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THE VULNERABILITY OF SCARPS CAUSED BY ANTHROPIC IMPACT. CASE STUDY: THE BREAZA TERRACE SCARP - THE PRAHOVA VALLEY

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Key words: Breaza town, terrace II scarp, elevation model, monitoring, slope processes, human impact, and evolution patterns.

Abstract. Les glissements de terrais sont parmi les plus dangereuses hasards naturels dans le cadre de la Vallée subcarpatique Prahova, surtout en cause d`une augmentation de la population après 1990. La grande variété des types des glissements de terrain met en scène la diversité des conditions et des combinaisons particulières des facteurs qui rendent les pentes instables. Les glissements de terrain de pentes de Breaza tiennent des périodes des réactivations occasionnelles et des périodes de stabilité relative marqués par de processus de creep dans la zone active des escarpements et l`aspect est d`entrecroisement sur les déclivités soit dans le cadre de la masse de glissement. Les mouvements de masse ont des différentes formes et dimensions, le moins profonds glissements de terrain étant les plus fréquentes. Les glissements de terrains sont récents soit réactivés dans le corps or dans la zone latérale des abrupts des masses qui les ont antérieurement mis en place. Dans cet article on a systématisé les résultats d`une investigation durant plus de 5 ans. Les analyses de cartographie et les modélisations utilisant la location des glissements de terrains, les aspects morphographiques, de la géologie, des aspects du sol, des aspects de la foret, une base de données qui nous permettent d`identifier quelques typologies d`évolution dans le contexte des instabilités provoquées par l`homme.

1. Introduction

In the perimeter of the Breaza locality, alongside the scarp towards the riverbed of Prahova, the field notes taken on a five year period emphasized specific morphodynamic aspects. The rock masses are marked by creep processes on the active escarpments and within the mass slide through the appearance of cross cracks parallel to the scarps. The landslides have a specific development near the constructed surface, giving the scarp a wavy aspect. During the 2002 and 2006 period the landslides were analyzed, described and monitored in stages of relative

stability. Reactivations have been noticed occasionally and locally and have been analyzed immediately after the starting stage.

The risk aspect involved by landslides is of a greater importance as there have been many constructions made on the Prahova scarp in the last 15-25 years, as a consequence of new financial possibilities and the local land and cadastre availabilities. Many "holiday houses" have appeared, of large dimensions, with 1 or 2 levels, some of which having the ground floor buried in the scarp. Many other constructions, inherited or bought, have been transformed or modernized after 1990 through redesign or reconstruction. Such interventions needed for the building itself, but also for its facilities, especially additions like sewerage, have disorganized the land. Parallel to the margin of the terrace, many houses of the eastside of the street M. Căproiu have been affected by landslides (buildings of 50 to 70 years old, considered "light", with no foundation, made of wood and "adobe" plaster). The events are memorized by the locals and marked on the facades of the buildings by handicraft repairs.

The problem of the foundations at the new buildings wasn't dealt with properly, studies concerning the load implied by the constructions and the emissive materials on the scarp weren't made and neither were studies concerning the taking over and draining of pluvial water and, following, of the domestic water (improper sewerage lines, septic tanks etc.). The construction of these buildings – placed on the margin of the terrace and/or « cut » in the scarp and also all the trenches made for the foundation/walls and the underground cable and pipe placements – was, most likely, the causing-anthropic element that favored the appearance of the 1997 landslides and of those in the autumn of 2005. As a consequence of the landslides taken place in September 2005, an old, inactive sewerage line was observed, parallel to the margin of the scarp.

The increasing interest in constructing residences in this urban sector wasn't correlated directly to the systemization of the roads, problems caused by the type and intensity of traffic and the gauge of the vehicles, or problems associated to the previous: the maneuvering activity, trepidations, the shocks received while braking, tilting operations etc. An important fact that should be mentioned is that at the end of the Eternity Street, towards the town center, a construction materials warehouse is functioning.

