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Landslide: Mineralogical and Physical Investigation

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Abstract. In order to construct a road bed foundation, if land has moved, on an area with old landslides, there is a high chance of it moving again. The investigation was made in a region with hilly relief, in which the parent materials of soils are argillaceous marls of Pliocene age. Because the slope is scarped and the versant has been cut, the soil mass slide favoured of the particle-size distribution dominated by heavy clay. With a reiteratedly percolative moisture regime, the soil material is saturated in water fora long period (700-800 mm precipitation /year), and that can increase the slope mass, thereby increasing the driving forces. In a soil profile situated on the top of the hill, with landslide for about 40 m length of the road, disturbed and undisturbed soil samples were analysed physic-chemical and mineralogical. For the heavy and light minerals from the sand fraction a polarized light analyser is used, and for clay minerals X-ray, differential thermal and infrared absorption method are used. The particle-size distribution in the soil profile is dominated by the clay fraction, which reached 53.2% in the ABt horizon and 63.0% in the Bt horizon (67-93 cm depth). The structure of the light minerals, consists of quartz (41-58%); feldspar (10.16-18.10%); muscovite (14.10-26.04). The heavy minerals are oxides (2.61-15.26%), hornblende (0.58-2.87%) and biotite (0.51-2.68%). It must be mentioned the presence of the metamorphic minerals, with the source of the Poiana Rusca mountains. These minerals are epidote (1.01-1.86%), disthene (0.70-1.86%), staurolite (0.73-2.46%) and sillimanite (0.35-0.45%). The clay minerals, inherited from the parent material or formed during the soil-forming process are dominated by smectite, which represent (71-85%) from the total clay minerals, illite 10-21%, and Kaolinite, 4-12%. Rheological properties, like plastic index (53.8%), activity index (1.01%) and consistency index (0.99- 1.00%) show that the shrinkage – swelling processes are active, and provoke landslide. We propose some technical measures for decreasing the driving force and increasing the resisting forces on the slope, such as: drainage net with track ditch and inspection chamber, driven pile a 10 m depth, and so on.

1. Introduction

Landslides are spontaneous movements of masses of soil at the foot of the slopes. The transition to instability is caused by changing internal and external forces acting on the slope and decrease of the resistance characteristics of the soil [1]. Size landslides can be from a few meters to several kilometres and speeds can vary from a few metres per year to meters per second.

Landslides occurring following heavy rainfall lasting, this increases the weight of the soil mass on the slope, or as a result of earthquakes or volcanic eruptions. Landslides can be classified as moisture state (wet or dry) and after speed [5] in translational rotational landslides, muddy, scree avalanche, falling rocks and solifluction, creep and flow of ground, mass movements, slump.

Landslides cause up to million euros (dollars) in damage and a large number of deaths every year [5,7]. It is considered that in the year 1020, December 16 occurred in China's largest disaster caused by sliding known in human history, the death of 180,000 people.

The most exposed areas to erosion in Romania are the Subcarpathian, Barlad and Moldova Plateau, areas where forests have been destroyed [2]. In Timiș county, land area of 5505 ha is active landslides, semi stabilized landslides of 7785 ha and stabilized landslides, the 30 940 ha [11]. A great detail study, exhaustively, realized F.V. de Blasio [4], with regard to fluid mechanics, the stability of the slope, the flow of rheological, granulation, falls of rock, gravity flow.

A group of researchers [6] in the work „Landslide Hazard and Risk" bring interesting contributions on the nature landslides, land vulnerability, risk assessment, control landslides.

Landslides may occur in slopes composed of very different rocks, but more frequently in clay soils, which, depending on the moisture content and structural characteristics radically change their compressibility and resistance. Early sliding movements can cause structural damage ties by reducing the lateral pressure on the ends of the layer, as a result of excavation or erosion due to water courses. On the hillsides with a slope of 5-10% and 1-2 km length, soil suffered successive old landslides due to surface water.

These unstable soils and the works on the slopes can trigger new landslides, due to gravity [7,8]. Landslides are magnified by the nature of minerals in the soil structure, the presence of expansive clay minerals mass favouring imbalance of the soil mass, hampered by water, which penetrates through cracks appearing by shrink.

2. Material and methods

The studied landslide is situated in the western part of Romania, in the Buziaş Hills at the east entrance of the Vișag village. The maximum altitude quota by nearby is 224 m. The road, which has undergone sliding over a length of 40m, before entering the village, link to the national road Lugoj - Resita, which is 5 km away.

