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Causes of Bursa Yıldırım district Mollaarap landslide and its improvement studies

Bursa Yıldırım İlçesi Mollaarap heyelanının nedenleri ve iyileştirme çalışmaları

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Abstract

The slopes at the north of Uludağ, where there is an unplanned and dense settlement, have landslide potential in terms of engineering geology. In this study, the causes of the landslide occurring as a result of the uncontrolled excavation carried out on the slope with landslide potential and the improvement or control studies were investigated. With the disturbance of the slope stability, settling and deformations on the upper part of the slope increased, and then 8 decares of area was affected by the flow and sliding mass movements on the slope, and approximately 80 houses in this section were evacuated for safety purposes. As a result of the researches and investigations made in the landslide field, an engineering geology model is revealed Geotechnical properties of geological units and the depth of slip surface were determined by the field and laboratory studies. Prevention and support projects are prepared according to geotechnical properties. As a first measure within the scope of the project, the construction of the support structure consisting of double rows of bored piles in the toe cut was then controlled by the production of a three levelled support structure. This study is a typical example where uncontrolled excavations without consideration of engineering geology and geotechnical conditions cause serious costs and other grievances.

Keywords: Landslide, Uncontrolled excavations, Landslide control methods.

Öz

Uludağ yükseliminin kuzey eteğindeki yüksek eğimli, plansız ve yoğun yapılaşmanın olduğu yamaçlar mühendislik jeolojisi açısından heyelan potansiyeli taşımaktadır. Bu çalışmada heyelan potansiyeli taşıyan yamaçta gerçekleştirilen kontrolsüz kazı sonucunda gelişen heyelanın oluşum nedenleri ve iyileştirme veya kontrol çalışmaları araştırılmıştır. Yamaç dengesini bozulmasıyla yaklaşık 10 günlük süreçte öncelikle şevin üst kesiminde oturma ve deformasyonlar artmış daha sonra yamaçta gerçekleşen akma ve kayma türü kütle hareketinden 8 dönümlük alan etkilenmiş ve bu kesimdeki yaklaşık 80 ev güvenlik amacıyla boşaltılmıştır. Heyelan sahasında yapılan araştırma ve incelemeler sonucunda mühendislik jeolojisi modeli ortaya konulmuştur. Arazi ve laboratuvar çalışmaları ile kayma yüzeyi, temel ve örtü birimlerin jeoteknik özellikleri saptanmıştır. Bu özeliklere göre önlem ve destek projeleri hazırlanmıştır. Proje kapsamında ilk önlem olarak topuk kesimde çift sıra şaşırtmalı fore kazıklardan oluşan destek yapısının imalatı, daha sonra 3 kademe destek yapısı imalatı ile heyelan kontrol altına alınmıştır. Mühendislik jeolojisi ve jeoteknik koşullar dikkate alınmadan yapılan kontrolsüz kazıların ciddi maliyet ve diğer mağduriyetlere neden olmaktadır. Bu vaka bu tür mağduriyetlere tipik bir örnek teşkil etmektedir.

Anahtar kelimeler: Heyelan, Kontrolsüz kazılar, Heyelan önlem yöntemleri.

1 Introduction

The rapidly increasing population in the cities with historical and cultural accumulation and the new residential areas needed due to this population increase are the most prevalent factors that disrupt the demographic structure of those cities. Requirements for defense and agriculture necessitated the establishment of such cities on plains, valley plains and the slopes surrounding these plains. This geomorphological structure and geological conditions that influence geomorphology are the main factors that control the further growth of the city. When the seismicity and hydrogeological conditions of the region are combined with the previously mentioned factors, natural risks increase even more in new settlements. Similar examples are encountered in many ancient significant cities of the world. The city of Naples is a typical example of such cases. Although the morphology regulates the settlement of the city, the increasing demand for residential areas has often caused illegal urban settlements and thus caused high landslide risks on high, inclined and unstable slopes. These uncontrolled settlements and technical initiatives in the region have caused different types of landslides and to combat these, strict rules have been put in place in city planning and selection of residential areas (Martire et al. 2012) [1]. The 2.6 km long historical wall, one of the inherited heritage sites in the Volterra (Central Italy) settlement, has suffered a significant amount of structural damage due to the disrupted slope stability that is caused by both the geological conditions and technical operation for facilitating uncontrolled settlement (Teresa et al. 2016) [2]. Bandara and Jayasingha (2018) [3] state that in Sri Lanka, which is one of the rapidly growing cities, there is a linear relationship between the increase in the urban population and the increase in the number of landslides. In the said region, the settlement strategies are regulated by NBRO (National Building Research Organization) since 1994.