Miron Căproiu Street, on an alignment that follows the edge of the terrace between Eternity Street (cemetery) and Windmill Street (Morii Str.), was organized as a street system – successively, connected to the urbanization of this sector. In the same time, the increase in the number of constructions caused the emission of some volumes of material from the foundations, either filling or waste, that were transported and deposited by spreading on the scarp of the terrace, in geomorphologically vulnerable areas (causing gulling, the degradation of the soil, of the grass cover and of the

arborescent and arbustive vegetation, which ensured previously a relative protection by stabilizing the natural landslides at a slope angle of 7 to 15°). On M. Căproiu Street, large volumes of rock, emitted from the foundation spaces starting with 1995, were deposited on the edge of the Prahova scarp, at the end of V. Alecsandri Street.

An important element, associated to the landslides, is the running pluvial water on the streets perpendicular to the body of the scarp, along M. Căproiu Street. These streets aren't equipped with a sewerage system and on a slope of approximately 0,2–0,3% towards the edge, all the water is evacuated on the margin of the scarp or it infiltrates in the last meters through the material that represents the street infrastructure and through cracks parallel to the scarp, in a continuous opening and deepening.

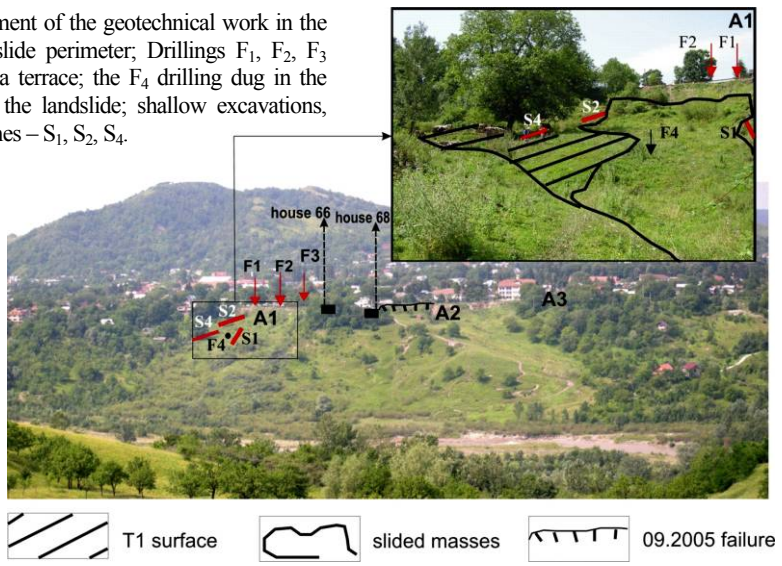
2. Methodological Aspects

The studies made on the field on a five-year period, in a wide area along the Prahova Valley, permitted us to describe the lithological and structural local conditions and to create a general image of the landslide processes. Direct geological and geomorphological observations were made; also uncoverings and ditches were executed and samples were collected for analysis and geotechnical studies.

The landslide between M. Căproiu Street and Eternity Street was monitored periodically (between 2003 and 2006). Its movement was monitored in time, by planting movement posts, by using telemetric mapping and volumetric interpretation of the active material.

In the summer of 2006 there followed the measurement of the thickness of the masses that slid and the identification of the geotechnical parameters of the sliding bed. Four drillings of small depth were thus made manually in the gravel of the terrace and in the mass that slid and two uncoverings and one ditch were made in the mass that slid reaching to the "in situ" rock. (Fig.1).

Fig. 1 The placement of the geotechnical work in the M Căproiu landslide perimeter; Drillings F_1, F_2, F_3 dug in the Breaza terrace; the F_4 drilling dug in the central sector of the landslide; shallow excavations, trenches and ditches – S_1, S_2, S_4.



Samples were taken from this work for granulometric and geotechnical analysis. The data obtained were correlated to the results of the measurements and the geotechnical surface probing.

