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Rehabilitation of Sliding Motorway Slopes on Deep Failure in Bulgaria

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REHABILITATION OF SLIDING MOTORWAY SLOPES ON DEEP FAILURE IN BULGARIA

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ABSTRACT

Bulgaria is situated on the Balkan Peninsula and she has highly varied relief. There are very much deep failures on here territory. The motorways cross these areas on many places.

The report present three interesting case histories related to landslides on the routes, caused by existing of deep failure, underground water and increasing traffic. The amplitudes of the vertical displacements have been more them 3 m.

Special structures applied for protection and rehabilitation of the route are presented. List of the structures included piles, micropiles, anchors, drainages, geoweb etc.

It is proposed estimation for the risk level of new failure after the protection.

INTRODUCTION

Bulgaria is located on the Balkan Peninsula, which determines its diverse relief and complex tectonic and geologic shapes.

The earth crust in Bulgaria is cut by many faults, a large part of which has played an important role in its evolution. The faults are of different size, age, space orientation and type of completed movements. Some faults are relatively shallow; others reach greater depths and even break the intactness of the surface of Mohorovichich.

The mountain regions are inhabited and connected by networks of railways and roads. In many places the routes cross faults and sometimes this creates permanent problems for the operation of the equipment.

The report discusses three examples of such faults along roads, for which a satisfactory technical solution has been found.

DESCRIPTION OF THE CASES

Landslides that have occurred near rode III-6222 at km. 13+750

Osogovo Mountain is situated at the west border of Bulgaria. Although the altitude does not exceed 1500 m, snows accumulate in the mountain and large reserves of underground water are formed, which give the origin of several small rivers in the basin of Struma River. Apart from the network of local roads, two international roads cross the mountain in the direction East-West. The road-bed is typical for high mountains, with lots of curves and serpentines, steep slopes and harsh climatic conditions. The first site discussed in this report is situated along one of these roads (road III-6222 at km. 13+750).

The heavy spring rainfalls, combined with the snow melting in March 2005, caused the sliding of a section of the road, long about 90 m, at km.13+750. The sliding is about 2 m, the culvert has been broken, and the traffic has been completely stopped. The road has a mixed cross profile. The outer slope is high about 50 m and there is a high-water river at its heel.

A. Geological, hydrological and topography prepositions

The sliding is part of an ancient landslide circus, which reaches the erosion base of the river at the foot of the slope (*Fig.1*). The uncovered layers along the steep inner slope consist of uneven alternations of decayed marls and cracked sandpits. The layers are tilted towards the slope. Once the

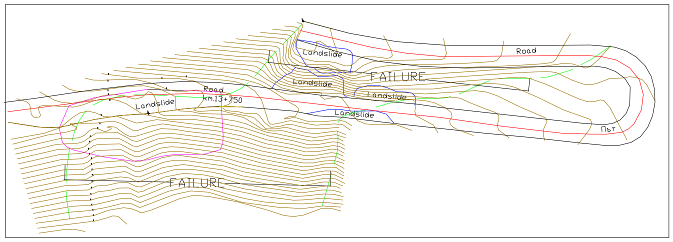


Fig.1: Situation at km.13+750

maps were prepared, and drainages and geophysics profiles were made, we found out that the broken culvert is located within a zone of tectonic movement with amplitude up to 0.5-1.0 m. An erosion gully was formed along it, which was filled with rubble and talus cover. The zone is wide 18 m. On the side of the fault the road is on the natural steep profile of the slope. The thickness of the talus layer starts at zero at the inner slope and reaches 5.5 m at the outer road lay-by. Under the diluvia is located the decaying zone of the rock padding, which has a variable thickness. In the drainage we have made along the axis of the gully, the zone is represented by cracked and decayed rock and marl materials with maximum thickness of 2.0-2.5 m. To the left and right of the axis of sliding the decaying zone gradually becomes shallower.

The key factors for the development of the processes are the erosion from the surface waters and the underground waters, which have accumulated in considerable quantities in the slope. There are springs in two places of the studied area.

B. Idea and Principe of the protection

The lack of a monolithic firm base under the landslide, where we could place a reinforcing construction, makes the task extremely complex. It is obvious that the reinforcement will counteract the relatively shallower landslides, such as this one, which are more likely to become active. The deep landslides, which encompass the general circus, are not discussed here as they can only be activated by tectonic movements.