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It is possible to present more of these examples. There are similar landslide risks due to geomorphological and geological conditions in many historical cities such as Bursa, Amasya, Afyon and İzmir in our country. These risks are encountered in the new settlements located on the slopes needed to accommodate the rapidly increasing population in these cities. This study is a case study that points out uncontrolled excavation, without considering engineering geology and geotechnical conditions, cause significant damage and serious costs. Within the scope of the study, the engineering geology model of the landslide area was defined, geotechnical parameters were determined and stability analyzes were made in different conditions. In line with the data obtained from the stabilized analysis, support and improvement projects were prepared and implemented. In this article, the studies and findings obtained since February 2018 are presented.

2 Study area and geological setting

The landslide area is located on the slope facing the north-northeast direction, with an average topographic slope of about 40% on the northern skirt of the Uludağ uplift, south of Bursa (Figure 1). The bedrock of the slope consists of metamorphic rocks of the Uludağ massif. There are 10 to 15-meter slope debris and slope deposits on this base unit. This cover unit, which consists of loosely attached, clayey and silty gravel-block size material, is generally derived from base rocks, slightly rounded and ~~was~~ moved from a short distance. These cover deposits, called colluvial deposits, were moved down the slope with the effect of gravity and reached a steady state on the slope in the recent geological period. However, being located on the slope that has a 40-45% inclination, under the control of climatic conditions and natural dynamic effects, these sediments have potential as cover materials for slide and flow type mass movements.

Figure 1. Location of the landslide area.

The base rocks consisting of metavolcanite, metatuffit, metaserpentinite and metamudstone lithologies in the study area and its surroundings, and the weathering products of these units constitute the cover units in the form of deposit cone and slope rubble (Kenar et al. 2013) [4]. These foliated lithologies, such as schist and phyllite, which offer the ability to change their physical properties with the effects of surface water and groundwater, are other factors for slide and/or flow. In the geological sequence, groundwater circulation in the carbonated rocks consisting of marble and recrystallized limestone and tectonic contacts forming the contact of these carbonated units and schists and phyllites (Streak Faults, Emre et al. 2011) [5] are other natural factors that increase the landslide potential in the region. The region has reached or is in the process of reaching its natural stability in accordance with geomorphological and geological factors. However, this slope with landslide potential can be transformed into an area with potential and active mass movements with uncontrolled technical operation.

Uncontrolled excavations, uncontrolled fillings and uncontrolled technical operations that would change the load balance on the slope will degrade the area's stability and cause mass movements in all of the critical balance slopes in the region. As a matter of fact, the excavations that were carried out in the study area that were uncontrolled and/or conducted without considering the geological and geomorphological factors that were previously defined caused the landslide by disrupting the slope stability. The landslide occurred after uncontrolled excavation on the slope that slopes 70-75 degrees to the north between Gürgür Street and Hüsamettin Tekke Street (Figure 2). Thus, firstly, a north-northeast oriented movement took place along the excavation slope, and subsequently, secondary fractures and settlements that progressed up to +340,00 to +345,00 m elevations occurred in the section that also includes Hüsamettin Tekke street. Sliding or moving material thickness ranges from 3.00 to 5.00 meters. After the initial movement, backfilling was attempted to pile up the bottom of the slope, but this attempt, which was considered as a measure, was not successful.

Figure 2. The view of the landslide field on Google Earth image.

The mass movement continued approximately for 10 days with an average of 10.00 cm/day vertical and 5.00 cm/day horizontal velocity. During this period, seating and deformation on Hüsamettin Tekke Street increased, houses to the east of the excavation site were damaged, 84 households in this section were evacuated for security purposes. After the uncontrolled excavation, an area of approximately 8 decares shown in Figure 3 was affected by the landslide.

Figure 3. Landslide affected area.

3 Research methods

Initially, in order to take the landslide under control and apply the necessary support system or improvement methods, the geological sequence of the slope was identified and secondly, boring investigations were carried out in order to determine the engineering geology model. Boring was carried out at 3 points, in the crown of the landslide area (29 m), in the middle part of the landslide area (31 m) and in the toe part of the landslide area (40 m). In drillings, soil profile and foundation rock depths were determined by taking continuous core samples. Laboratory tests have been carried out on the samples taken from the drillings to determine the engineering geology and geotechnical properties of the geological units. With the help of these data, the engineering geology model of the landslide area has been defined and engineering geology-geotechnical profiles have been prepared.

