

BÖLGESEL TEKTONİĞİN HEYELANLARDA ÖNEMİ VE JEO-MÜHENDİSLİK ÖZELLİKLERİNE ETKİSİ: MEMLİK MAHALLESİ, KUZEY ANKARA

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ÖZ

En yaygın görülen jeolojik afetlerden olan heyelan, mühendislik yapılarını ve çevreyi olumsuz etkilemektedir. Özellikle yapılaşmanın planlanması aşamasında, heyelan oluşum mekanizmalarını belirlemeye yönelik detaylı jeolojik ve jeoteknik incelemenin yapılması ekonomik ve/veya hayati kayıpların önlenmesinde önemli rol oynamaktadır. Bu çalışmada, Ankara ili kuzeybatısında bulunan Memlik mahallesine ulaşımı sağlayan ana yolun doğusundaki Neojen yaşlı zeminlerde gelişen heyelanın mühendislik jeolojisi incelenmiştir. Heyelan aynası ile kabarma bölgesi arasında yapılaşma 1990-2000 yılları arasında başlamış ve günümüze kadar yeni yapılar eklenmiştir. Yapıların bulunduğu alandaki tali yol ile yol dolgusunda çökmeler ve doğuya doğru hareketler gözlenmiştir. Heyelanın yaklaşık boyutları belirlenerek, kayma düzleminde alınan örneklerin sınıflamaları yapılmış, ayrıca doygun şartlarda makaslama dayanımı parametreleri incelenmiştir. Geriye dönük analizler ile limit denge koşulunu sağlayan artık kohezyon ve içsel sürtünme açısı belirlenmiştir. Heyelanın çökme bölgesinde birçok farklı boyutlarda su sızıntıları ve göller oluşmuştur. Heyelanda en yüksek eğim 13° olup, heyelan sonsuz yamaç modeline uygun şekilde yayılmıştır. Kahverenkli yamaç molozu gri-yeşil killer üzerinde yamaca paralel olarak hareket etmiştir. Arazide gri-yeşil killer ve yamaç molozu düzensiz şekilde kaymış olup, dairesel veya karışık türde hareket belirten bir görünüm yoktur. Efektif gerilmenin sıfır olduğu yenilme düzleminin konumu sonlu elemanlar yöntemi (FEM) ile belirlenmiştir. Ayrıca, yenilme düzleminin konumunun belirlenmesinde hacimsel makaslama deformasyonu ve gerilme faktörü değişiminden yararlanılmıştır. Heyelanın, kontrolsüz yapılaşma ve kazılar yanında tektonik olarak bölgenin aktif yükselmesi nedeniyle gelişen düşey hareketlerle ilişkili olduğu düşünülmektedir.

Anahtar Kelimeler: Heyelan, Mühendislik Jeolojisi, FEM, Tektonizma, Memlik

SIGNIFICANCE OF REGIONAL TECTONICS ON LANDSLIDES AND THEIR GEO- ENGINEERING PROPERTIES: MEMLIK DISTRICT, NORTHERN ANKARA

ABSTRACT

Landslide is one of the most common natural hazards with significant unfavorable effect on structures and environment. Detailed geological and geotechnical investigations are the back bone of preventing possible economic loss of property and life, especially during residential planning stage. This study covers the engineering geological investigation of the landslide, which took place in Neogene aged soils nearby the main road to Memlik district in Ankara. The south section of main accumulation zone of the slide has been excavated and several structures have been constructed up to date. Shallow slides and recent damage on the road to the resident area indicate the movement is in east direction. The

dimensions of the slide were determined with sampling from the sliding surface. The classification of the samples was conducted with the testing of saturated shear strength parameters. Residual cohesion and internal friction were extracted from back analyses, which satisfied the limit equilibrium. Several ponds and water leaking points were encountered within the depletion zone of the landslide. The maximum slope is 13°, regarding to the infinite slope model. Brownish slope debris material slides on the grey-green colored clays parallel to the slope. The grey-green colored clay and slope debris exhibit an irregular sliding surface with no distinct circular or non-circular shape. The failure surface where effective stress is zero was evaluated by finite element method (FEM). Moreover, the location of the sliding surface was determined by the shear deformation and strength factor variation. One of the main reasons of the landslides might be the tectonically active vertical uplifting in addition to the unrestrained urbanization and excavations.