The geological formations that were made for the road works are Pliocene - Pannonian age and consist of grey marl and layers of sand and gravel. Physical, chemical and mineralogical analyses were made the flat ridge located above the landslide that was triggered on the axis road. Methods for analysis of soil samples correspond and meet the requirements of RENAR and STAS in force.

Mineralogical composition analysis of the sandy fraction was performed on skeletal fragments, in the soil profile horizons located on the Visag plateau, and by granulometric classes. Previously it been necessary to remove sesquan and argillan film by treatment with sodium citrate, and dithionite, sifting through the sites set diameter 0,5-0,25-0,15-0,10-0,074-0,060 mm and manufacturing of thin sections or polished sections, reading to the polarizing microscope at transparent and opaque minerals. The material detritus was consolidated by embedding the durakril. Besides identifying light and heavy minerals (separated by bromoform) they were followed and morphological properties, size and quantities, in order to assess the degree of alteration, the percentage of participation and origin. The method of separation used to analyze the clayey fractions consisted of treating the soil with perhydrol and acetic acid, filtering, peptization with NaOH, repeated pipetting and washing with distilled water, and finally saturated in glass containers of 10 litters with ethylene glycol, calcic chloride and potassium chloride. The separates obtained were analyzed using X-ray diffraction, infrared absorption and thermal analysis. X-ray diffraction analyzes were effectuated by a diffraction instrument U.R.S.50.J.M; it features 35 KV, 7 mA, balancing speed of 2 to 52^{o} angle 20. Infrared absorption spectra were obtained with a double beam spectrophotometer R.H. - 20 using prisms KBr, NaCl, and LiF in the spectral region from 400-4000 cm^{-1}. Infrared absorption analytical preparations were obtained using the technique of potassium bromide pressed discs by incorporating a 0.6 mg sample in 300 mg KBr vacuum of 5-10 mm Hg at a pressure of 150 kg / cm^2. Thermal analyzes were performed with derivatograph M.O.M.O.D-103 with ceramic crucibles. The heating rate is 10°C/minute. The analytical methods used are those recommended and used in the Laboratory of clay mineralogy at I.C.P.A. Bucharest. They were investigated according to the methodology mentioned clay fractions of less than 1 micron, from soil samples collected from soil profile of Visag, located on the scales, the same that were studied and minerals of sandy fraction.

3. Results and discussions

Lugoj Hills, located on the right TimisRiver and Buziaş Hills, located on the left river Timis, have a clayey soil which is why the slopes are many landslides, especially where intervened with works on roads or other structures as case the study area. Old landslides (figure 1) have thus been reactivated.

Figure 1. Old landslide in Visag

Table 1. Physical-chemical analysis of the soil located on the ridge.

Depth, cm	**0-20**	**20-42**	**42-67**	**67-93**	**93-120**	**120-160**
Coarse sand, %	6,3	6,4	6,1	5,9	7,6	14,2
Fine sand, %	27,7	22,2	18,7	8,0	18,3	19,5
Silt, %	29,0	26,8	22,0	23,1	23,9	19,3
Clay<2µ, %	37,0	44,6	53,2	63,0	50,2	47,0
Bulk density, g/cm^3	1,44	1,21	1,24	-	1,25	-
pH_{H2O}	6,43	6,75	7,10	6,75	6,33	6,45
SB, me	18,8	19,2	22,2	21,0	19,8	20,0
SH, me	4,6	4,3	3,4	3,6	3,6	2,8
T, me	23,4	23,5	25,6	24,6	23,4	22,8
V, %	80,34	81,52	86,71	85,36	84,43	87,71
Textural classes	TT	TT	AL	AF	AL	AL

TT –medium clayey loamy
AL – clay loamy
AF – fine clay

Analysing the clay content, it is found that soil, located on the flattened ridge where the road was built, is loam-clay in the first 40 cm (37.0 to 44.6%) followed by an 80 cm layer of clay, even fine clay (53.2 to 63.0%). Since the regime of precipitation is 700 mm / year and compacting the surface state is large (bulk density = 1.44 g / cm^3), soil loads through rain, entering the cracks appeared during drier summer. Cracking is caused by the vertical character of the soil. Construction works of the road, with cutting foot slope, leading to the release of the landslide and the road over 40 m in length, with 1-2 years before 2015. Added granular material (ballast) for remediation, which explains the textural differences between the drilling on the ridge and the drilling on the slope and base on slope. Clay content on the slope is between 36.6 and 43.8% (medium clayey loam), and at the base slope between 33.3 and 41.7% (clay-dusty clay) and from 22.5 to 38.5 % (clay dust). Textural difference between the three soil profiles is caused by the previous landslide, oldest, named „landslides in waves"

Table 2. Rheological properties.