3. Geomorphological and Lithological Local Particularities (M. Căproiu Street, on the Section between Eternity Street and V. Alecsandri Street)

In the studied perimeter, Breaza II terrace has a wide development, placed at an absolute quota of 500-550 m and approximately 60 m above the present riverbed of Prahova. The geomorphologic analysis led to the identification of a level that represents terrace I, at a relative quota of approximately 30 m. The geotechnical work executed confirmed the level of the terrace mentioned previously, "contaminated" by the slide material (the M. Căproiu landslide), with a thickness measured at 2,45 m at the F_4 drilling. At the S_3 ditch, dug on a geomorphologic surface in relation with the level of terrace I, there was identified, measured and tested the terrace material, 2,30 m thick, placed directly on micaceous red sands.

Terrace II, Breaza, has a stored gravel material formed mainly by Sinaia flint-limestones. This material differs granulometrically and through particularities of its shape and the way it roles (flat cm-dm dimensions) from the one used in the infrastructure of the street.

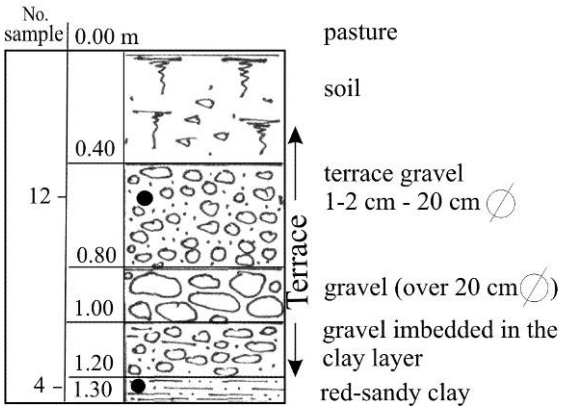
The extension of the material in the terraces was estimated by interpreting some carbonatic tubercular material stored with a granular concentric structure, formed on the surface of the buckets through the circulation of the water in the gravels of the terrace. We noticed these aspects in the material of terrace II and on the gravels uncovered slide (opened and analyzed in S_4 ditch- see Fig. 2, a). This observation proves that even a short period of time in which the gravels were covered by the slide mass (characterized by an active water circulation) can determine the "wash of this ornamentation" (on the gravels taken from 2,40 m deep in the F_4 drilling, dug in the central sector of the landslide – see Fig. 2, b).

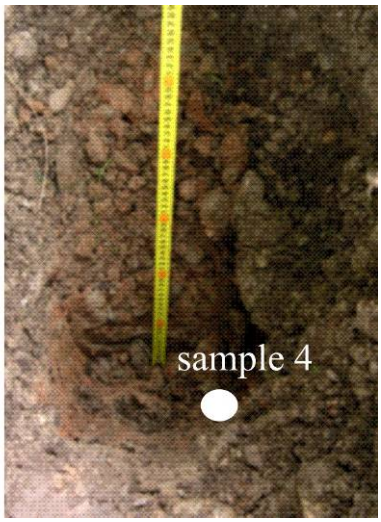
By mapping the Prahova scarp, in the section uncovered by the failure of the scarp under M. Căproiu house number 66, and from the lithological particularities emphasized by the landslide at the intersection between M. Căproiu Street and V. Alecsandri Street – the geological characteristics of the layers from this flank of the Breaza – Buciumeni syncline could be observed (Fig. 3).

In the scarp of the Breaza terrace, in the area of the landslides there are sedimentary formations, stratified in centimetric and decimetric banks. They are made of flint and clay, tuff, gipsiferous marls. At the base of the succession there are red sands,

bearing mica, solidified. In a dry state, they have a consistency index of a *solid rock*. (Towards the edge of the landslide, the ditches dug showed slide masses of 1.5 to 2 m thick and the bed of the slide formed by red sands with centimetric pellicles of clay).

Fig. 2.a.