Keywords: Landslide, Engineering geology, FEM, Tectonics, Memlik

1 INTRODUCTION

Landslides cause significant damage to environment and property which are the most common natural hazards. The basic definition of the landslides is movement of geological material on an inclined plane [1]. Other definitions of the term “landslide (also cited as landslide)” has been extensively discussed [2]. Main triggering agents of landslides are excess rainfall and earthquakes [3] and also the unplanned residential activities [4]. The 21% of the damage in residential areas was landslide related between 1950 and 2008 [5]. The damage in Ankara capital was 18% with a total of 2400 buildings which suffered damage from landslides. This percent is the 3% of total building count within the capital boundaries [5]. The aim of this study was to investigate the engineering geological characteristics of the landslide happened nearby Memlik district of northwestern Ankara. The geological map of the area was prepared with particular concern in the tectonic features. The aerial photo of the area revealed that the landslide has existed before 1980, however the recent buildings were constructed by the early 1990's. Between 1980 and 2018, a road cut has been projected in the accumulation zone of the existing slide. Such constructions have triggered the slide to re-activate based on recent field observations.

2 GEOLOGY AND GEOMORPHOLOGY

The north-northwestern part of Ankara residential area is within an uplift region, bounded by Kazan on the west and Çubuk plain on the east (Figure 1). Several lithological units of Triassic-Quaternary exist within this area [6, 7, 8, 9]. Upper Triassic meta-sandstone, Lower Jurassic conglomerate, Cretaceous ophiolitic mélange, Neogene sandstone, claystone, extremely altered sandstone and Quaternary

undifferentiated alluvium are the main units around the landslide based on recent geological mapping (Figure 2). Quaternary faults are thrust/reverse and normal. The earthquakes with magnitudes between 3.0 and 4.4 indicate the activity of such faults (Figure 1, 2). The study area is located within the uplift area bounded by Kazan Fault [10] on the east and blind thrusts [11] in Çubuk plain on the west; which is an evidence of a NW-SE trending regional compression up to date [12, 13]. This active uplift should be one of the reasons of landslides and normal faults in the study area and northern vicinity. Kazan and Çubuk plains are lower than 1000 m altitude, while Kazan plain is lower than that of Çubuk plain. The study area is located between 1000 m and 1500 m (Figure 1b). Folds and faults which indicate varying tectonic stages between Upper Triassic and Quaternary [7] around the study area, which has been classified as “flat top mountain” in terms of geomorphology [14].

The landslide, as outlined in this study is located on the footwall of the normal fault which bounds the Upper Cretaceous ophiolitic mélange and Neogene aged units. It has occurred in the weakly cemented sedimentary units. Several landslide ponds and irregular topography reveal the existence of such slide.

3 MATERIALS AND METHODS

The dimensions of the landslide were determined by in-situ inspections and satellite imagery. Geotechnical data were compiled from previous boreholes and geotechnical investigations. Sampling was performed for shear box tests and determination of index soil properties. The sliding surface of the landslide was determined based on 2D finite element modelling. Back analyses under static conditions were performed to attain the shear strength parameters.