Periodic measurements were made by placing inclinometer pipes in 3 boreholes in order to determine the landslide sliding surface and to determine the sliding speed (Figure 4). After the reference reading, the measurements were continued for the next 2 months with 7-day intervals, then for the next 4 months with 15-day intervals, and until January-2019 at 30-day intervals.

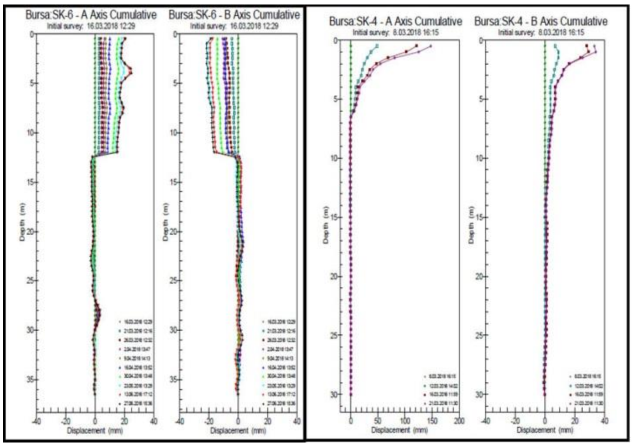

Figure 4. Inclinometer measurement records.

The engineering geology profile was correlated with the deformation records obtained after the first 4 measurements, to determine the main sliding surface, the sliding speed, and secondary sliding surfaces. The sliding surface depth was 12 meters at the crown, 16 meters at the middle and 18 meters at the toe. By taking into account the geotechnical design parameters that were determined by the results of the laboratory experiments and units of the engineering geology model and main sliding surface derived via the inclinometer readings. The V2018 version of the Geo5-Slope Stability computer software was used in the slope stability analysis. As a result of the slope analysis made for non-earthquake and earthquake situations, the current unstable conditions are also revealed in the analysis results. Safety coefficients are very low, especially in the event of an earthquake. In other words, in case of an expected earthquake for the region, the risk of landslides increases even more (Figure 5).

The bored piled and anchored support system has been proposed as the improvement method to reinforce against the landslide or ensure slope stability. In line with this prediction, 4 rows of piles and 3 belts of anchors at the top row were designed and stability analyzes were carried out under this condition. As a result of the slope analysis for this situation, stability conditions were reached in both earthquake and no-earthquake states (Figure 6).

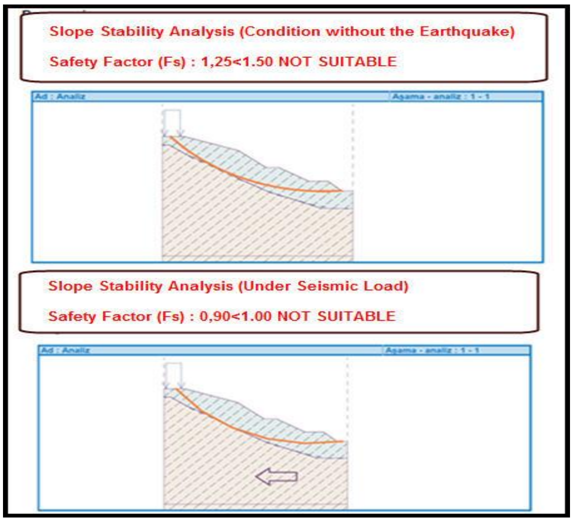

Figure 5. Slope stability analyses result for the current state.

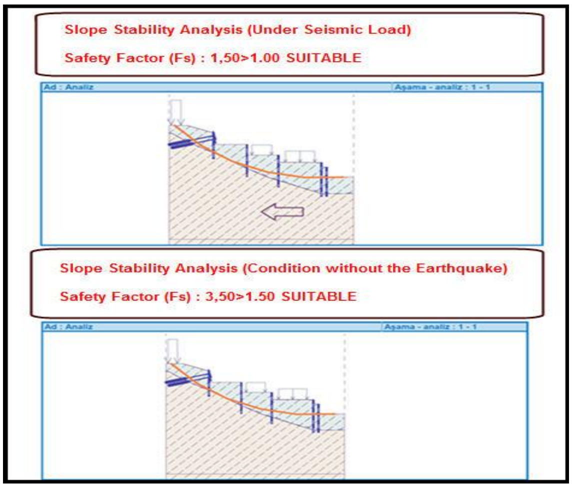

Figure 6. Slope stability analyses after the bored piled and anchored support system.