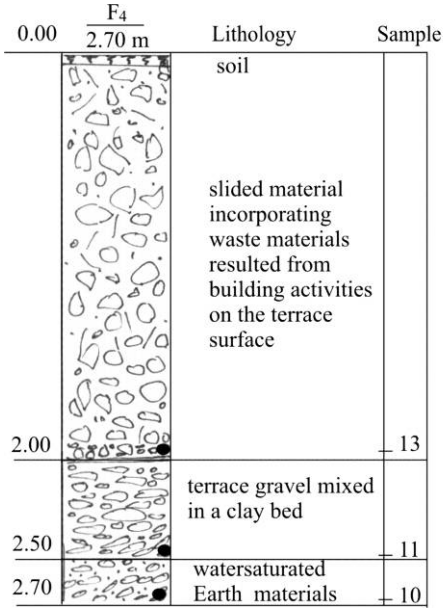


Fig.2.b.

Fig. 2. The lithological characteristics shown in the geotechnical work: a) the S_4 ditch; b) the F_4 drilling, dug in the central sector of the landslide

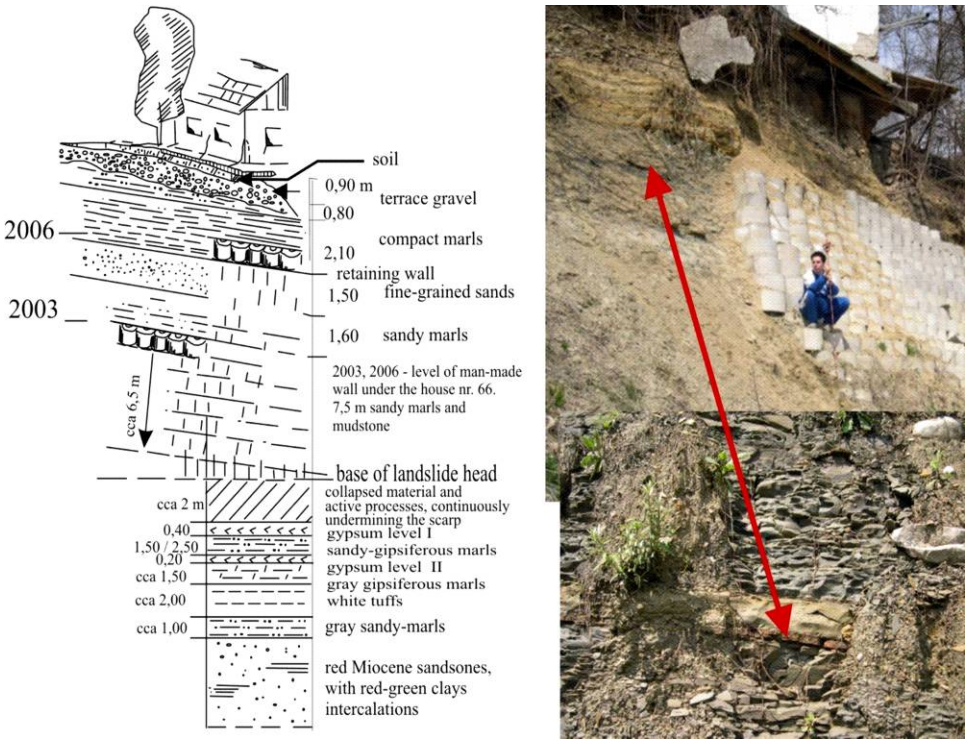


Fig. 3. Outcrop formed under the number 66 house (A1 landslide)

The existence of the clay pellicles and the contact with the active water on these interfaces leads to the formation of a soft, slippery material. The presence and the type of the clay classify these rocks as " *lands with swellings and strong contractions*".

The geotechnical indexes are related to the presence of some inflatable minerals – illite and montmorillonite, which increase in volume in contact with water. The geotechnical characteristic mark reveals clay that stands at the "very active" limit.

In a wet state, the resistance parameters at scissoring decrease consistently and this lithological level can become the one on which the covering deposits, relatively stabilized slide, after the rock fall has started the process.

