

The influence of landslides on Belgrade, Serbia

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Abstract: By analyzing individual landslides within the Belgrade area the general causes of the major landslides were synthesized and the spatial hazard defined. The landslides are caused by the interaction between the surface, ground waters and geology. Anthropogenic effects also cause these landslides. The majority of landslides are large in surface area, and deep sliding is encountered in the Miocene clays and marls with sand partings, particularly in slopes inclined towards the River Danube.

Résumé: D'après l'analyse des glissements particulières sur le territoire de Belgrade, ils sont synthétisés des causes générales de commencement de la plus part, même que degré d'activité et défini menacement de la superficie et des objets. La plus grande cause de commencement des glissements représente l'eau souterraine ou de superficie en collaboration avec des conditions géologiques, bien que des causes anthropogènes. La plus part des glissements, de grande espace et profonde, sont notés dans les argiles sarmatiennes avec des couches sableuses. Toutes ces phénomènes sont orientés vers Danube.

Keywords: data analysis, environmental protection, environmental urban geotechnics, geoenvironmental engineering, geology of cities, landslides,

INTRODUCTION

The modern model that defines soil as a part of the lithosphere interacting with human activities, and as the physical environment for direct interchange of matter and energy between man and nature, requires treating soil as an integral part of the environment, and indeed a threatened environment.

In addition to the common contaminants in water and soil, various fills, piling and associated construction, and possibly ill-planned infrastructural systems, threaten the environment. Add to this numerous landslides in the centre and suburbs of cities like Belgrade, gives an indication of the nature of the contaminated or endangered contemporary urban environment. Landslides, however, are also a threatening factor in areas away from cities, as they limit the scope of planned future land use, and it is landslides that form the focus of this study.

THREATENED AREA

The case study of Belgrade and its suburbs, judging by the frequency, number and extent of areas affected by landslides or other recent geological phenomena, is an example of long, almost historical, neglect of the environment. The most responsible factor is the natural soil conditions under the town, but man with his long and heedless activities has had a significant effect on this urban environment.

All the landslides registered in the Landslide Registry by municipalities on the territory of Belgrade, when analyzed gave the following proportions of landslide and municipality areas:

- Belgrade city itself, 3% of the area affected by active landslides,
- In the entire Belgrade, 7% of the area is affected by active landslides.

Most endangered, compared to their areas, are the municipalities of Zvezdara and Barajevo (23%), and followed by Obrenovac, Cukarica, Sopot and Grocka (9% to 10%). These proportions are graphically represented in Fig.1.

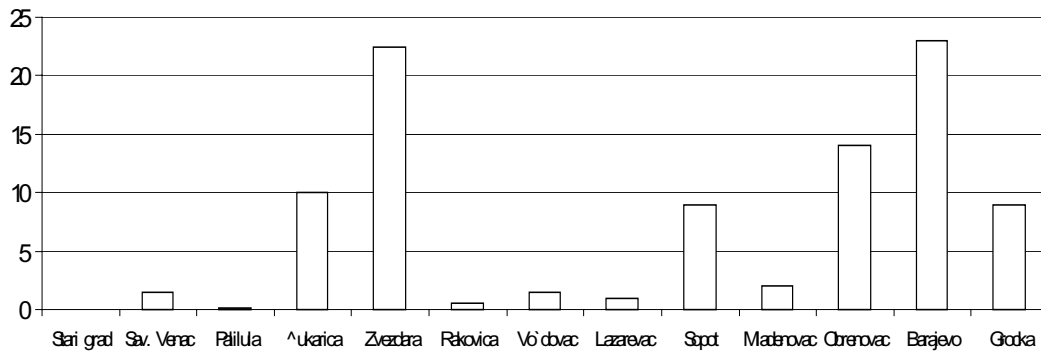


Figure 1. Histogram of active landslide surface areas related to the Belgrade municipality.

In terms of the number of registered landslides, the municipalities with the highest are Vozdovac (410) and Cukarica (234), and there are 284 active landslides over about 400 ha in area, and 101 slides of about 1800 ha in area, in Vozdovac and Cukarica, respectively.

Landslide activity is more intensive and continuous in Grocka (30), Obrenovac (25), Vozdovac (21) and Barajevo (20). The number of permanently active landslides, and the rate of seasonal slide activity and recurrently active slides are given in Tab.1.

Table 1. Activity of landslides (number).

