Study of the causes for a landslide occurring on a national road

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***Abstract*—** In the beginning of the report, the authors present several general considerations regarding the geographic, geological and climatic placement of the area where the landslide occurred. Further on, the situation regarding stability conditions and technical state of the affected road is described. After the analysis of the geotechnical and technical-geological aspects, its causes and characteristics are established. Following these aspects, the report presents the recommended and applied consolidation solution.

***Keywords*—** landslide, consolidation, drain, reinforced concrete columns.

I. General considerations

THE present document focuses on the landslide occurred in February 2006 on the downstream nearby mountainside of the DN 57 road. This landslide has caused traffic restrictions at first and complete closing of the traffic afterwards.

The affected road section lies on the outskirts of Orsova and is situated in the cliff area of the Ogradena - Orsova subsidence, which connects the Danube Defile, after the cauldrons area, to the south-eastern basis of the Almăjului Mountains.

The micro relief of the area is characteristic to peaks and cliffs, connecting the lower areas (fields, major river beds, meadows) to the mountains and is of the hilly type.

Creeks and gulleys are present on the surface of the terrain. They have the role of conducting the surface waters in the area towards the Danube. There are also some small local closed subsidences, in which water abounds and stagnates, as a result of heavy and lengthy rain.

Geologically, the Almajului Mountains are characterized by the presence of the Danubian crystalline, partly penetrated by eruptive rocks, represented by granite and granodiorites [1].

Besides crystalline schists and eruptive rocks, sedimentary rocks (conglomerates, sandstones) are also present in these mountains.

The covering roof rock of the connecting peaks, including the one towards the Danube Defile near Orsova, is comprised mainly of clayish soils, clayish-dusty soils and clayish-sandy soils.

Pebbles, gobbling, sand, as well as mica-schists are partly contained in these soils. In excessive humidity, in bent areas, this clayish covering roof rack in frequently affected by instability phenomena (landslides, ground failing, settlements etc.).

The landslide area is situated near the intersection of Timis-Cerna track with the Danube Defile. Climatically, it beneficiates of a higher temperature compared to the nearby areas, with an annual middle value of 9... 10^0 C.

The pluviometrical regime of the area is characterized by an annual middle value of precipitations within 800... 1000 mm, but with a greater variability in January and July.

II. Description of the situation

The on-sight examination of the situation occurred at the end of February 2006, regarding the stability and technical state of the road delimited by km 4+000 and km 4+300, has provided the following main aspects:

- the existence of the landslide in the mountainside on the left side of the road, which has affected its earthwork, at first about half of the breadth of the road and a length of 35 m;

- the presence of a subsidence (Fig. 1) filled with water on the right side of the road (upstream), 15...20 m from the landslide. It did not dispose of any bypass since the culvert supposed to unload the water in this area was completely clogged;

- the existence of an embankment retaining wall, on the left side of the road, with a length of about 100 m, which begins near the occurred landslide. Its weepholes were completely clogged up;

Fig. 1 Swampy soil

- the existence of another culvert with θ =1,0 m, situated at about 200 m from the clogged one near the water subsidence, which was also clogged and improperly built (without falling room);

- the complete degrading of the collecting ditch in the area of the road and their absence on some sections.

Because of the intensification of the precipitations in March 2006, the landslide has evolved, affecting the entire length of the carriageway and extending in length up to the aforementioned cut retaining wall.

III. Geotechnical aspects of the landslide area

The four geotechnical test borings executed in the area have evidenced the presence of clayish - dusty and clayish - sandy layers in the covering roof rack, where the landslide occurred [2], [3].

Thus, in test boring F_1 (Fig. 2), executed at the level of the roadway, under the vegetal layer, a sandy clay layer was discovered. It relies on a sand stone schist, present in depths of about 2,50 m. In test boring F_3, executed in the middle part of the landslide's length, the slid mass was signaled on the surface in a depth of 3,5...4,00 m. Because of the deranged structure, it had a filling character and its basis was comprised of sandy dust and sandy clay layers (both plastic consistent). In depths of 5,50...6,00 m a layer composed of dusty clay and hard state consistency clay was present. The land stratification resulted from test boring F_4 executed near the base of the landslide (Fig. 2) is approximately similar to the one obtained from test boring F_3, except the fact that the thickness of the mass is lesser (about 2,50 m).