The main reinforcement measure includes the strengthening of the heterogeneous base through a system of injection micro pilots (*Fig.2*). Cement solution is injected; it fills the cavities and cracks in the base, connects the broken rock particles and considerably increases the strength of cutting of the talus cover. A thin steel pipe is left in the body of the pilots, which reinforces the base and thus creates a hardened body of cement and soil.

The heads of the micropilots are unified by a reinforced concrete rostwerk. On its outer side the rostwerk has a trapezium-shaped curb. A road embankment is constructed behind the curb.

In order to stop any horizontal movements of the road embankment, there are 20 rag nails, which pass through the rostwerk under a slope of 1:3.8 and penetrate the rock base under the internal slope.

Trench drainage has been constructed along the road under the eyebrow of the landslide. It absorbs the underground waters of the slope. The accumulated water flows to the slope by means of three transverse drainage branches.

A pocket wall has been constructed along the inner outline of the road in order to prevent erosion and protect the road.

As a result of the designed constructive measures the probable sliding surface under the road is moved much deeper under new balancing conditions, which require larger active forces. The cutting down in depth could be performed only after overcoming the high values of friction between the rock parts. There is no talus cover, and the draining properties of the environment are sufficiently good to prevent the accumulation of high hydrodynamic or hydrostatic pressure.

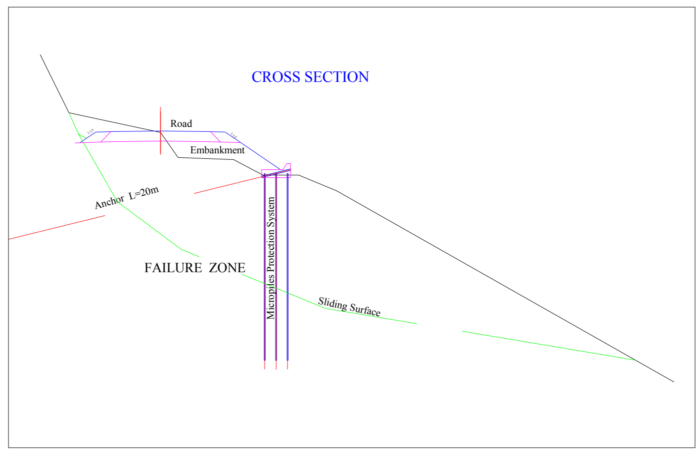


Fig.2. Cross section of the protection at the km.13+300

C. Over again failure on the same place

In the next 2006, during the same period of snow melting and heavy rains around March 15, a new landslide was activated in the same section, but this time high above the road, along the inner slope. As a result of the landslip, one lane of the road was covered with earth and rock masses, trees and branches. The one-meter pocket-wall, which is supposed to prevent the rode from erosion, turned over.

The described fault, which crosses the road in many places up to the mountain crest, has again created hydrodynamic pressure with large hydraulic slope in the crushed rock mass. The uncovered steep rocky surface of the slope is subject to the constant atmospheric influence, which leads to decay, cracks and destabilization. To prove the thesis we could use the example of an analogical sliding of rock pieces with a mass of 5 to 50 kg in the same fault zone, but in the upper part of the adjoining serpentine of the road. The rock pieces there covered the drainage trench and reached the axis line of the road. The two discussed landslides are in the same aperture in the direction of the fault, and are obviously connected with each other. The overflowing water along the road from the upper part of the serpentine has streamed down the slope towards the lower section located at km.13+750, causing the second landslide, which is larger.

No deformations have been discovered on the road lane, which was reinforced with micro piles and rag nails in 2005, or on the reconstructed culvert.

Reconstruction of a section along road II-35 – Troyan – Karnare at km. 89+383

The road Troyan - Karnare is the highest passage in Stara Planina Mountain. Its altitude reaches 1700 m. The described site is situated on the North mountainside.

As a result of the snow melting and heavy rainfalls in the spring of 2004 and 2005, a road section long about 30 m slid along its outer lane at km.89+383. The amplitude of sliding was unusually large: about 2.50m. The sliding surface cut the road slantwise and reached the inner slope, where it joins the folded rock structures.

A. Geological, hydrological and topography prepositions

We have found out that the reason for the sliding lies in the increased hydrodynamic pressure and the erosion of the slope waters. Prerequisites for the loss of firmness are also created by the fault, which is situated slantwise the road, and which concentrates the waters and contains crushed rock materials. As a result of former tectonic movements, the main rock – alternation of sands and marls – is very largely folded and slanted downwards along the slope. The talus layer, which constructs the sliding body, is rather thick (6 to 9 m). The slope under the sliding tong is steep, densely afforested and practically inaccessible.