4. The Morphodynamics of the Miron Căproiu Landslide in the Extension of the Eternity Street (A1)

From the repeated field observations, the tendency of morphological reorganization in the alignment of the precipice can be noticed, constantly regressing towards the perimeter of the part of the road that permits the passing of vehicles (Armaş et al., 2007). On the old map, the residence from M. Căproiu Street number 66 is placed on the terrace at approximately 10 meters from the present development of the edge (based on the topographical and geological measurements represented on the topographic map 1:25.000 L-35-100-A-d Breaza from 1964 to 1965). The failure of the scarp in 1992 led to the present state, the construction being undermined on 1/5 of its surface and suspended on a width of 1,5 m above an almost vertical failure wall.

The local authorities have tried to stop the processes of rock fall/landslide through operations of consolidating the road and filling the precipice with material coming from the foundation of some buildings and waste (according to SC CONSPROIECT Ploieşti project a supporting gabion wall was built on a 70 m length and under the footway of the street a supporting wall of a length of 100 m).

In the field activity we could notice that the filling material, of a diverse nature (gabions, waste) remobilizes by detaching in steps. The filling material steps, which fall periodically from the main landslide head, manage to accumulate and reorganize at the base of the precipice, mobilizing especially in the rainy period, towards Prahova, on a direction imposed initially by the presence of some natural limits, represented by two gypsum layers. The actual landslide develops through rock falls that evolve in sliding steps with a rotational character. In the rainy periods, the surface drainage is accompanied along the Eternity Street by an underground drainage that follows relatively the course of the road (with suffusion effects). Behind the gabion wall, at the basis of the landslide, lakes appear and maintain in the rainy periods, alimented by the sliding water that cannot turn towards Prahova.

In the landslide monitored on the period 2003-2005, at least two gypsum levels were noticed, each being 0,80–1,20 m thick, that showed supporting alignments with the function of leading the slide masses (see Armaş et al., 2003, 2004). At the base of the gypsum levels there are medium-fine granular quartzous gritstones with carbonatic and gypsum cement, in centimetric layers, crossed apparently chaotic by fissures filled with gypsum and anhydrite. The dissolving process of this succession is favored by the infiltration pluvial waters – the ones drained in the street lines, but also the ones redirected by executing some construction works: foundations, fountains, septic tanks, ditches for roads etc.

Going beyond the limit of stability leads to the block landslide of some masses of metric thickness that combine also the chemically destabilized levels by the gyps – a phenomenon that was observed after the rainy period in September 2005.

Because of an unorganized drainage, at the surface and on the sliding interface (processes identified in the ditches executed in the summer of 2006, to observe the thickness of the slide mass), numerous course shifts could be noticed, by alimenting puddles and swamps, developed in an area used for grazing.

5. The Miron Căproiu Landslide in the Extension of the V. Alecsandri Street (A2)

On M. Căproiu Street, at the intersection with V. Alecsandri Street, as a consequence of the abundant rain, which caused great fluidity of the material from the terrace and from the street infrastructure, a rock fall was produced at the edge of the scarp, where M. Căproiu Street is situated. The rainfall registered at S.H. Prahova, from 23.09.2005 to 25.09.2005, showed a total of 39,5 mm (of which on 23.09.- 20,1 mm) and 24.2 mm at Câmpina Station on 24.09. The landslide started as a rock fall on morning of 25.09. The orientation of the direction of the slide was and is influenced by the fact that the synclinal structure plunges towards east, with a lower angle than the one of the topographic surface, puddling in the slide mass. The whole road system was destroyed, in the whole intersection and on all its width (From that day, Miron Căproiu Street is out of use in this section). A fountain of 3.5 m deep was opened, an electric post, part of the town lines, fell, a 450 mm long water pipe was uncovered and 20 m long electrical cables stayed suspended.

The failure of the material at the edge of the terrace cumulated and reorganized at its base, by pushing and covering a previously destabilized material. By observing the body of the slide mass, effects of the push and rearrangement of a construction destroyed previously (remobilized through rotation and rolling) can be identified.

This type of failure-landslide with a shape of partially stabilized waves has also lateral precipices with active liquid drainage. This fact will cause shortly a rotational landslide that will direct northeast on the stratification face, towards the axis of the synclinal structure.