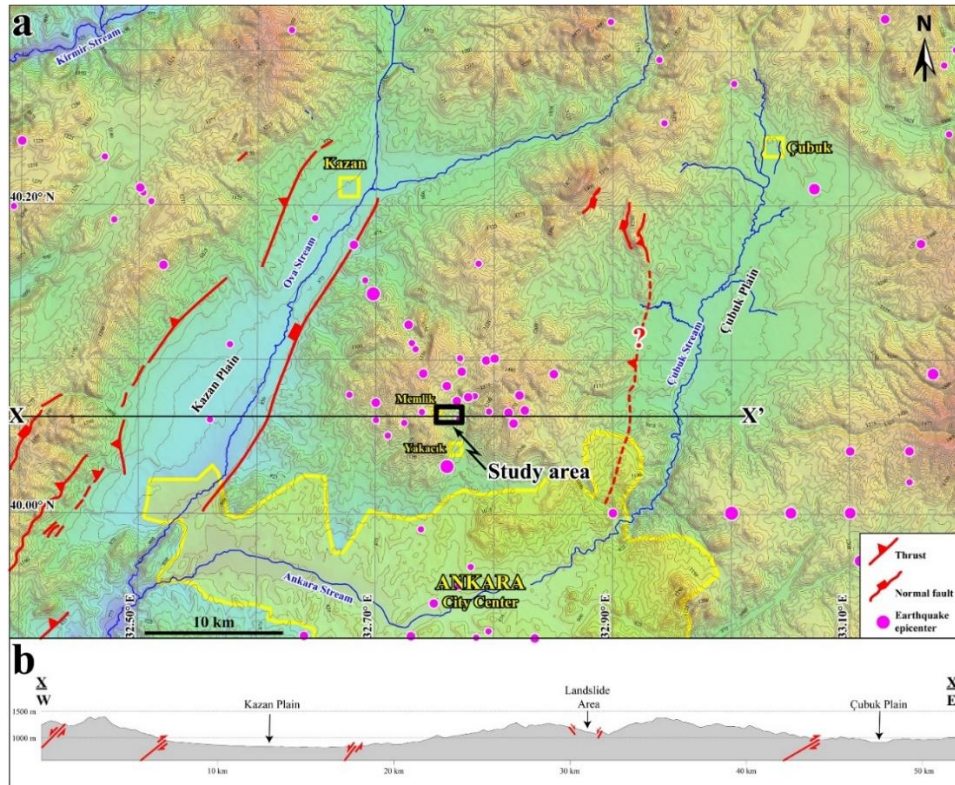


Figure 1 - (a) Main neotectonic structures (red lines) [10, 11, 14]. Epicenters of the earthquakes ($3.0 < M < 4.4$, compiled from Bogazici University KOERI catalogues). (b) Cross section along X-X' (topography is exaggerated 3 times)

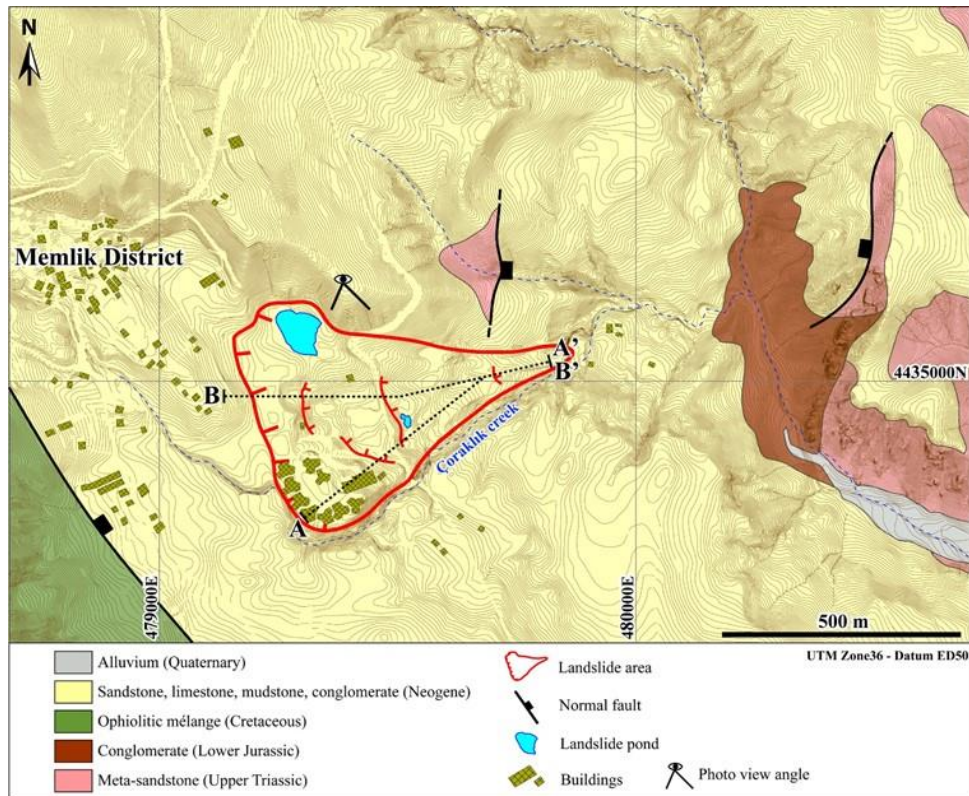


Figure 2 - Geological map of the study area and the location of the landslide

The natural water content, particle size distribution and Atterberg limits of the disturbed greenish grey colored clayey soils were determined (Table 1) using the relevant standards [15]. The unit weight and saturation degree of the undisturbed samples were also determined.

