The mass movement response of tectonics phenomena in urban areas, Albania

Le glissement de terrain comme réponse aux phénomènes tectoniques dans les zones urbaines, Albanie

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ABSTRACT

Albania is a neo-tectonic region with high seismic intensity. Two of thirds of Albania area is built by hills and mountains, which are much affected from tectonics and neotectonics events. These events have played a main role in the slopes stability, from which are formed many landslides, where are damaged and destructed a lot of engineering objects as population buildings; heritage and historic center, roads and geoenvironment of urban areas. In this paper we present the mass movements-earth slides, earth flow, rockslides, which are caused from tectonics phenomena in the main town of Albania. The present paper is based to the engineering geological investigations carried out in the Albanian area during the year 2000-2007. It takes under consideration some more serious stability slopes, where besides engineering objects (buildings, heritage and historic center, roads etc.) are threaten population life from the development of this phenomenon. That's why are carried out a lot of studies in urban areas, as Lezha, Kruja, Tirana, Durresi, Gjirokastra, Vlora etc. towns, where are occurred landslides on hills and mountains slopes, which are much favored by tectonics and neotectonics, processes.

RÉSUMÉ

L'Albanie est une région néotectonique à séismicité intense. Deux tiers de l'Albanie sont constitués par des collines et des montagnes qui ont été beaucoup affectés par des événements tectoniques et néotectoniques. Ces événements ont fortement influencé la stabilité des pentes, ce qui ont produit des glissements de terrain et qui ont détruit et endommagé des édifices du génie civile ; des habitations, le centre historique, des routes et le géoenvironnement de la zone urbaine. Ce papier est basé sur les investigations géologiques effectuées en Albanie durant les années 2000-2007, et il prend en considération la stabilité des pantes qui posent des sérieux problèmes au niveau des édifices du génie civile (bâtiments, centre historique, routes, etc.,), ainsi que pour la vie de la population. C'est pour cette raison que des nombreux études ont été effectuées dans les zones urbaines, telles que les villes de; Lezha, Kruja, Tirana, Durresi, Gjirokastra, Vlora, etc., où des nombreux glissements de terrain sur les pantes des collines et des montagnes sont plutôt favorisés par des événements tectoniques et néotectoniques.

Keywords: landslide, tectonic, lithology, slope morphology, manmade activities, rainfall, urban area

1 INTRODUCTION

Mass movement is a serious geologic hazard in Albania. In whole of Albanian territory the mass movement-landslides cause damages and demolish many engineering objects, as well as, lost many hectares land. This work is a summary of the engineering geological mapping and geotechnical investigations carried out in the main towns of Albania during the year 2000-2008. In this paper we present the engineering geological mapping and geotechnical results taken in the urban area of Lezha and Kruja towns. The Lezha town is located in northwestern part of Albania (Fig.1). It's a historical, cultural center and touristic place in Albania, because of is near (10 km) of beautiful Shengjini beach. The Kruja town is located in central part of Albania on Skanderbeg Mountain's slope. It represents one of more famous heritage and historic centers in Albania, as well. For as much as, on some parts of these towns have occurred landslides from which many engineering objects as buildings and roads are damages and demolished and are threatened others we undertaken a detailed engineering geological mapping (scale 1:5000) and geotechnical investigations, where are done many drilling and laboratory test analysis of soils and rocks.

2 DISCUSSION AND ANALYSES

2.1 *Geological and tectonics-neotectonics setting*

According to geological and tectonics-neotectonics phenomena the eastern part of Lezha and Kruja town take part in Kruja tectonic zone, which include in external area of Alpine folding (Fig.1). It is strongly affected by pre-Pliocene compression phases. The Kruja tectonic zone has been deformed by folds, reverse faults-thrusts and occasional back thrust, as well as by strike slips from the main Alpine compressive phases which folded the above mentioned tectonic zone. Generally, the structures Kruja tectonic zone extend from NW to SE (Fig.1). It must be emphasized the hilly urban area of Lezha town is situated on intensive tectonic zone (thrust faults), which is formed by movement of Krasta tectonic zone over Kruja tectonic zone (Fig.1, 2,). The eastern part of urban area of Kruja town is built on tectonic zone caused from uplift of the normal thrust of limestone's formations over flysch formations (Fig.1, 3, 5).