The infiltration process of pluvial water in gravel and sand continues till it reaches the interface of the clay levels. The quantity of water is increased by the presence of the groundwater running free in the gravel of the terrace that is also associated with the domestic water (uncontrollable because of the bad alimentation system and the free emission from the inadequate septic tanks). This process is continuous and it represents a main and constant factor of instability.

In warm and dry periods, the eastward exposure of the sunny scarp leads to an increased dryness of the sliding surfaces, ensuring some stability that is inevitably lost during the rainy periods. During these periods (statistically proven and *perceived as such by the locals*), in relation with the geological details (the inclination of the layers, the particular-synclinal structure, the permeable/impermeable alternations) the starting factor is identified. The imbue beyond a critical limit determines the mass movement of the pack saturated with water, by detaching and sliding the rocks on the faces of the layer towards a north-eastern direction. The landslide is very active and progresses regressively towards the terrace surface. Until the autumn of 2006, no measures were taken to establish a balance in this sector (there are some delimitation posts of the rupture of the road that cannot be even considered elements of pedestrian protection).

From M. Căproiu Street towards Prahova, an unorganized road descends on an accentuated slope, bordering the southern section of the new landslide. Precipices that allow the visible infiltration of the pluvial water on the sliding interface undermine the road; the phenomenon is accentuated by the drainage of the water in the same direction on the constructed perimeter, for which this road is used.

The lithological elements, the geological situation and the field observations made the next day, after the September 2005 landslide started (small, wet detaching precipices, sliding beds with free running water) makes us draw some attention on the process that is undermining the stability of the foundation of the electric post, of the electric transformer post and of the three buildings situated on the slope, at the southern extremity of the destabilized area, with access to the road in question.

By changing owners, these residences were modernized: annexes were executed; courtyards were filled and concreted – without ensuring a drainage system, transversal supporting walls were constructed and elements of a system that could store up water under pressure are now present. This water slides partly towards north – where the slide mass in question is situated. The existence and the fluctuation of the volume cumulated by the water are proved by the presence of a spring in the courtyard of the M. Căproiu nr. 68 household, that appeared under the concrete supporting wall that lacks a drainage system. Storing up the water excessively leads to some instability that extends to the spoil of the road.

6. The Northern Extremity of the Landslide at the End of the V. Alecsandri Street (A3)

An example of anthropic destabilization of the scarp can be seen on M. Căproiu Street, towards north, at about 80 m from the intersection with V. Alecsandri Street (Fig. 1).

A previous landslide, relatively stabilized, by redrawing the slope and constructing a supporting parapet made of stamped in the substratum wood trunks, was reactivated because of work done in the area.

A heavy supporting parapet was built and about 20 mc of rock were placed in two steps, supported by metal poles placed vertically about 2 m deep. Metal nets were put among between the poles (Fig. 4).

Because of the rock mass slide appeared while executing the work, posts of a similar type were placed at the edge of the terrace, on which supporting straps were fused.