The geological cross-section of the slope is represented by dust clay with fragments of marl, decayed marl with layers of clay, and a base of alternating at each 20-30 cm sandstones, marls and alevrolits. The sliding has developed in the clays. The main sliding surface is along the contact with the rock padding. A considerable part of the road embankment has slid. The road lane has sunk about 2.50 m and has moved horizontally nearly the same distance. The depth of the main sliding surface in the zone of the road is from 6 m to 9 m (*Fig.3*).

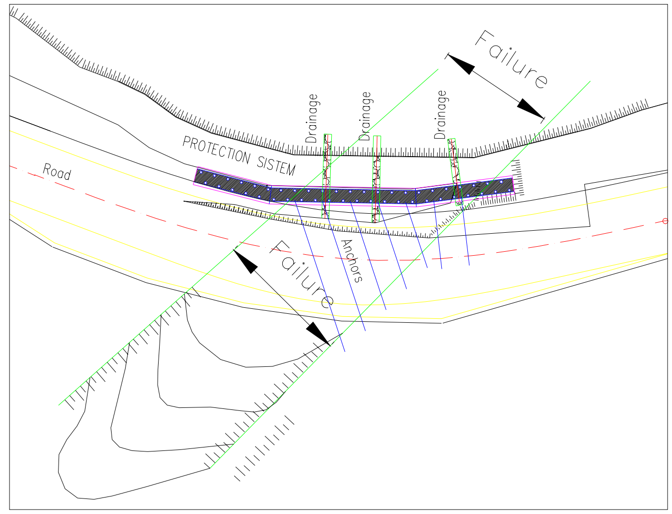


Fig.3. Situation of the protection at km.89+383

B. Scheme for protection

The following reinforcement scheme was adopted:

- The horizontal load of the landslide and earth pressure was taken by a pile system, which was stuck in the base of sandstones and marls, and was fixed by rag nails in its upper part. The rag nail roots were formed in the rock under the inner slope of the road (*Fig.4*).

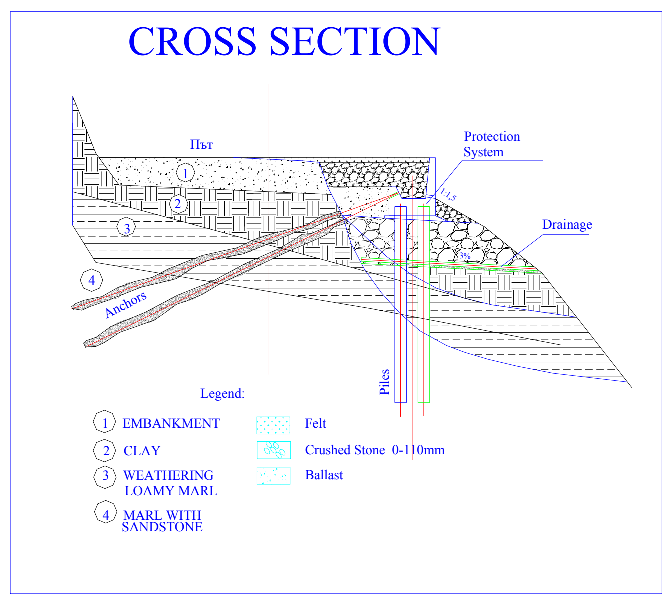


Fig.4. Cross section of the protection system at km. 89+383

- The heads of the pilots were unified by a reinforced concrete rostwerk, above which there is a reinforced concrete wall high 1.70m. The main surface of the rostwerk is located upon the slid lane of the road.
- The space between the rostwerk and the indent was covered with 1.25 mm mineral material, consolidated to degree D=0.95, which creates a steady hard basis for reconstruction of the road embankment.
- Three transverse trench drainages, each deep 2m, were constructed under the main platform of mineral materials and the rostwerk. They ensure a reliable water-reduction of the embankment body.
- The road embankment and the transverse profile of the road were reconstructed on the rostwerk and the main platform (*Fig.5*).

