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Geologic-Geotechnical Assessment for Leaning Tower Antenna GSM Cosmote "Sinaia-Cota 1000"

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Abstract

Surface geological observations and research drillings associated to geomorphological and stratigraphic context of the GSM Antenna Tower "Sinaia-Cota 1000" site allows considerations regarding to the stability of the ground subjacent to the tower. In the paper are made proposals for improving the geotechnical quality of the foundation ground.

Key words: *geomorphologic-geologic setting, landslide, Păduchiosu Mountain, Bucegi Massif, landslide counteracting analysis*

Introduction

The land corresponding to the foundation and the surrounding wall of the 60 m high lattice tower GSM antenna Cosmote located at Sinaia Cota 1000 on the East periclinal termination of Păduchiosu Mountain from Bucegi Massif, has active landslide events which require geological-geotechnical analysis in order to optimize the measures to counter of the landslide phenomenon.

In the paper are presented the geomorphologic and geologic context of the formations that framing foundations, is assessed the damage degree of the foundation by landslide and are suggested measures to counteract the landslide phenomenon.

Geomorphologic-Hydrologic Diagnosis

Plaiul Păduchiosu land with access from the saddle crossed by national road DN71 (Sinaia-Fieni segment), between interfluve of Prahova Valley (Izvor river) and Ialomita Valley (Ialomicioara river) followed by a forest exploitation road (DE998) and a ridge parallel to the west, is developed having geomorphologic aspect of depression circus affected by landslides (fig. 3). The ridges mentioned, with north-south orientation, are bounded by steep detachment of the landslides becoming stronger and deeper (6.0-8.0 m) to the assembly center, and attenuated (2.0-4.0 m) to the east side. The main valley with north-south orientation of the depression circus appears divided by sliding masses from slopes in several torrential valley routes which is then connected with erosional valleys or small depressions leaving from the east or west margins of the main ridges. The greatest slope gradient of the whole depression is inclined 20-25° to the south, attenuated at 10-15° to the downstream side of the perimeter. Vigorous active landslides creates a relief of drumlins and little depression with glimee lakes or with humidity excess/hydrophilic vegetation, underlined by the aspect of „drunken forest" of the fir and beech forest from the perimeter. The high level difference between the central part and the downstream part of depression circus is creating a strong erosional call, resulting in increasing depths in the thalweg of the erosion valleys, strong gullying of the space between the slided masses and destabilization of the rock mass from upstream. Toward to the eastern half of the depression circus, the general gradient attenuation is determining the thinning of the slided prism and decreasing of the movement tendency up to aspect of stabile area, unaffected by slides. Thus, the land adjacent the eastern ridge, marking out by forest road of access to Păduchiosu Mountain, it is presented as a stability band, with approx. 10-15 m width to the north, extended about 50 m to the south, toward to the crossing saddle of the ridge by DN71. This stability band was chosen for location of GSM antenna towers, including Cosmote 60 m high lattice tower.

The mentioned tower reveals the location to west-south-west toward the narrow ridge of stability, within in the upper third of a depression affected only by superficial gravity flow of delluvial material superjacent to firmly geological bedrock (represented by Comarnic Beds). In the depression area, adjacent Cosmote tower, the prism of unstable delluvial deposits increase from 0.0-0.50 m thickness in the ridge of forest road to 2.0 m in upstream side of the tower site and respectively to 2.60 m thickness in the downstream side of the tower site. The maximum deepening of the depression is on the inclined alignment north-east to south-west, located adjacent to the north-northwest from de tower site. This maximum deepening of the depression started as a scarp of a landslide from east stability ridge (i.e. forest exploitation road DE998) with slopes of 35° straight to the tower site, decreasing to 10° at approx. 12.0 m downstream of tower site. Alongside of this alignment are developed phenomenons of superficial active landslide: drumlins, intermediary scarps generating stepped microrelief, small depressions with temporary lakes and hydrophilic vegetation. The landsliding phenomenon are facilitated by the gradient slope and excessive humidity which, in extra-wet seasons, determining springs and even small rivers with torrential regime. Site tower Cosmote is located to the top of the depression in the thinning area of the delluvial material prism with landslide potential. Superficial landslide affected the concrete wall adjacent the foundation. The site side from south-southwest = downstream as well as the west and east ones appears cracked, dislocated, compacted; while the upstream side (north-northeast) of the site where is recorded thinning sub-meter of superficial delluvial prism appears unaffected. Involvement in landslide of the concrete wall adjacent to the site can be explained by the difference in depth of foundation between concrete wall (embedded in sliding superficial delluvial cover) and the foundation of the tower itself (whose support bearings/bolsters of the tower legs reveals embedded into semi-rocky bedrock of diagenized claystones, with rare intercalations of thin sandstones). Although the efforts created by the superficial sliding mass are felt to the top of the bearings, the ones appear unaffected by the land instability. It is noticed only a slight disaggregation/segregation of the concrete, related more by weathering and an improper casting in successive stages of the bolsters.