The dynamic penetrations P_2 and P_3, executed near test boring F_3 and F_4, have confirmed (based on the variation module in depth of the terrain resistance) the transition from the slid mass to the base layer, on which the landslide occurred.

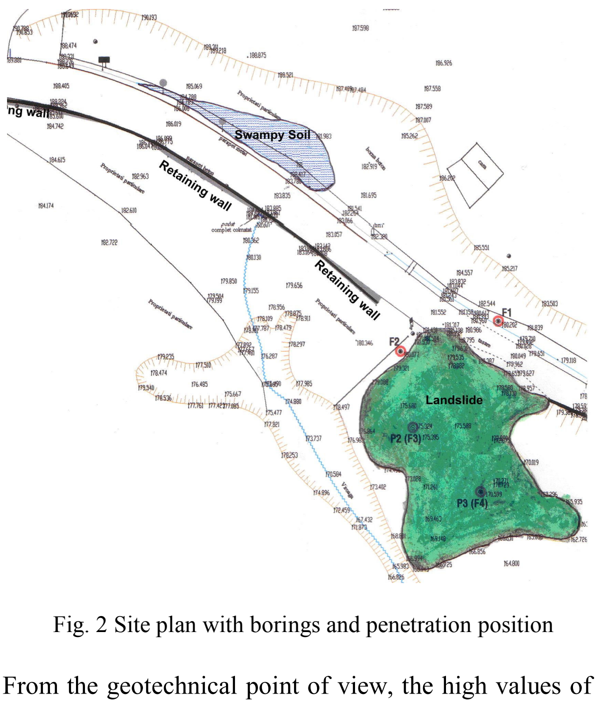

Fig. 2 Site plan with borings and penetration position

From the geotechnical point of view, the high values of the natural humidity and of the humidity grade (corresponding to the slid clayish - dusty and dusty-clayish layers) are remarkable (w = 25...30 % and S_r = 0,90). Also, the consistence of these layers was mainly plastic consistent and partly plastic soft, whereas the shearing resistance was reduced (ϕ = 7...12 degrees and c = 8 ... 35 kPa).

In the case of the dusty clay present in the stratification of the terrain in the area of the landslide, a reduced inflation - contraction potential was discovered (w_L = 78%, I_p = 26%, U_L = 70...90%).

IV. Conclusions regarding the characteristics and causes of the analyzed land slide

As a result of the analyze and interpretation of the obtained data, direct on-sight observations and geotechnical investigations, several conclusions regarding the characteristics and causes of the landslide were drawn.

Compared to the initial depth of the land sliding surface, the landslide was considered a "middle depth landslide", with the possibility of an in-depth extension (caused by the occurrence of other sliding surfaces).

From the point of view of the mountainside displacement, the type of the landslide was considered moving. It was also a slow landslide, from the point of view of the land sliding speed.

The presence in the lithology of the mountainside in the area of a permeable layer succession (dusty sands, sandy dusts) and less permeable or even impermeable in-depth layers (sandy and dusty clays, clays) had allowed the infiltration and circulation of the water through the massive and its quartering in the deep areas. This has contributed to the negative modification of the geotechnical characteristics of the soils, especially the reduction of the shearing resistance parameters [4].

Besides the direct infiltration of water in the mountainside, the main source of water alimentation for the earthwork and foundation terrain of the road was the water collected in the aforementioned subsidence, which (as proven above) had no draining conditions.

The complete clogging of the culvert (meant to unload water in the subsidence) and the malfunction of the weepholes in the cut retaining wall reduced the transversal draining conditions through the earthwork of the road. Thus, besides sustaining the embankment earthwork, the retaining wall with malfunctioning weepholes has acted like a block in the track of the transversal drainage, contributing to the water circulation in longitudinal direction towards the area of the landslide

The lack of the collecting ditch (partly on the upstream side of the road) or its improper conservation has also favored the water's entry in the road pavement, causing degradations of the road structure.