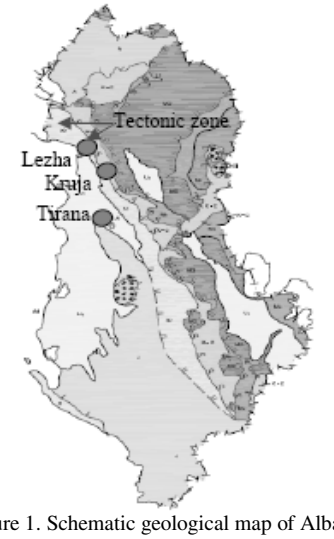

Figure 1. Schematic geological map of Albania

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Geologically the urban area of Lezha town are represented from Lower Oligocene formations-flysch rocks are composed of are thin rhythmic clay-siltstone-sandstone-flysch that are part of Kruja tectonic zone and Maastrichtian-Eocene formations-flysch are sequences composed mainly of siltstones intercalated with sandstones and marl layers, which take part on Krasta Cukali tectonic zone. The second one uplift with intensive tectonic zone on Lower Oligocene formations (Fig. 1, 2).

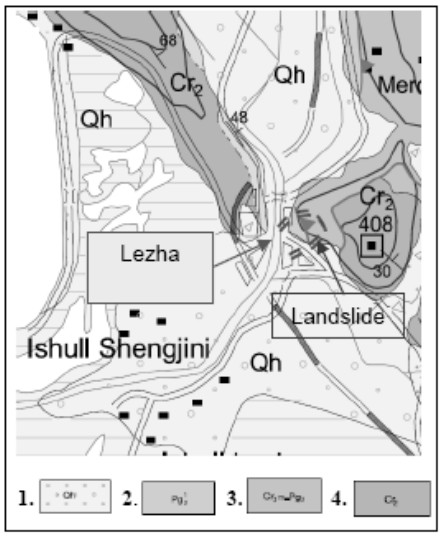

Figure 2. Geological map of Lezha region

1. Quaternary deposits,-silts and sands, 2. Flysch rocks- siltstones and claystones, 3. Flysch rocks-siltstones intercalated with sandstones and marl layers, 4. Limestone,

From the lithological point of view, the studied area of Kruja town is built from the Lower Oligocene formations-flysch rocks Mostly of the bedrocks covered by the Quaternary deposits are silts with gravels and sands mixtures (Fig. 1, 3), which form an overturned syncline with dip angle of the limbs to east. Over this structure with intensive tectonic with normal thrust uplift the Upper Cretaceous limestone's rocks, which extent on eastern part of Kruja town. The flysch rocks represent from combination of the siltstones and claystone's layers. Generally flysch rocks are covered by the Quaternary deposits are silts and silty clays with mixtures of gravels and sands.

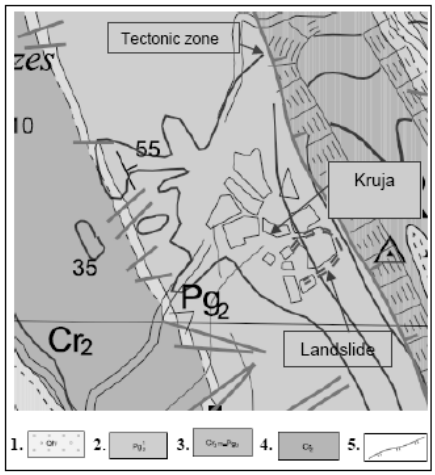

Figure 3. Geological map of Kruja region

1. Quaternary deposits,-silts and sands, 2. Flysch rocks- siltstones and claystones, 3. Flysch rocks-siltstones intercalated with sandstones and marl layers, 4. Limestone, 5. Tectonic,

2.2 *Geomorphology of the site*

Based on field investigations, the studied area of Lezha and Kruja towns represent a hilly zone built by flysch rocks with slope inclination range from 30° up to 45°. The slopes are characterized by the features such the concavo-convex profile, which are formed as result of the geodynamics phenomenon occurrences-earths lips and erosions. During rains, a lot of hill slope mass in the form of debris and rock fragments flows down through these drains and gets accumulated in the middle and lower horizons hilly zones. Where-ever the slope angle exceeds the angle of repose of the slope material, the hill mass shows signs of distress and fails. The failed slopes are generally devoid of any vegetation whereas the surrounding area is moderately vegetated with pine trees. It has been found that a number of cracks are present in the upper horizons, particularly in the south and eastern parts. These cracks mostly trend north – west and dip towards the hill slope.