Municipality	Active landslides			Inactive landslides	Stabilized slides
Palilula	33	1	9	16	
Cukarica	53	14	7	133	
Zvezdara	7		3	6	
Rakovica	6		7	9	12
Vozdovac	91	21	39	126	14
Obrenovac	36	25	19	19	
Barajevo	62	20	11	26	
Grocka	94	30	163	248	5
Total	382	111	258	751	31

THREATENED STRUCTURES

Landslides in Belgrade, both active and inactive, have caused physical damage to different types of structures including: houses, industrial plants, public buildings, utility structures, and farmland. Tables 2 and 3 give the landslide threats to structures in the active slide areas.

Table 2. Threatened structures

Municipality	Houses		Industry		Public		Utility		Farmland	
	Struct.	Slide	Struct.	Slide	Struct.	Slide	Struct.	Slide	Area (ha)	Slide
Stari grad	-	-	-	-	-	-	-	-	-	-
Savski venac	-	-	1	1	3	1	3	1	-	-
Palilula	97	11	1	1	3	3	44	7	104.76	29
Cukarica	68	19	-	-	3	3	-	-	1407.97	77
Zvezdara	27	6	1	1	3	3	43	3	160.14	10
Rakovica	7	2	-	-	1	1	3	1	3.97	4
Vozdovac	127	12	1	1	1	1	45	3	103.23	52
Lazarevac	31	4	-	-	-	-	-	-	111.00	9
Obrenovac	624	55	-	-	-	-	298	19	1745.00	91
Barajevo	184	25	-	-	1	1	136	18	2267.35	108
Grocka	490	34	3	1	5	3	100	7	1580.21	255
Total	1655	168	7	5	20	16	672	59	7483.63	635

Table 3. Threatened line-structures

Municipality	Local road		Street		Trunk road		Asphalted road		Railway	
	(m')	Slide	(m')	Slide	(m')	Slide	(m')	Slide	(m')	Slide
Stari grad	-	-	-	-	-	-	-	-	-	-
Savski venac	-	-	-	-	-	-	-	-	-	-
Palilula	1960	7	160	2	450	1	1380	3	-	-
Cukarica	740	14	-	-	680	4	150	1	-	-
Zvezdara	-	-	-	-	-	-	1500	2	-	-
Rakovica	185	1	-	-	-	-	-	-	-	-
Vozdovac	325	5	180	1	410	5	80	1	850	5
Grocka	16635	49	-	-	2400	4	930	13	425	4
Total	19845	76	340	3	3940	14	4040	20	1275	9

Tables 2 and 3 clearly indicate that the threatened structures are numerous and varied. Many of them are vital structures for the town, such as tunnels, railway, main and major roads, water distribution mains and sewage collectors, long-distance power lines, factories, and schools.

CAUSES OF LANDSLIDING

An analysis of the causes of landslides does not indicate a relationship between the threatened area and the local geology, because landslides have been registered in almost all geological environments, at different depths, with different spatial extents, and varied origins and movement mechanisms. Essentially, the most susceptible geological units are the Miocene clays and marls, which, given the hydrologic character of the ground, result in the contemporary geological and geodynamic process activities (e.g. landsliding) which are exacerbated by urbanization.

Landslide occurrence (Lokin, Komad, & Ivetic, 1990) is common in residential areas; and whilst naturally initiated in Belgrade they have been extended and intensified by human activities. However, the examples of human operations being the only cause of land deformation are rare. Construction techniques, mainly responsible for exacerbating the effects of contemporary geological processes such as slope instability, are associated with large structures: bridges, tunnels or other underground works, railways, roads, urban infrastructure and individual buildings. The influence of earthworks on slope stability is the greatest, because they cause physical and dynamic changes at the ground surface (Susic & Djokovic, 2002). The changes manifest themselves as disturbances to the soil and hydrologic regime that eventually leads to reduced soil shear strength and cohesion.

The influence of man on slide development is evident in equally important alterations of the hydrological and hydrogeological conditions caused by uncontrolled water infiltration from unregulated water distribution and waste water disposal pipe networks, unplanned housing without infrastructure, and various losses of large amounts of water.

CONCLUSION

Man influences landslide development by disturbing the natural slope equilibrium caused by land levelling and filling, digging various excavations, slope cutting and changing hydrological and hydrogeological soil conditions by allowing uncontrolled loss of water into the ground. All these artificial influences contribute to the development of landslides by disturbing equilibrium in the soil and consequently making an area unsuitable for planning further development. Landslides in the complex geology of Belgrade developed in unpopulated or slightly urbanized zones. The registered landslides are not, nor can be, the consequence solely of human activities, excluding a few cases, but are mostly a result of the combined action of several factors.

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