Towards the hidrogeological and geotechnical causes of the landslide, the traffic on DN57 can also be counted, especially from the landslide evolution's point of view.

The consolidation of the landslide and the rehabilitation of the road in the affected area was executed during the year 2006.

From the conclusion of the presented consolidation work and until now, its conduct has been very good; the instability phenomenon has been completely eliminated.

V. Applied Consolidation Solution

Analyzing the characteristics and the causes of the landslide, the authors of the present report, recommended the applied consolidation solution [5], which basically referred to:

- reinforced concrete drilled columns, with a diameter of 880 mm and a variable length (depth) of 15,00...22,00 m, depending on the local stratification. They are disposed in the landslide area, up to the existing embankment retaining wall, with their ends at the level of the existing road platform (Fig. 3);

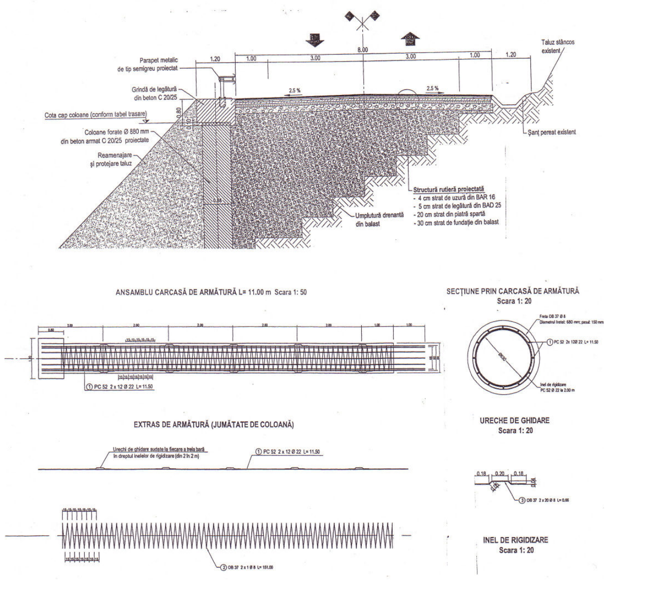

Fig. 3 Consolidation with columns

- unclogging of the existing culvert in the area of the water filled subsidence and the execution of a stone facing ditch, in order to absorb the water from the weepholes;
- unclogging of the weepholes from the existing embankment wall and the construction of a stone facing ditch in front of it, in order to collect the water unloaded by the weepholes;
- longitudinal drain (bottom ditch) on the right side of the road (upstream side) which unloads in the falling chambers of the two culverts. (Fig. 4).

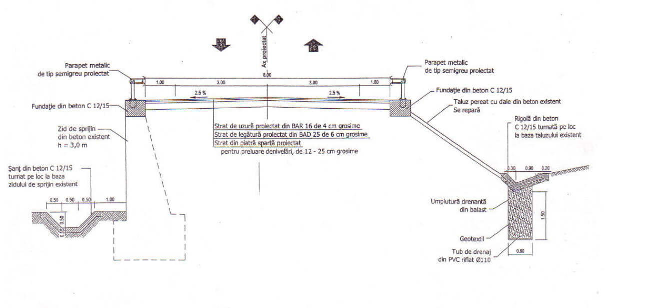

Fig. 4 Longitudinal drain

The reinforcing casing from the columns were built from 12 longitudinal bars (with ϕ = 22 mm out of PC52 steel) and hooped reinforcement with ϕ = 8 mm from OB37 (Fig. 3).

The columns were executed by drilling by SC BAUR ROMANIA S.A., with the help of equipment with a Kelly shank.

In addition to the consolidation of the landslide and elimination of its causes, the rehabilitation of the road structure in the affected area was also considered an important task.

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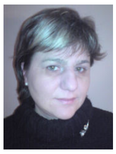

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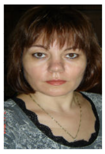

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