2.3 *Mass movements*

Slope instability activity is related to various influencing factors, which caused landslide in the studied area. The main factor, which has initiated the favored this phenomenon. Also, for that have influence and lithology (soils and rocks), morphology (slope inclination and slope shapes), rainfalls and manmade works. In this paper we treated two case of story selected from geodynamic phenomena occurred in Albania.

2.3.1 *Lezha landslide*

The landslide occurred on hills slopes extend en eastern of urban area of Lezha town (Fig.2, 4). This part is one the most active tectonically area in Albania constituted by thrust fault, where limestones rocks uplift on flysch rocks. During the uplifting of the Krasta tectonic zone over Kruja tectonic zone (Fig.1, 2, 4) the flysch rocks of urban area have changed their geotechnical properties, transforming from rocks to soils. So, decomposition of the flysch rocks from this phenomenon and weathered processes produces conducive conditions to mass movement in this area. Beside of them, the landslide was triggered by the rainfalls-storms, with the most notable being the disturbed zone by tectonic phenomenon. From this phenomenon are damaged demolished 8 homes (1-2 stores) and main town road etc. The homes damages are cracks of the walls 4.0-10.0cm, cracks and subsidence of the floor and demolition of the home. There also was widespread debris flow and damage to homes, buildings, and roads in areas along the main boulevard and hospital road of Lezha town. The landslide according to classification of Varner 1978 include in rotational types that are generally shallow-deep. The geologic structure, lithology and morphology of the urban area are profoundly influence by the active processes of regional tectonic. Thus, as above mentioned it, the natural events such as tectonics phenomenon, rainfall, slope morphology, manmade construction activities and underground water have caused of the mass movement. The landslide is vary greatly in their volume of soils, the length, width, depth of the area affected, frequency of occurrence, and movement. Therefore, inherent factors related to rock discontinuities provide a basis for understanding landslides and also in the formulation of long and short-term pro-active responses to natural hazards from slope instability. The size of a landslide is 450-500m wide, 220-250m up to 300m long and 7.0-10.2m deep, whereas the its volume is 1 009 375 m^3. Slides move in contact with the underlying surface, which are the much disturbed or decomposed of flysch rocks.

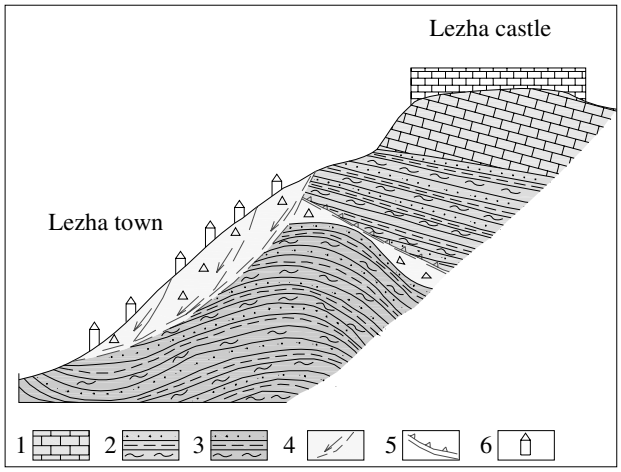

Figure 4. Cross section Lezha landslide
1. Limestone, 2. Flysch rocks- siltstones and claystones, 3. Flysch rocks-siltstones intercalated with sandstones and marl layers, 4. Landslide, 5. Tectonic, 6. Building

