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LANDSLIDES IN SUCEAVA COUNTY

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Abstract
In the county of Suceava, the landslides are a real and permanent problem. This paper presents the observations of landslides over the last 30 years in Suceava County, especially their morphology, theirs causes and the landslide stopping measures. It presents also several details regarding the lanslides from the town of Suceava, of Frasin and the village of Brodina.

Keywords: instability phenomena, sliding slopes

1. INTRODUCTION

In Suceava County, instability phenomena are a real problem due to their spread and intensity. They have been producing for many years and the expenses already made are huge. In the following will be presented the main slides in Suceava County, causes, age, damages, shapes and dimensions, as well as the measures already taken or proposed.

2. GENERAL

In Suceava County instability phenomena are affecting more than one third of the valleys in the hilly area and also mountainous large areas.

The causes are of geological type - a clay substrate in alternation with friable loose rocks, morphological type - slopes with gradients higher than 3-5%, climatic - average annual rainfall more than 500 mm and human - irrational use of the land. The land is, generally, dusty clay that rests on other types of rocks. It is known that a clay layer may be the cause and the surface of a landslide starting, and that is a land which basically cannot be drained by conventional means. Landslides often are extending and / or reactivating. In 2008, in our county 104 landslides were inventoried, of which 60 represented direct major risks, and in 2010 the phenomenon was manifested in 32 other residential districts.

3. IN SUCEAVA CITY

The geological substrate where the city is placed belongs to clay, marl and sandy formations (lower Sarmatian), with the thickness of approx. 500 m. It is crossed by calcareous layers. Near the surface there are quaternary deposits, represented by alluvial, delluvial and proluvial materials, with Riss, Wurm and Holocene age, with thicknesses reaching in some places more than 10 m (Brânduş and Grozavu, 1998; Cristea, 2003).

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The Suceava River is part of the first generation of valleys, with a consequent character, having in some places sectors with subsequence aspects (Cristea, 2003).
For Suceava city have been defined three areas of landslides.
A first sliding segment is located on the north-east slope of the city, the second area is on the north-west slope (platform of Suceava city) at whose base flows the Șcheia creek and a third perimeter is on the eastern side located to Suceava Fortress.
Since 2006 another land sliding was reactivated, on the Monastery Hill of Teodoreni, Burdujeni district, on the left side of the Suceava River.

3.1. Landslides on north - west slope of Suceava city

The region is framed between Suceava and Șomuz rivers, on an upper terrace of Suceava River. The relief is accumulative type, of Pleistocene-Holocene age. The medium plateau of Suceava city is connected in steps to the upper plateau Zamca and to lower plates, the general fall being to the southeast. The plateau levels of the city can be assimilated to old terraces with generally horizontal surfaces, connected by gentle slopes (Grădinaru, 2008). On the slope and at its base we find also deposits of colluvial or proluvial origin, generally caused by gravity entrainment and their depositing. Mentioned formations are covered by a continuous layer of topsoil, with thicknesses between 0.60 and 1.20 m.
Lithological speaking, the land contains quaternary formations and volhinien formations. The volhinien formations are liable to clay and clay marl with sandy inclusions. In Sarmatian there appear more tiles levels of 0.30 ... 0.50 m thickness. In the sliding area, the quaternary layers came from Sarmatian formations alteration and have a similar loamy lithology. On the unaffected slope, it appears a clay dusty quaternary with loess origin.
The groundwater has a permanent character, with terrace flowing, and came from the water falling on the high plateau of Suceava city and which through infiltration get into terraces, draining then to the southwest. The phreatic layer is fed discontinuously, accumulating in fine deposits of the slope, in the sandy areas of quaternary clays or in sandy lenses located in the marl clay. An accumulation occurs also in less permeable rocks, but the water circulation and disposal from these is very slow.
The slipping is detrusive type and was started in 2004, as an extension of the detachment front from the northeast slope, in the Zamca Monastery area. In these conditions it was imposed a geotechnical study, but the slope consolidation works and the phenomenon halt have been delayed for lack of funds. There were streams of rainwaters and puddles on the slope, with runoff areas with chaotic trails, and mudflows were formed.

3.2. The N-E slope

This slope is on the right bank of Suceava River, between Șcheia creek and Fortress creek, and it is, in terms of the current geomorphological processes intensity, one of the most active. The landslides, in various stages of evolution, occur over a length exceeding 2 km. In the past 50 years there have been made stabilization works, but the danger of new landslides is still high. The slope is a hillside where hard rocks alternate with the soft ones (a cuesta), type of relief which, it is known, favors the occurrence of slipping. Because of the topo-climatic conditions (northeast exposure) it was produced a more pronounced substrate wetting. These conditions, combined with a lithological substrate composed of clays loess, which is based on Sarmatian clays and sands, to which is added the Suceava River movement which caused the base slope digging, and the groundwater variation, all these favored the land slides. On one side of this slope, before 1918, there was a railroad that was abandoned and it is believed that the infrastructure works, including the water collection and