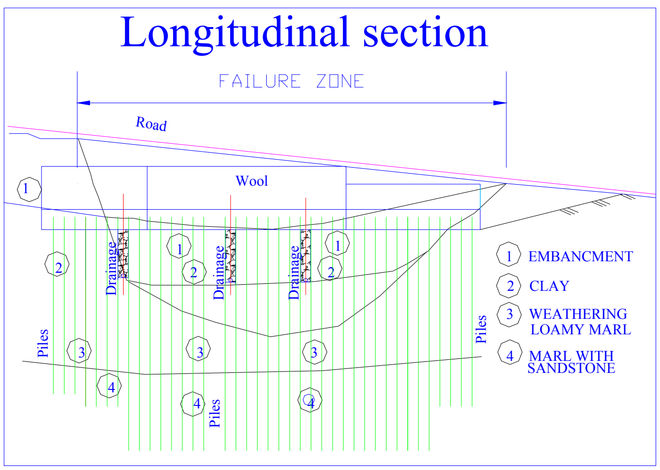


Fig.5. Longitudinal section of the protection at km.89+383

Nearly three years after completing the construction, the road section has not suffered any other deformations or destructions.

Reinforcement of a landslide in Bosna village, on rode II-95, km.38+860

The region of the site is located in South-Eastern Bulgaria, in the low Strandzha mountain, near the large fault line along the stream of Maritza River and the seismic focus in the Sea of Marmora. Not far from the village of Bosna passes the international road from Constantza to Istanbul through Varna and Burgas. In 1999 the road was interrupted at km.38+860 by sliding of the rock embankment. The sliding of the road had amplitude of over 3 m, and the length of the broken down section was 40 m.

A. Geological, hydrological and topography prepositions

The road is situated in a steep Northern slope (*Fig.6*). It is parallel to a small river, which is located at the heel of the slope, more than 30 m below the elevation of the road. At this place the route crosses a shallow gully, which is filled in its lower part by the road embankment. There is a culvert, which, for unknown reasons, is located about 15-20m away from the gully. Most likely the talus accumulations have leveled the furrow of the gully to such an extent that its role of water catchments was underestimated when constructing the road.

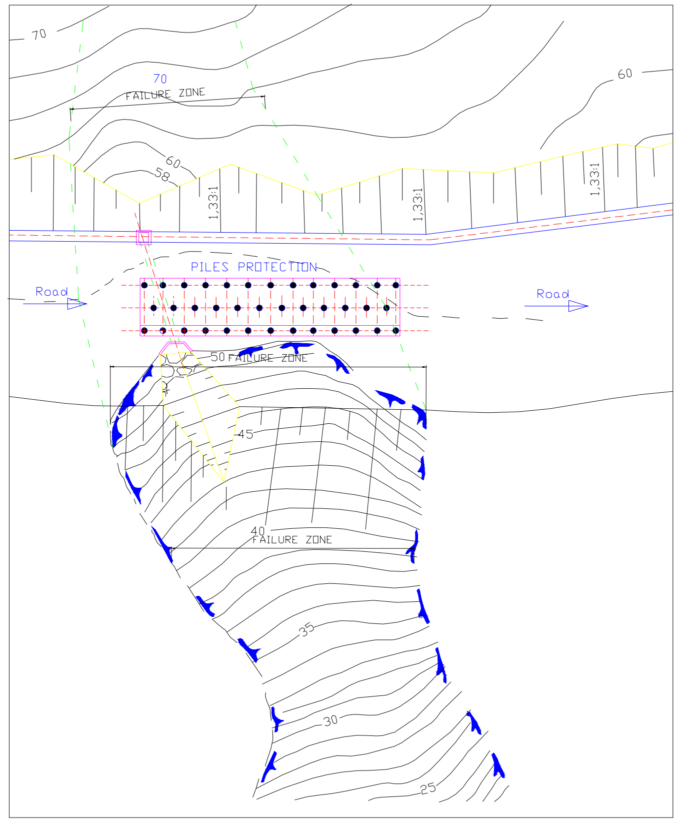
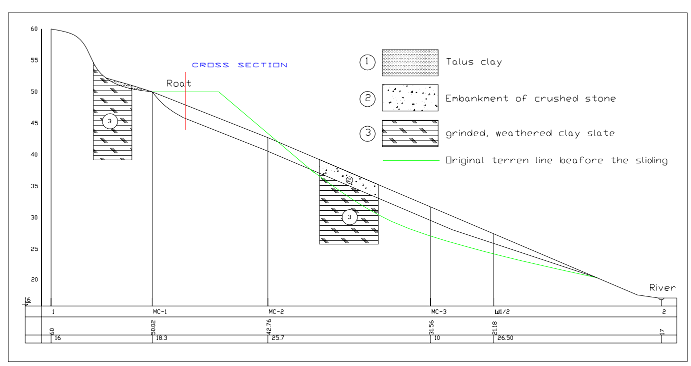


Fig.6. Situation of the protection near Bosna village

The geological surveys conducted reveal that the gully covered with diluvium represents a calmed down fault.



