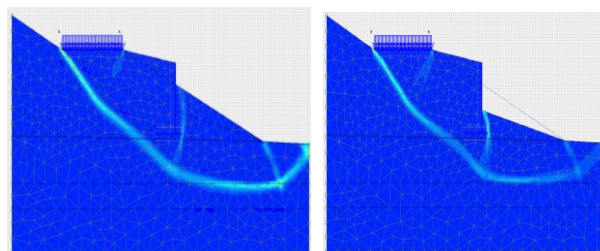


Fig. 5. Surfaces to yield calculation models II.2 (left) and II.4 (right)

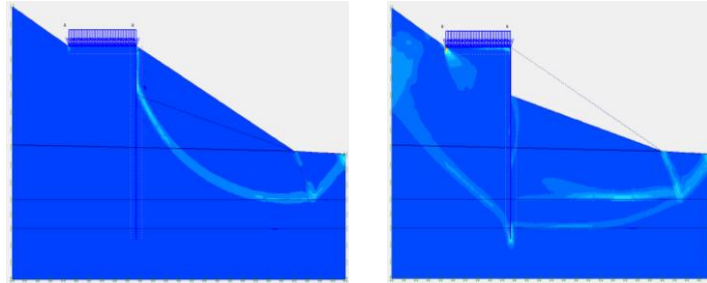


Fig. 6. *Layout Surfaces Model III.2 (left) and III.4 (right)*

On the base of stability calculations made can draw the following conclusions:

- In case of arranged slope without load can be noted that failure is produced at foot of the slope by hydraulic erosion of this; in case of slope with load can be noted that failure surface have a circular-cylinder shape, the failure affectinfg the whole embankment of the road; to mention that stability factor presented are valid just in situation in which foot of the slope is not erodate by river water Tazlău Sărat. In case in which the foot of the slope is eroded, the stability factors will have subunits, fact that can be found at this moment on emplacement

- In case of supported embankment by a reinforced concrete support wall, cornier type, can be noted formation of o cylinder shape failure surface, surface who extend in depth and cover the whole supported zone; it was considered as critical situation the erosion of the foot of the slope, erosion which leads to the failure of the embankment in front of the supporting wall at a height of about 2.00 m; regardless of the analyzed situation it can be note that appear a downstream surface of the supporting wall, a surface who indicate the possibility of loss of the stability of the wall by GEO-type failure at rotation and bearing capacity;

- In the case of embankment supported by a drilled pilots wall with interspacings, can be noted that apperar a cylindric shape failure surface, but it is produced only downstream of the supporting wall, the road embankment presenting stability; it was considered a critical situation the erosion of the foot of the slope, erodation who can lead at failure the embankment in front of the supporting wall at a height of about 3.00 m; in this case an increase in the stability factor is observed since the failure surface is formed in depth including the entire supported area.

4. Solution Analysis

All three of the above proposed solutions provide stability to the site, but analyzing the execution technologies and the conditions of construction exploitation have resulted the following:

- the road sloping solution without the disposal of other works to protect it, is applicable in the short term, because the slope will be eroded by the water and thus the embankment will collapse again in the analyzed point;

- for the execution of support walls afferent to the minimal solution, open excavations with depths of about 2.00 m are required (depth of embroidery + depth of recess)

which leads to the formation of a vertical slope with heights of 3.00 - 5.00 m, to the route of the road; in this situation there is the problem of creating a system for supporting the slope in order to keep it stable during the execution of the works; to prevent the phenomenon of assaulting foundations may be carried out by unplugging the riverbed, with the arrangement of boulders recovered from the riverbed at the base of the supporting wall; as it can be seen on the site, the flow and speed of the Tazlăul Sărat River lead to the strong displacement of the terrain beneath the foundations of the existing walls (Figure 3);

- execution of pilots at the roadside edge of the road provides a high degree of stability of embankment even under the assumption of a failure of the slope in front of the supporting wall at a height of about 3.00 m; to execute pilots safely it is necessary to purge the riverbed and to make a slope at the edge of the embankment by arranging the boulders in the bed, work that provides stability to the slope during the execution of the pilots as well as stability in exploitation by fulfilling the role of the anti-erosion "mattress".

5. Conclusions

In all the cases where it is necessary designing some support structures a careful assessment is necessary to find the most efficient solution from a technical and economic point of view.

Improvement of a steep embankment is not appropriate having regard to its height, reducing the section of the bed and the possibility its erosion by the river water.

The solution that requires the construction of a supporting wall is difficult to achieve from a technological point of view.

The achievement of a support structure of the pilots confers a high degree of ground stability and is simple to execute. Although the solution is apparently more expensive, this reduces the volume of work, the risks in execution and increases safety in service.

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