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drainage of the slope were neglected in the years that followed. The morphology of the area consists of an alternation of slope secondary cornices of 2 to 10 m, with pseudo-terraces and mounds. Structurally speaking, the landslides are of insecvent and asecvent type (those occurring in delluvial), and as a way of producing it is believed that initially there were delapsiv type, so that now dominate the detrusive character (Hociung, 2009).
The area has been affected by repeated reactivations since 1939. Several drainage works have been executed, but the results were not fully satisfactory, because of cohesive soils predominance, resulting only free water drainage.
The triggering factor of the landslides recrudescence in 2001was the abundant precipitations, when took place the detachment of the plateau cornice and the displacement of a soil mass with a length of 70-80 m, thickness of 70 m and a maximum width of 7-8 m. The volume of moved material was about 10000 m^3.These slides affected the area of the upper level of Zamca plateau over a width of 100 - 150 m. In the period 1977 - 1978, the downstream area has been reinforced by deep drainage works (casings with radial vibro-drilled drains), supporting and vertical systematization works. The cornice resulting from recrudescence in 2001 has a height of 7 - 8 meters and a slope of about 80^0-90^0. The loess clays in which the phenomenon developed, are crossed by numerous cracks and there are affected by landslides, especially the northern sector, a process that contributes to the cornice withdrawal.
New stabilization works were executed in 2004 - 2006. Currently, the landslide is considered partially stabilized, but after the large amounts of rainfall in June-July 2010, the phenomenon was reactivated.

4. "ŞANDRU" LANDSLIDE IN BRODINA, 2002 – 2004

The landslide is located in the mountainous area of Obcina Mare, on the left slope, called Sandru's Hill. The phenomenon was triggered on the right side of Brodina River, about 2 km from the confluence with Suceava River, in the torrential basin of Şandru creek, under 972m quota of the hill bearing the same name (Oprea, 2000).
In this area, Brodina valley, at the main riverbed and lower terraces level, has a width of approx. 250m and it presents, from the left slope, the base of which is installed the current minor riverbed, a succession of four terraced levels whose altitude is 2 - 4 m, meadow steps, frequently flooded, respectively 6 – 8m and 10m, slope steps. The last level is parasitized by the alluvial cone of creek mentioned above.
Structurally and petrographically, the area is part of Tarcău Unit western facies, which is characterized by a complex fold - scales tectonic structure, nested and discharged to the northeast, highlighted by a Hogback relief.
The slipped material represents an old delluvial, with 4 – 6m thickness, composed of a clay matrix, which includes rough sandstone blocks. Due to the current occurrence, on the right side of the landslide, of the rock "in situ" (green marls) and of some tiles blocks with 20 – 30cm thickness, fresh crack, unaltered, caught in the sliding body, it can be assumed that the sliding affected the rock over a thickness of 2 m.
Brodina Valley has a course oriented from south to north, almost consequent to geological structure. The torrential affluent valley where we find the landslide has the flowing direction from east to west, oriented almost transversely to the geological structure.
In terms of hydrogeology, in the area is separated the continuously phreatic water, stuck in the permeable and semipermeable alluvial deposits from the base terraces, which continues with the

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free flow of water from creek, and the cvasi-impermeable layer consisting of Senonian-Paleocene formations.

In the slopes, the underground flow follows the surface flow and feed the courses of torrential tributaries. The groundwater flow is regulated by very low permeability of local Quaternary formations. Accordingly, the hydrostatic level has in the slopes probably a discontinuous character. The landslide remodeled the right slope of Șandru creek on approximately 1250 m, a width between 80 to 150 m, energy of about 300 m and an average slope of 20^0. The forefront of sliding body forward even on the 10m terrace bridge of Brodina River (614 m altitude).The landslide has the upper cornice at 900m altitude, the body being fragmented by a series of secondary cornices that mark different points in landslide timeline.

There's been an initial delluvial movement in the years 1974 - 1975, after which appeared a delluvial body with sliding waves, behind which were created puddles. The landslide detrusive character and the fact that there were found logs in an advanced state of putrefaction, suggest a longer history of landslide in the area, for at least several decades.

It was found the triggering of a land displacement with mud flow aspect on the left side of land sliding, which entails in the movement delluvial material and also rock (clay and purple marl). The flow can be the result of accumulation and the drainage of the water behind the sliding body from 1975, as well as high humidity due to significant amounts of precipitation during the reported period. The landslide forefront parasites the 10 m terrace bridge, on 4 - 5 m from its forehead. It is estimated that it was displaced from July 2002 to October 2004 approximately 40 m.

Such landslides, as those shown in this paper, in terms of causes and evolution, are characteristic for Obcinele Bucovinei and generally for the flysch mountains of the Eastern Carpathians (Zarojanu et al., 2014).

5. CONCLUSIONS

The causes of landslides in Suceava County are of geological, geotechnical and anthropic nature. The occurrence of landslides has a periodic and generally predictable character.

Remedying the effects of landslides, or stopping such phenomena, can be done by draining, planting and supporting. A multidisciplinary approach would be the most appropriate.

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