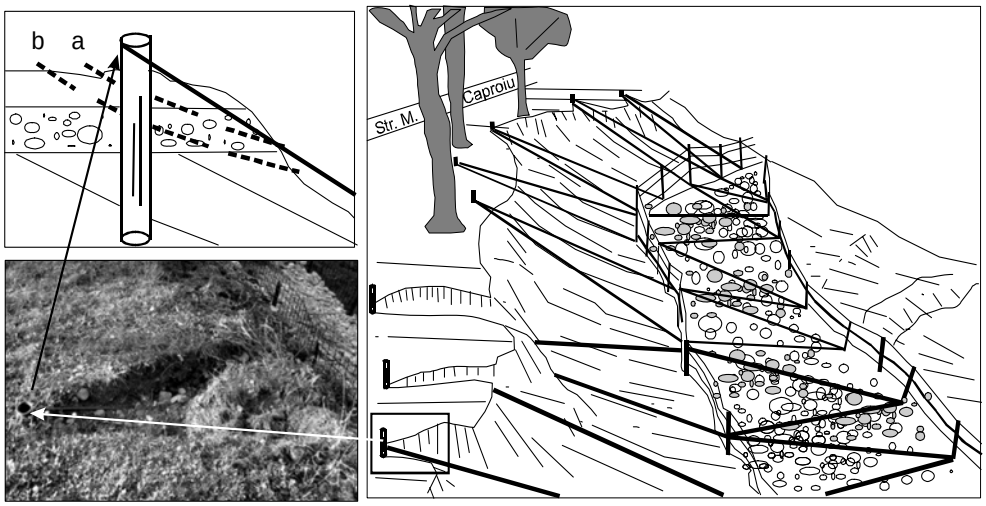


Fig. 4. Landslide A3, reactivated by the "supporting walls" and anchor straps. "a" and "b" are ditches deepening very fast by washing processes

At least some aspects of "active and accelerated anthropic disorganization" can be seen:

1. The rocks brought (with heavy trucks!) which form the two "supporting walls" are obviously too heavy and were placed on an accentuated slope, without processing the base in order to become stable;

2. The anchor straps are inadequate to the static pressures (wire with the diameter of 0.8 cm, fused punctually on the pipes in question);
3. The pipes placed have very small diameters in relation with the tasks done (5 cm in diameter); they will be easy to bend and will be chemically corroded in a short period of time (they are already filled with water that contains ferruginous gel);
4. The scarp was prepared for this work by uncovering the vegetation and, on the path of the straps, by digging positioning ditches. These ditches, initially of low depth, from 10 to 30 cm, are deepening very fast (in Oct. 2006) by the washing of the soil and of the terrace material;
5. At the base of the whole "structure" water is being drained and in some sectors it is puddling.

7. Conclusions

As a general conclusion, we emphasize the fact that the initiation/the acceleration of the landslide processes in the analyzed area is due to the intervention of an initiating factor that is primarily natural (the rain! – but also the circulation of residual water, drained on the street system, and especially the circulation of domestic water), in an anthropic affected context.

Thus, the "heavy" constructions placed at the edge of the scarp, along Miron Căproiu Street, present the following problems:

- The constructions are executed on recent landslides, morphologically visible, where the slide mass has a thickness measurable in meters. Often, these landslides, which appear stable, were sectioned by the execution of trenches for the foundations/walls; this fact places them in a different risk category from the one for which the geological project of foundation was made;
- The landslides didn't affect some constructions in 1997, but the vicinity with the destabilized masses causes a geotechnical and hydrogeological pressure. The landslide in September 2005 represents an alarm signal for the whole section built on Miron Căproiu at the intersection with V. Alecsandri Street, reaching to Windmill Street;
- The constructive solutions led to the leveling and filling of the land (in slide masses!) in order to make the courtyards and protect the road. Terraces were made by remobilizing the material inside some concrete formworks (2 to 3 m high and even more) that are not equipped with windows for draining the water! (for example Miron Căproiu Street, nr. 68);
- Inside the constructed perimeter (with terracing) utilitarian structures were made, inadequate for the domestic water. Thus, drains to transport the

potable water, trenches and ditches for draining the pluvial running free water and the one coming from the roofs were executed. The septic tanks have concreted walls (but practically they all have an "open bottom/end "). They accumulate and drain water with detergents in the closest substratum, which has an increased action of fluidization on the slide slopes.

The measures proposed were provided to the Local Administration, in specially organized meetings in the plenum of the City Counsel. Although the measures were approved at this level, most of them couldn't reach a consensus City hall – citizens. These measures refer mainly to the adjustment of the activities in the areas potentially instable and those confronted with landslides, especially referring to the execution of roads, ditches, wells, foundations and unauthorized and/or authorized inadequate constructions and imposing a restrained circulation; eliminating the trepidation sources, putting interdictions on loading the scarp with constructions or on depositing/ spreading; responsible geotechnical notice on the execution of different constructions, septic tanks etc; putting interdictions or limiting the usage of landslides as pastures.

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