Geological Setting

From geological-regional point of view, the studied location belonging to the Bratocea sub-unit of the Ceahlău Unit from Eastern Carpathians, on the northern flank of the Plaiul Hoţilor-Plaiul Păduchiosu anticline (north east-south west orientation), where the stratigraphical outcrop context of the *Comarnic Beds* formation (Barremian-Aptian) and *Upper Sinaia Beds* formation (Hauterivian) is facilitating, through the different lithology of the constituent layers, the presence of same cuestas with incompetent deposits in the top (figs. 1, 2) . The incompetent deposits facilitates developing of a depression relief covered by delluvial-prolluvial quaternary deposits, at their turn, involved in old and actual large ground sliding.

Local geologic context belonging to tower site Cosmote and adjacent reveal the presence of a delluvial deposit of very plastic clays, consistency, wet and to the base, at approx. 2.00-2.60 m very wet, very plastic behavior, that facilitates the occurrence of an area/plan of superficial sliding. From lithological point of view, the local drilling investigation is showing the presence of superficial sliding cover with thickness in the range 0.00-1.00 m to 0.00-3.00 m) of delluvial material composed of very wet clays, very plastic, with soft consistency in the base of the suite (where is outlined the sliding plan) under which is developed the semi-rocky bedrock composed of claystones and marlstones with rare thin sandstones of Comarnic Beds.

Conclusions

Considering the geomorphologic and regional/local situation analyzed it was proposed a set of applicable measures function of depth of foundation of bolsters – foundation tower legs and analysis of evolution of landslide phenomena and eventually in function of tower leaning = tower deflection (fig. 4).

In economic variant, the location of foundation legs in the margin of depression with superficial sliding of delluvial material, respectively in bedrock, would create minimal risk of involving in landsliding of foundation. The technical documentation of the foundation, through depth of excavation measured from natural ground level (CTN) can give the degree of embedding of foundation in bedrock, i.e. below to the 2.20 m depth representing the thickness of superficial sliding cover at distance of 1.00 m in downstream side (west-southwest) of tower site and respectively below to 2.20-3.00 m in the area of the foundation leg from north-north-est.

The sliding of foundation and surrounding wall of the site is related to the lower depth of foundation excavation of the wall, respectively in the superficial sliding cover; the sliding of the foundation of the surrounding wall is dissociated by the bedrock of the tower legs/bolsters foundation (figs. 5, 6, 7, 8).

Insofar as the foundation legs were excavated below the sliding cover of 2.00-3.00 m thickness (i.e. bedrock) this represents the insurance of the tower foundation. The embedding with more than 1.50-2.00 m in bedrock can be considered ensuring from stability point of view, but this statement would require consultation with the construction engineer and structural engineer.

As palliative actions it can proceed to a better collection of meteoric and infiltration waters in the greatest slope line of depression area by execution of a groove excavated at least 1 m deep in the bedrock, i.e. deeper than 2.20-3.00 m. The groove will have the outlet to the downstream and will be equipped with perforated tubes covered with crushed stone in reverse filter arrangement. The stability of the downstream land can be achieved by executing a straight girder embedded at least 2.00 to 2.50 m in bedrock. The girder will be manufactured from reinforced concrete, properly dimensioned, with trapezoidal transversal profile and will be provided with drainage holes. Greater efficiency would provide the execution of an alignment of metallic casings drilled at minimum 5 m depth, concreted, solidarized by stitching cables at top and trapped into a concrete girder at the land surface. In upstream of the perimeter it will be executed a superficial tiled groove for collecting and routing / bypass toward downstream of meteoric waters. The context adjacent tower site would be appropriate to be afforested / planted with trees for optimizing the slope stabilization and decreasing of humidity excess. The concrete wall cracked/damaged on the site perimeter will be consolidated by several bolsters from reinforced concrete with trapezoidal transversal profile embedded at least 1 m depth in bedrock.

In the unfortunate variant of an insufficient embedding of tower foundation legs in bedrock, correlated with a vigorous manifestation of tilt of the tower proved by topographic measurements, this will prove damaging of the tower foundation by superficial landslide, and measures to counter the phenomenon will have to be strengthened. In this case will be necessary geotechnical analysis on the samples collected both from superficial cover and from bedrock in the range 5.0-10.0 m from the natural ground level. A ring of drilled and concreted steel casings (from abandoned wells), solidarized in the top with stitching cables and eventually reinforced concrete should be solidarized by reinforced concrete slab with legs/bolsters of the tower foundation. The conventional pressures (according STAS 3300/2-85) for a foundation having footing width B = 0.60 m and depth of foundation in the range 1-4 m, are shown in Table 1.

Table 1

Conventional pressures (kPa)	F1 drilling	F2 drilling	F3 drilling	F4 drilling
Pconv. 1.00 m	90	100	100	105
Pconv. 2.00 m	120	400	140	140
Pconv. 3.00 m	500	500	300	500
Pconv. 4.00 m	-	-	500	-

Elastic coefficients of foundation ground (bed coefficients) calculated for depth of 3 m are shown in the table 2.