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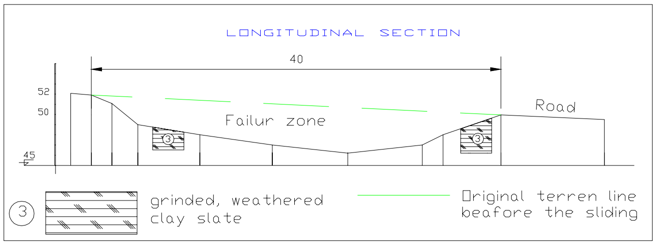

Fig.8. Section of the road, across the failure near Bosna village

Therefore, the rock base in the fault section is hidden along its whole vertical profile. Water is constantly concentrated there and forms a steep depression curve, joining the river at the heel of the slope (*Fig.7*). The disconnected fractioned rubble, used to construct the road embankment, slid under the influence of the hydrodynamic pressure, caused by the infiltrated waters from heavy rainfalls during the period of the spring snow melting. When uncovering the rock base in the fault section at a depth of 6 m and more, it turned out that its density is not higher than that of the surface (*Fig.8*). This fact is an additional proof of the existence of a fault. At the two ends of the damaged section one could clearly notice the transition to monolithic rock along the sides of the fault.

There is no data for activation of the fault; however no special measurements or observations have been made.

<u>B. Scheme for protection</u>

Obviously, when reconstructing the road, one has to take into account the existence of the fault and the lack of a firm rock base. It is also necessary to ensure an efficient draining of the water. There is a real possibility that after its reconstruction, the embankment may slide again because of its unsteady base.

In case of potential hydrostatic or hydrodynamic pressure, the pilot foundation will be more resistant to cutting because it decreases the possible sliding surfaces to a depth of more than 10 m (*Fig.10*). If there is a movement of the fault surfaces, the cassette embankment would move as a single hard body, with a possibility for easier reconstruction of the road structure (*Fig.9*).

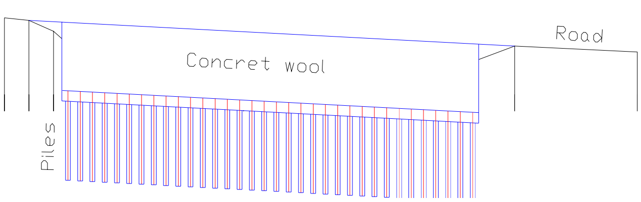

Fig.9. Longitudinal section of the protection near Bosna village

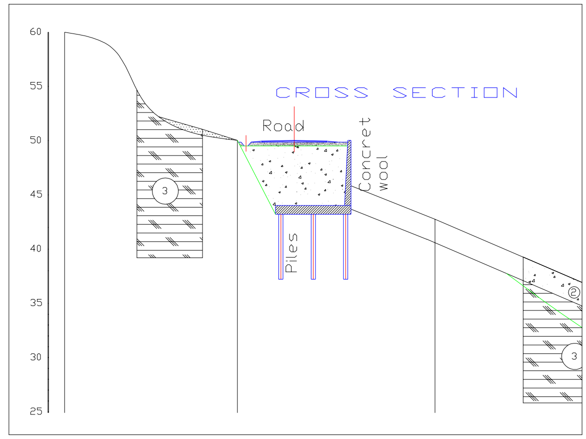

Fig.10. Cross section of the protection near Bosna village

More than eight years later no deformation has occurred in the reconstructed section.

CONCLUSIONS

1. The faults represent obstacles that are difficult to overcome in construction. Rational solutions could be more easily found for quiet or rarely active faults.
2. The practice indicates that the reinforcement and reconstruction of the damaged assets in the fault sections require both measures for efficient draining and for considerable increase of the firmness of the earth base to a greater depth.
3. It is reliable to anchor the hard earth bed to the strong rock boards around the fault.
4. Depending on the type of fault, the reinforcement could have shorter or longer durability. In any case, the adopted principle presupposes a milder exploitation and maintenance of the fault sections of the roads.