2.3.2 *Kruja landslide*

It's located in south-east part of the Kruja town. On this earth slide is constructed a square of the Kruja town, where 12 buildings are demolished by this phenomenon. The slide body is lying over siltstones and claystones of flysch formations (Fig.5). The dimension of the earth slide is 500.0-550.0m long, 400.0-500.0m wide, 8.0-12.5m deep and volume of 2 362 500 000 m^3 (Fig. 3, 5). The slide mass consist of clays, silts, sands, gravels and limestones blocks. The slide plane occurred in these flysch formations, and it has a typically a polished surface at the base, where on it is a thin soft layer (0.2m up to1.5 -2.0 m). The Kruja town is situated on hills slope, which have e dip angel ranging from 30^o up to 45^o. It's moving slowly downwards on hills slopes. Taking into account the landslides according Varner 1978 can be classified as rotational and earth flow types that are active, deep and shallow. Some result in private property damage, while other landslide affects transportation corridors, fuel and energy conduits, and communication facilities. They also pose a serious threat to human life. The landslide generally is slow moving and less rapidly moving (debris flows). First at all it cause significant property damages, but are less likely to result in serious human injuries, where rapidly mass movement present the greatest risk to human life, and people living in mass movement prone areas are at increased risk of serious injury. The upper part of the landslide body is situated directly on tectonic zone, which the main factor that has favored this phenomenon. That's because of flysch rocks formations are intensively disturbed becoming more susceptible to landslides than others, the tectonics zone serve as a collector for the karstic water, which drained from limestones rocks of Scanderbeg mountain and infiltrate in the contact of the soils and flysch rocks doing lowering of geotechnical properties of the soils and rocks. It is certified by the several waters spring, which are found along of landslide body. It often triggered by periods of heavy rainfall (1800-20000 mm/year) and excavations, as well. Also, the morphology of the steep slope of this area can also increase susceptibility to landslide event. Beside of them in this area the people can be exacerbated by human activities as the grading for road construction and development where is increased the slope steepness, as well as, the grading and construction of several buildings, which decrease the stability of a hill slope by adding weight to the top of the slope, removing support at the base of the slope, and increasing water content. Other human activities effecting landslides include: excavation, drainage and groundwater alterations, and changes in vegetation. From landslide occurrence are damaged 14 homes-2 stores, town roads etc.

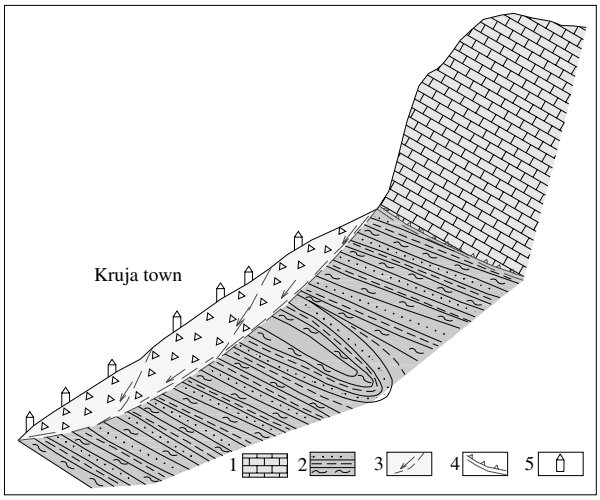

Figure 5. Cross section Kruja landslide
1. Limestone, 2. Flysch rocks- siltstones and claystones, 3. Flysch rocks-siltstones intercalated with sandstones and marl layers, 4. Landslide, 5. Tectonic, 6. Building

2.4 *Geotechnical investigations*

The studied area are represented by the two of the main town in Albania are Lezha and Kruja towns, which are historical, cultural, heritage centers and touristic place of Albania. So, they are very important places for Albanian culture. Therefore it was very necessary to carried out the engineering geological and geotechnical investigation related to slopes stability of at this site. Also, evaluations of the physical-mechanical properties of the slope materials in conditions are completed. The field investigations include the engineering geological mapping on scale 1: 5000 carried out in whole area of urban area of both towns and drillings works were done in the landslides body, from which determine the slide plane. In the Lezha town in related to slope stability are carried out 12 drillings 8.0m to 12.0m deep and taken 22 undisturbed and 6 disturbed samples. Whereas, in the Kruja town has been done 8 drillings and taken 18 undisturbed and 7 disturbed samples. The rock and soil samples (both disturbed and undisturbed) have been collected out and in landslide body for laboratory testing. The soils geotechnical parameters of landslide materials as bulk density, specific density, moisture content, grain size distribution, Atterberg's limits, shear strength and uniaxial compressive strength of rocks have been determined from these samples in the laboratory. The results are briefly discussed here and given in tables1, 2, 3, 4, 5 and 6.

2.4.1 *Lezha landslide*

From field works and laboratories test analyses are determine as following geotechnical unit:

Geotechnical unit nr. 1. Represents landslide body soils. These soils consist of the sands and clays mixtures with pebbles and rubbles content which are in medium geotechnical conditions and have a thickness range from 7.0-10.0 up to 14.0-16.0m (Fig. 4). According to unified soil classification system these soils are "SC" type.

Geotechnical unit nr. 2. These soils built the slide's plane. They are made of inorganic silts and very fine sands. This layer is situated below geotechnical unit nr. 1, and have a thickness varies from 1.4 up to 1.7 m (Fig. 4). According to unified soil classification system these soils are "ML" type.