Table 1 - Index properties and classification of green clay

	ω_n %	Sieve		Atterberg Limits			USCS
		+4, %	200, %	LL, %	PL, %	PI, %	
E1	46.00	2.10	80.20	101.04	18.91	82.13	CH
E2	51.50	0.37	96.44	108.81	21.23	87.59	CH
E3	53.70	1.13	94.80	100.46	24.95	80.50	CH
E4	35.05	0.26	76.92	74.50	20.03	54.49	CH

The grey clays, forming the sliding surface are “highly plastic” and “normal” [16]. Natural unit weight Degree of saturation ranged between 78% and 86%.

The normally consolidated grey clayey soils are the residual sections of the tuff. Based on the plasticity index and fine percent, grey clays have “very high expansion” and experience swelling. Due, the consolidated and undrained (CU) shear box tests were performed on undisturbed samples. Peak and residual cohesion and internal friction angle values (Table 2) represent the post-failure conditions. Consolidation of the samples were recorded in order to calculate the shearing rate as outlined by [17]. The time to reach the 50% consolidation (t_{50}) was determined under normal applied stress. This time interval should be multiplied by 50 ($t_r=50 \times t_{50}$) to obtain the total time to failure in minutes. The shearing rate is the ratio of the estimated total shear deformation to t_r . Based on this standard procedure, shearing rate was applied as 0.025 mm/min. Such results were determined to compare to the results which were determined from back analyses.

Table 2 - Shear strength parameters of green-grey clays

	Peak		Residual	
	c_p (kPa)	ϕ_p (°)	c_r (kPa)	ϕ_r (°)
E1	37.2	7.4	16.9	3.8
E2	24.5	11.0	10.9	5.4
E3	10	10.2	9.6	5.7

4 ENGINEERING GEOLOGY

The term “landslide” has been denoted as the movement of a mass of rock, debris or earth down a slope [18]. Several other definition and terminology about the landslides exist. Moreover, types and relevant terminology about the slides in rock and soils were extensively reported [19, 20, 21]. The slope stability of London clays were performed the by state of the art studies [23, 24]. The limit equilibrium method and ordinary method of slices [25] was developed through new case studies [26, 27, 28, 29, 30, 31, 32]. The infinite slope stability analyses of saturated and partially saturated soils with respect to geotechnical parameters, ground water level and infiltration was also reported [33, 34, 35, 36].

This study aimed to investigate the dimensions and mechanism of the landslide, occurred in the weakly cemented sedimentary units deposited during the Neogene. The brownish debris, including gravelly sand has slid over highly plastic grey-green colored clays. The landslide is bounded by a fault controlled steep hill on the north and Çoraklık creek on the south. Length of the landslide is 600 m, while the width is 300 m. The sliding surface of the landslide does not represent a circular or planar failure. Several ponds and leakage points were determined in the depletion zone. The accumulation zone of the landslide is completely deformed with some secondary slides and cracks in varying directions. The slope of the landslide ranged between 6°-13°. The main geological and natural causes of the landslide are the regional tectonics, carving of the toe by Çoraklık creek and the shallow groundwater level. The aerial photo of the area indicates that the landslide exists back in 1983. The temporal change of the area is investigated by comparing the aerial photo and the recent satellite imagery served by the Google Earth (Figure 3). It is observed that, residential development began after early 1990's. In addition to the geological causes, new constructions on the top of the slope and additional loading of excavated and uncompact soils are main triggering factors for the reactivation of the landslide (Figure 4). Several tension cracks were also observed during the field studies which are 10 to 17 m in length with 60 to 70 cm depth. The crown of the slope at northern section of the slide could be determined with a depth of nearly 2 m.