Depth, cm / Property	0-20	42-67	67-93
Upper plastic limit, w_L, %	55.3	74.6	86.3
Lower plastic limit, w_P, %	20.3	20.8	22.5
Plasticity index, I_P	29.0 active	53.8 very active	63.8 very active
Clay, <2μ, %	37.0	53.2	63.0
Activity index, I_A	0.78 inactive	1.01 active	1.01 active
Moisture content, W, %	19.3	21.4	22.1
Consistency index, I_c, %	1.24 hard	0.99 plastic-tough	1.00 plastic-tough
	shrinkage	swelling	

The results of mineralogical analyses on soil and sediment underlying clay, highlights the predominance of light mineral fraction, represented by quartz, feldspar, and muscovite, and the low presence of heavy minerals. (table 3)

Table 3. Mineralogical composition (%) into granules at Vișag

Mineral-rocks fragment	Depth, cm					
	0-20	20-42	42-67	67-93	93-120	120-160
Quartz	41,74	41,81	47,76	52,18	58,80	48,25
Feldspar	18,10	17,25	16,32	15,22	10,16	11,98
Muscovite	26,04	25,16	16,36	15,34	16,85	14,10
Oxides	2,61	10,18	13,84	15,26	7,94	13,56
Hornblende	2,87	1,12	1,10	0,58	0,78	-
Chlorite	0,55	0,58	0,76	-	-	2,60
Biotite	2,68	0,51	0,51	0,59	0,82	2,15
Epidote	1,86	1,01	-	-	-	-
Disthene	-	0,70	-	-	-	1,86
Staurolite	2,46	0,73	1,35	-	-	-
Rutile	0,34	0,85	-	0,38	-	-
Zircon	1,75	-	1,00	-	-	2,20
Sillimanite	-	-	-	0,45	0,35	-
Augite	-	-	-	-	1,75	1,26
Rock fragments	-	-	-	-	2,55	2,04

To this is added the presence of iron oxides such as magnetite, less than hematite, which has a maximum accumulation percentage in Bt horizon. Quartz has the highest concentrations in Bt horizon and crossing BtC (58.80%), minimum percentage (41.74%) being in the first 20 cm of soil profile. Morfoscopic appearance of quartz granules is almost invariably rounded. This means there were significant detritic contributions, wherein the carrier was water, material brought from areas with older reshuffles and sedimentation. Feldspars, represented by plagioclase and orthoclase group, are in excess of the Ao (18.10%), AB (17.25%) and Bt (16.32%) horizons. Muscovite also has a maximum accumulation in the A horizon (25.16 to 26.04%), and then remained constant until the horizon C. From the heavy minerals group, hornblende has a maximum in the A horizon, with 2.87% between 0-20 cm deep and decreased to 0.58% from 67 cm down. Biotite and chlorite have similar uniform value concentrations, not exceeding 2% for biotite 0-20 cm (2.68%) than in the depth of 120-160 cm. We believe that the presence of biotite and chlorite even on top of the soil profile is explained by pedogenesis processes.

Figure 2. Assembly of heavy mineral from the sandy fraction of soil from Visag – 20-60 cm depth

cls. 0,10-0,05 mm; X 70 parallel nicoli

a=rutile; b=disthene; c=oxydes; d=epidote; e=chlorite; f=sfen; g=staurolite

In the mineral composition of the sandy fraction of the soil occurs and detrital minerals such as epidote, disthene, staurolite, rutile and zircon, concentrates at the top of the soil. The presence of the metamorphic minerals such as power supply is connected to the frame of Poiana Rusca Mountains. Based on mineralogical analysis of sandy fraction soil at Visag can say that sources for soil formation were quaternary clay and east mountainous frame, respectively Poiana Rusca Mountains.

Figure 3. Assembly of heavy mineral from the sandy fraction of soil from Visag –350cm depth, cls.0,10-0,05mm; X70 parallel nicoli

a= hornblende; b=oxydes; c=zircon; d=olivine; e=disthene

In the particle size fractions from soils and parent materials, clay minerals are intimately mixed and chemically coupled with humus and hydroxides of Fe, Al, Mn, with amorphous silica, quartz and various other components. Many of these compounds have similar chemical resistance to the clay minerals, so that the separation processes can alter the characteristics of clay minerals and their composition. Even the simply dispersion in distilled water may change the chemical composition by reducing the contents of salts. The results obtained are shown in table 4:

Table 4. Mineralogical composition (%) of clay fraction from Visag

Horizon	Depth, cm	Expandable minerals	Illite	Kaolinite
Ao	0-20	71	17	12
AB	20-42	75	21	4
Bt	67-93	85	11	4
BC	120-160	85	10	5

X-ray diffraction analysis revealed the presence of minerals with expandable network, of illite and kaolinite subordinate. This is found by diffraction spikes from 10 to 10.1 Kx (001), 4.91-4.97 Kx (002) to illite with basal parameter (003) and line 3.32 to 3.33 Kx, basal parameter (006) with 1.99 Kx line. Maximum of diffraction 7.11-7.18 Kx confirms the existence of the kaolinite (12% at the top of the soil). Diffraction line at Kx 3.52-3.56 represents the basal parameter (002) of kaolinite.

In the case of expandable minerals, at calcium saturation, the diffraction line is 14.1 to 14.6 Kx, at potassium saturation is 11.8 to 12.3 K and at ethylene glycol saturation the values are in range from 16.3 to 17 1 Kx (figure 4)

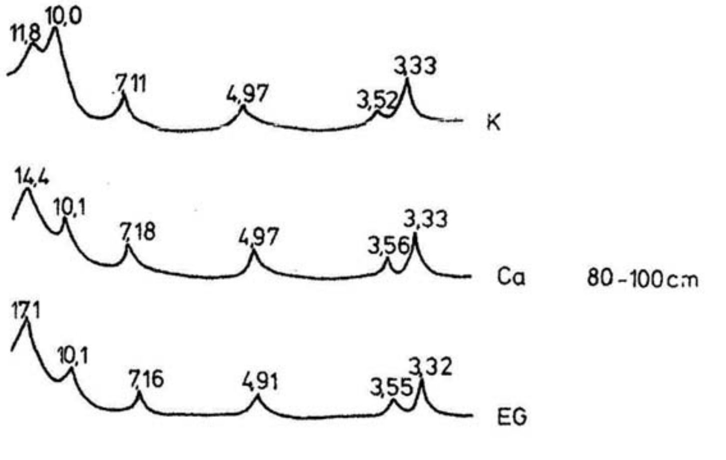

Figure 4 The X-ray diffraction diagram of the Visag

Infrared absorption analysis (figure 4) confirmed by absorption bands 3710-3712 cm^{-1} kaolinite and the bands 918-920 cm^{-1} (H-O-Al), 535-537 cm^{-1} (Si-O-Al) and 3633-3637 cm^{-1} connections at Al_2OH. By doublets 782-785-786 cm^{-1} and 802-803-804 cm^{-1} are found to quartz and colloidal silica existence.

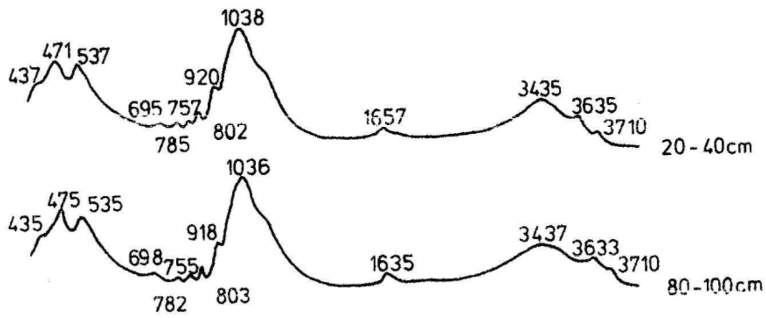

Figure 5 Infrared absorption spectra at Visag

Stabilization of the road and the land that has suffered sliding impose a series of works that lead to the elimination of excess water and making a connection between the mass of soil sliding and stable substrate. In this regard it has completed an open trench on the right way of road and was captured a fountain existing under way. It is proposed to build a system of horizontal closed drains, equipped with inspection chamber and drain head reinforcements for support and consolidation with driven piles with large diameter in drilled column to 10 m depth.

4. Conclusions

The lands in the study area, with slopes with 5-25% range, have at the upper part marls and clays. The soils are with clayey-loamy texture and have 50-100 cm depth, a clay content of over 60%. Rheological properties of the soil material showed that is contractile materials type. The appearance of fissures and cracks in the rainy allow water penetration depth, which causing swelling of clays and the creation of sliding surfaces.

Mineralogical analysis of sandy fraction was identified by dominance of quartz, feldspars and muscovite. During solification one part of these minerals was converted to oxides and hornblendes, which subsequently gave the clay minerals. Analysing the clay was revealed the presence of large amount of smectite, expandable minerals. To stabilize the landslide are proposed control measures and drainage or soil mass consolidation slide

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