Table 2

Coefficients (daN/cm^3)	F1 drilling	F2 drilling (2m)	F3 drilling	F4 drilling
Cz	3.73	3.73	3.73	4.04
Cx	2.80	2.80	2.80	3.03
Cα	5.26	5.26	5.26	5.69

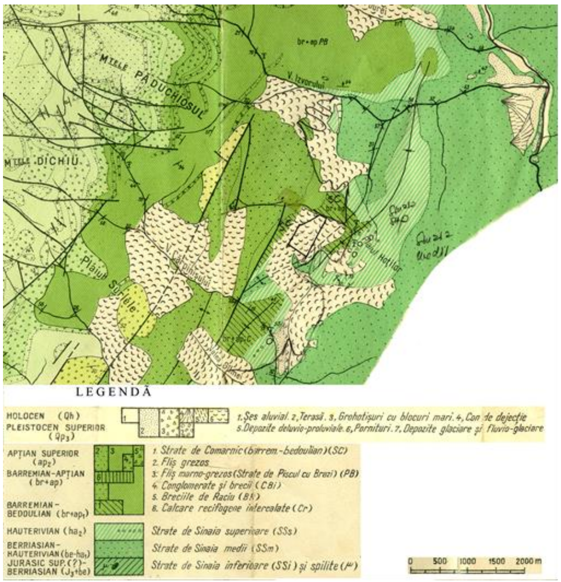

Fig. 1. Geological plan of the studied location (after D. Patrulius, 1969).

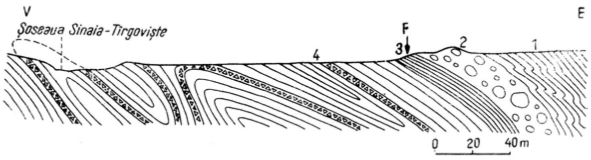

Fig. 2. Regional geologic section in Plaiul Păduchiosu area: 1. Upper Sinaia Beds: marly-clay schists and sandstone intercalations and variegated micro-breccias; 2. tilloidal conglomerates with olistolites from limestone Stramberg type; 3. strong marls with fucoids, ammonites and plants debris; 4. marl-sandy schists with calcarenites intercalations; F – fossil-bearing (after D. Patrulius, 1969)

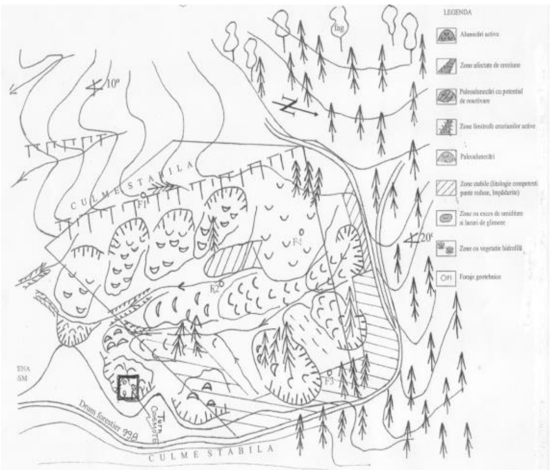

Fig. 3. Regional geomorphologic sketch in Plaiul Păduchiosu area (no scale)

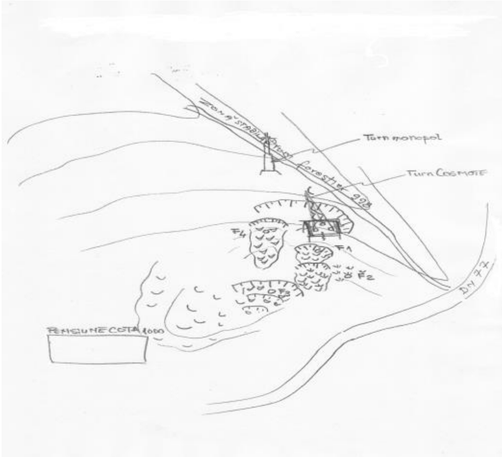

Fig. 4. Detail geomorphologic sketch with location of drillings in Cosmote GSM tower site in Plaiul Păduchiosu (no scale)

Fig. 5. Drilling in proximal position (south-west) to the tower site

Fig. 6. Downstream view (west) to the tower site

Fig. 7. Drilling in ravine developed at six meters downstream (south-west) to the site

Fig. 8. Drilling in proximal position (south-west) to the tower

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Evaluare geologico-geotehnică pentru turn antenă înclinat GSM Cosmote Sinaia Cota 1000

Rezumat

Observaţiile din cartare de suprafaţă şi forajele de cercetare asociate contextului geomorfologic şi stratigrafic al site-ului pentru turnul de antenă GSM COSMOTE "Sinaia-Cota 1000" permit consideraţii asupra stării de stabilitate a terenului subjacent turnului. In lucrare se fac propuneri pentru îmbunătăţirea calităţii geotehnice a terenului de fundare.