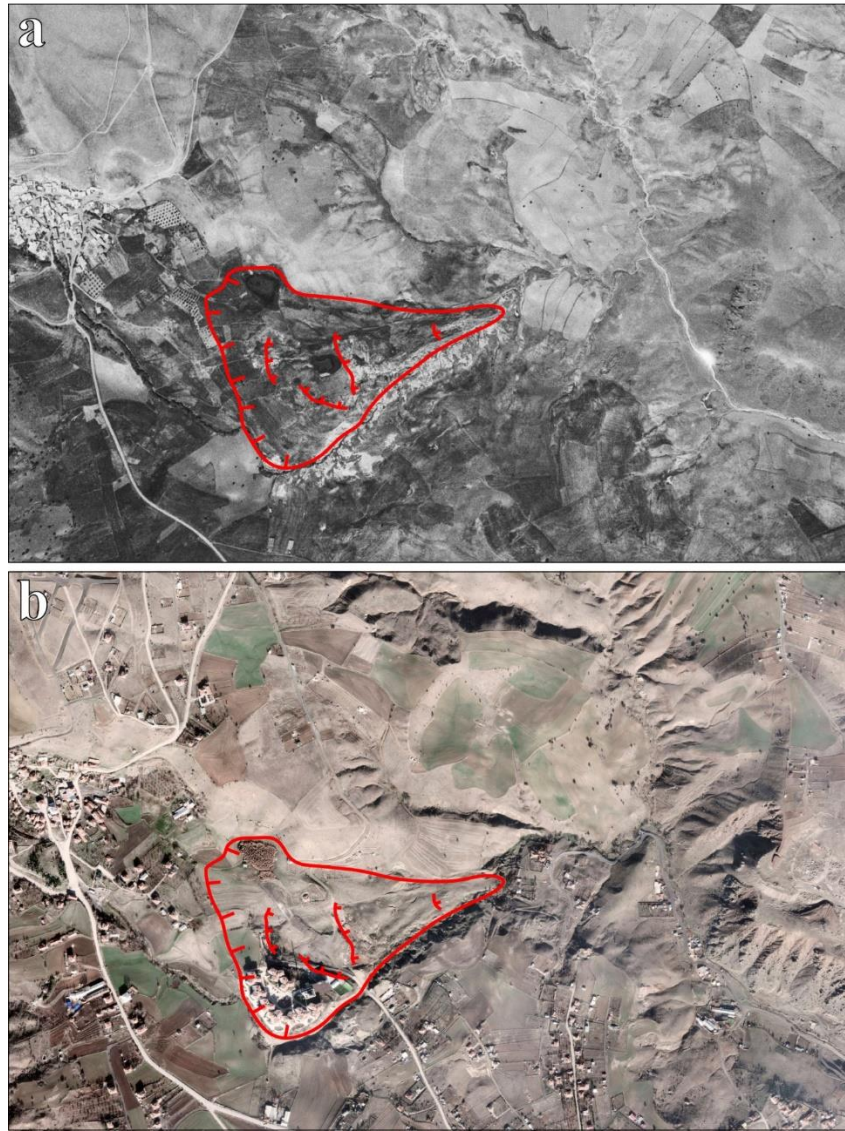


Figure 3 - (a) The aerial photo on 1983 and (b) recent Google Earth image. Red lines represent the landslide area



Figure 4 - A view of the landslide (Please refer to Figure 2 for photo direction).

5 SLOPE STABILITY

The main crown is located in nearly NW-SE direction, bounded by the Çoraklık creek to the south. After 1990's the sliding has been triggered and secondary crown is located on the road which links the buildings to the main road (Figure 5). A concrete wall has been constructed on the secondary slide crown. However, the landslide has caused relative movement of the wall and a minor tilt in downslope direction. The road also experiences displacements. Such local deformations on the man-made structures are the indicators of residual shear parameters which dominate the secondary slides [36, 37]. Back analyses was performed in order to

determine the drained peak and residual cohesion and internal friction angle, which provided limit equilibrium. The relation between the shear strength parameters are represented (Figure 6). Residual effective cohesion was 12.2 kPa and residual internal friction angle was 1° . Moreover, the shear strain distribution and strength factor distribution along the slope were determined by FEM, taking the mean groundwater level into account (Figure 7a, b). Maximum volumetric strain deformation and strength factor in tension indicate the locations where deformations in concrete wall deformation and sanitary fill exist. It was not possible to detect the possible deformations in the buildings or the residential area.