The application project for the bored pile and anchored support system, which provides the stability condition as a result of the analysis, has been prepared. In the project, pile diameters, pile lengths, pile placement, and anchorage lengths were determined according to the engineering geology model and the geotechnical design parameters of the geotechnical units. All with the data, the loads that will be carried by the support systems were calculated and pile reinforcement and anchorage tension loads were defined accordingly. In this context, detailed project solutions were prepared. A general model of the project is presented in Figure 7.

Support applications and slope arrangements within the scope of the project were carried out in stages from the toe to the crown. In parallel with the improvement studies, a stationary trend was observed by the inclinometers. Within the scope of the improvement works carried out, a total of 290 piles and 314 meters long head beam were manufactured in 4 different rows in the study area. In order to reach Hüsamettin Tekke street elevation (+346.00 meters) on the top row head beam, a curtain wall of 5.00 meters high and 67.00 meters long was built. The structure behind this wall for drainage, backfill, anchoring and barbican outlet is an ongoing effort. The current state of the pile-supported walls and the location of the platforms behind these support structures are presented in Figure 8.

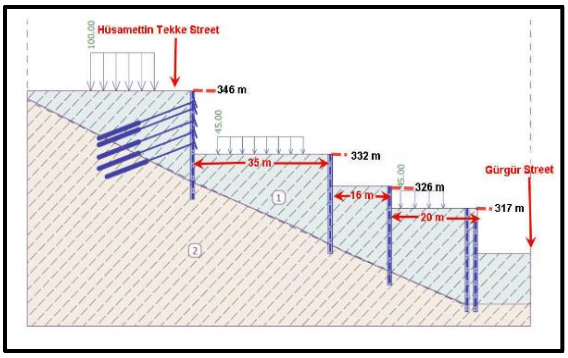

Figure 7. A general model of the support project.

Figure 8. View of the applied support system.

The support structures secured the landslide on the slope. Stability in inclinometer readings and geodetic measurements indicates that the stability conditions are met in the landslide area.

4 Conclusion

The landslide incident experienced in the Yıldırım district of Bursa province is a typical example in terms of uncontrolled excavations made without taking into account the engineering geology and geotechnical conditions, causing serious costs and other problems. Unfortunately, similar uncontrolled initiatives are increasing their presence in our country. In this type of excavation, besides the stability of the excavation slope, the stability conditions of the entire slope should be taken into consideration and analyzes should be made in a holistic manner. The flow regimes of the surface and subsurface waters that vary according to the seasonal changes, the vibrations that will occur after the possible earthquake and other important and possible factors that will activate the potential risks on the slope should be evaluated. Drainage systems should be designed.

It is an inevitable necessity to evaluate the stability of the slope wholly and to handle the load and excavation balance within this integrity. If this is not taken into account, the risk of encountering stability problems in different sections of the slope will increase. This may also adversely affect the support system created by the improvement works carried out within the scope of project. As a matter of fact, the excavation in the construction of the school in the toe part of the slope, just west of this study area, disrupted the stability of the slope. Similar ruptures and damages to the structures in this part were observed. For this reason, 45 residences in this region have been evacuated in line with AFAD (Disaster and Emergency Management Organization) officials' suggestions for life safety due to possible risks.

As in this negative example, any excavation and technical intervention to be carried out on such slopes, where the settlement is dense and has a potential landslide risk, primarily affects the stability of the slope and causes local disruptions. However, it is possible that such movements can affect the integrity of the entire slope. Therefore, the stability of the entire slope should be taken into consideration in all local excavations and other technical constructions on the slope and stability analyzes should be evaluated in an integral manner. Excavation and excavation slope analysis on the basis of parcels should not be considered as sufficient, it should be taken into consideration that such local initiatives will affect the slope stability completely and change the load distribution of the entire slope and cause sliding and landslide-like movements. As a result, controlled technical operation should be made in landslide sensitive areas, building load, structure density and layout planning should be evaluated in line with this view.

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