Geotechnical unit nr. 3. This geotechnical unit consist of sandy clays soils. They are situated under the slide's plane and over the flysch fresh rocks. This geotechnical unit represents the

weathered flysch rocks. According to unified soil classification system these soils are "CL" type.

Table 1.. Physical properties of soils and rocks, Lezha landslide

Geotechcal unit	Fines(clay&silt) (%)	Sands (%)	Gravels (%)	W_L (%)
1	48.0	27.4	24.6	40.2
2	60.6	33.12	6.28	42.3
3	53.4	40.6	5.0	31.4

Table 2. Physical properties of soils and rocks, Lezha landslide

Geotechcal unit	W_p (%)	W_n (gr/cm^3)	γ (gr/cm^3)	γ_o (gr/cm^3)
1	23.3	32.1	1.85	2.66
2	25.9	38.4	1.72	2.69
3	20.8	20.4	1.99	2.68

Table 3. Physical properties of soils and rocks, Lezha landslide

Geotechcal unit	c (kg/cm^2)	φ (o)
1	0.1	30
2	0.05	8
3	0.57	26

It must be emphases the laboratories results indicate that the soils nature of the geotechnical unit nr. 3, which are the weathered flysch rocks included in "CL" type- sandy clays soils with low-medium geotechnical properties.

2.4.2 *Kruja landslide*

In the studied area of Kruja fro field works and laboratories test are determine:

Geotechnical unit nr. 1. The soils of this geotechnical unit built the landslide body soils. They consist of inorganic silty clays with sands content and have a thickness range from 7.0-10.0 up to 14.0-16.0m (Fig. 5). According to unified soil classification system these soils are "CL" type.

Geotechnical unit nr. 2. It's built the slide's plane. These soils are made of silty clays with sands content with sands, and situated below geotechnical unit nr. 1, having a thickness varies from 1.1 up to 1.9 m (Fig. 5). According to unified soil classification system these soils are "CL" type.

Geotechnical unit nr. 3. Represents the weathered flysch rocks. It's consist of inorganic sandy clays soils. They are situated under the slide's plane and over the flysch fresh rocks. According to unified soil classification system these soils are "ML" type.

Geotechnical unit nr. 4. It's represents by soft rocks – combination of claystones with siltstones layers, grey color and is found below the layer geotechnical unit nr. 4 (Fig. 5).

Table 4. Physical properties of soils and rocks, Kruja landslide

Geotechcal unit	Fines(clay&silt) (%)	Sands (%)	Gravels (%)	W_L (%)
1	60.2	39.0	0.8	41.4
2	65.6	34.4	-	40.3
3	58.9	41.1	-	38.6
4	-	-	-	-

Table 5. Physical properties of soils and rocks, Kruja landslide

Geotechcal unit	W_p (%)	W_n (gr/cm^3)	γ (gr/cm^3)	γ_o (gr/cm^3)
1	23.6	34.5	1.84	2.69
2	22.6	37.7	1.70	2.70
3	24.1	22.1	1.98	2.69
4	-	-	2.2-2.5	2.53

Table 6. Physical properties of soils and rocks, Kruja landslide

Geotechcal unit	c (kg/cm^2)	φ (o)	σ_{sec} (kg/cm^2)	σ_{an} (kg/cm^2)
1	0.1	16	-	
2	0.05	7	-	
3	0.60	24	-	
4	-	-	$4.6x10^3$	13.4-36.1

γ - bulk density, γ_o - specific density, W_n - moisture content, W_L - liquid limit, W_p - plastic limit, c – cohesion, φ – inner friction angle, σ_{sec} - secant module Young uniaxial, σ_{an} - compressive strength of rocks

It needs to mention the laboratories analyses shown that the soils condition of the geotechnical unit nr. 3 of the Kruja landslide are the weathered flysch rocks and related to unified soil classification system they are "CL" type- sandy clays soils with low-medium geotechnical properties. It means that these soils contribute on the new mass movement development. To protect from these phenomena in the studied area of Lezha town are used several engineering measures as retaining structures as concrete walls and piles, whereas in Kruja town are applied retaining concrete walls.

3 CONCLUSIONS

Weathering and decomposition of the flysch rocks from tectonics phenomenon produces conditions conducive to mass movement.

The cooperation of tectonics phenomena with several geo-factors such as lithology, slope morphology, rainfall, manmade construction activities and underground water have caused of the mass movement, which have demolished respectively 8 homes and 14 homes (1-2 stores) in Lezha and Kruja town, as well as injured of the main roads and gardens.

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