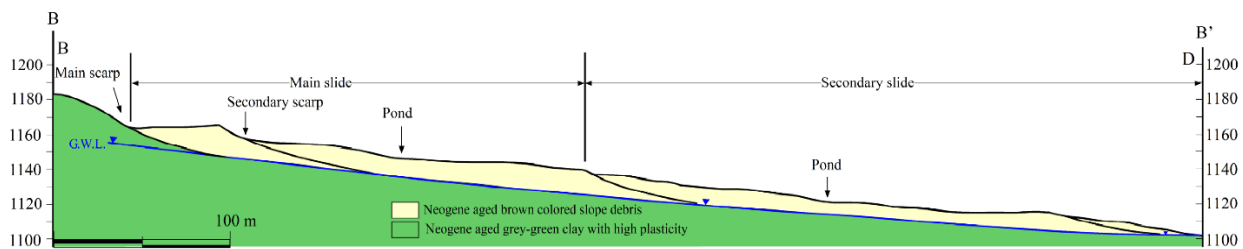


Figure 5 - Engineering geological cross-section of the landslide

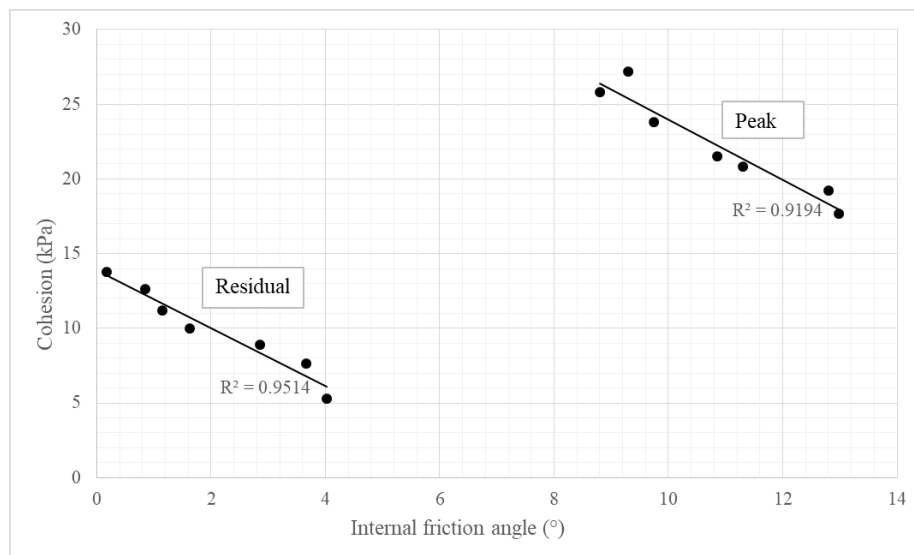


Figure 6 - Results of back analyses

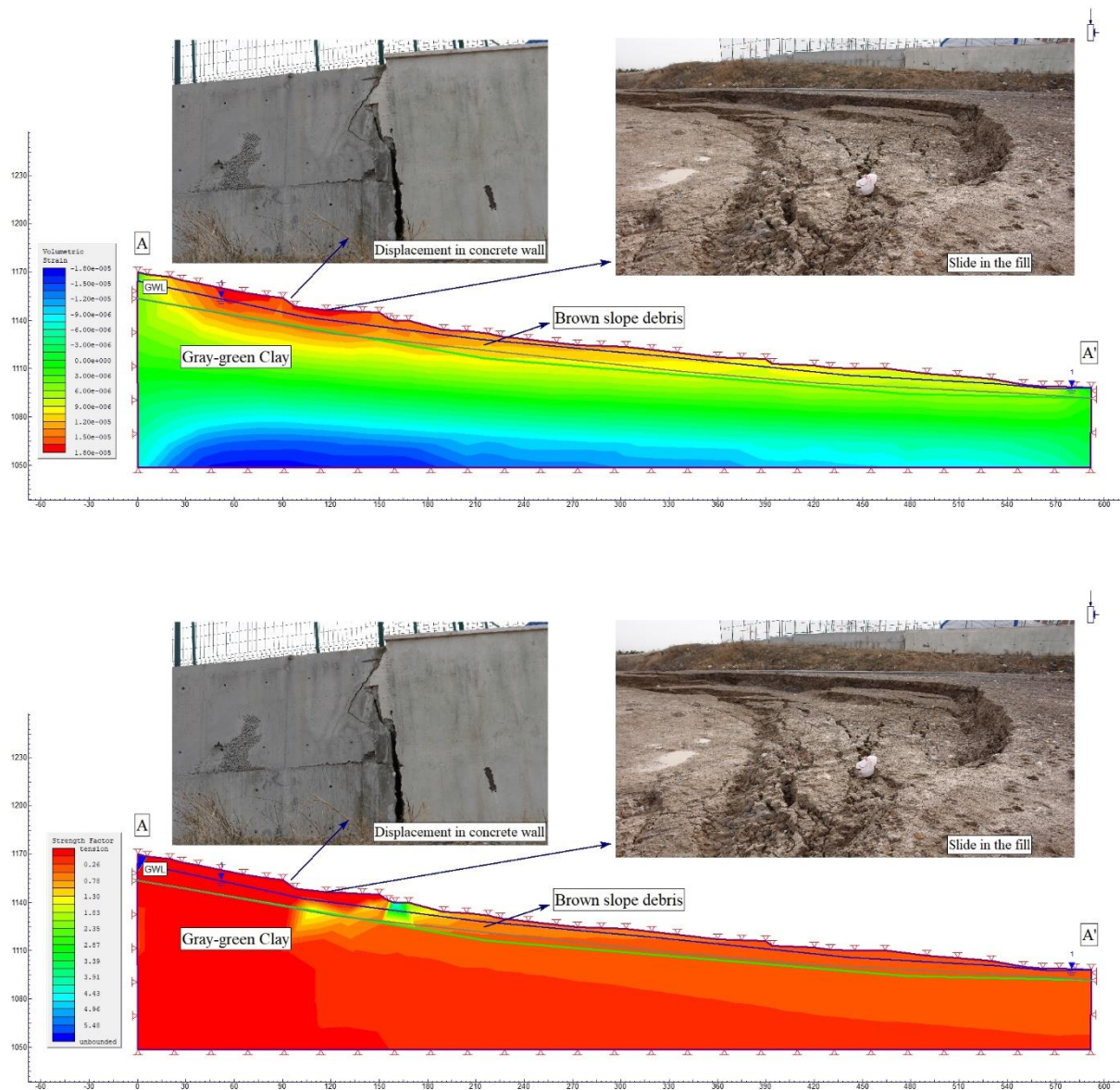


Figure 7 - (a) Volumetric strain and (b) strength factor in tension along the sliding area. Please refer to Figure 2 for cross section location

6 RESULTS AND DISCUSSION

The study area and proximity are located in a tectonically uplifted region. Neogene units have a normal fault boundary with the ophiolitic mélange rocks. The landslide is considered to have taken place nearby this contact.

Brown colored slope debris slides over the green-grey colored clay which are the main alteration products of volcanic sedimentary bedrock. Several buildings exist on the main scarp of the slide. A distinct displacement of 15 cm was detected on the concrete wall parallel to the sliding. Moreover, the uncompact fill material and the asphalt road are still repaired due to the cracks caused by the sliding. Another road

construction has been cancelled nearby the separation zone of the slide.

Back analyses were performed in order to determine the effective peak and residual shear strength parameters of the green-grey colored clay under static conditions. A detailed site specific deterministic seismic hazard analyses should be done, since there were some earthquakes recorded nearby the study area. Several pond and water leakage points were determined. The variation of groundwater level was investigated by statistical analyses. The shallowest level is parallel to the surface with a depth between 0.5-0.8 m. The deepest level should be the contact between the gray colored

clay and slope debris. The mean groundwater level was determined in order to run the detailed analyses by FEM.

Based on the FEM analyses, the variation of volumetric strain and strength factor (tension) along the sliding area were determined. The maximum volumetric strain and maximum tension are in accordance with the locations where deformations have taken place.

The main causes of the slide are, carving of the toe by Çoraklık creek and recent buildings located on the main scarp. The waste water from the buildings are not drained by a drainage system. Due, a detailed geotechnical investigation should be planned immediately, including boreholes and inclinometer readings.

This study covered a single landslide, which occurred in Neogene clastics in close proximity of a normal fault between ophiolitic mélangé and Neogene. The whole area is prone to several types of mass movements in other geological units. The contact between Neogene and ophiolitic mélangé is a section of the NW trending normal fault. This fault is a predominant structure within the close vicinity of Memlik village. However, details of such fault is not included in this study since the landslides have occurred in varying geological units with some different mechanisms.

There are radial and transverse cracks in the depletion and accumulation zone with varying directions and dimensions. Moreover, the toe of the slide is completely deformed. The sliding area should be monitored with drones periodically in order to detect the sliding vectors and the movements. The buildings should be carefully monitored with drones to outline the possible movements.

A detailed remediation project should be planned and performed, including environmental aspects. The residential buildings are still in use and also there is a primary school. After monitoring the slide area at least two rainy seasons, relevant project should be applied immediately in order to prevent loss of life and property.

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