LANDSLIDE INVESTIGATION IN KESBAYER AREA IN NORTH EAST IRAN

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ABSTRACT: Due to the geographical location, geology, geomorphology, and climate, Kesba yer area undergoes mainly a special natural disaster related to landslides. In this paper an attempt has been made to present the findings of a study that has investigated the Doreghanlu landslide. A number of exploratory borings with the maximum dept of 30 m were sunk and undisturbed and disturbed soils were sampled and tested in this research. Considering the results of bore holes, it was found that the slip surface would be deeper than 15 m below ground level. The shear strength parameters from test results have been performed to analyze the landslide movement. The stability analyses were carried out using the modified Bishop method of slices.

RÉSUMÉ: En raison de l'endroit géographique, de la géologie, de la géomorphologie, et du climat, région de Kesbayer subit principalement un désastre naturel spécial lié aux landslides. En cet article une tentative a été faite de présenter les résultats d'une étude qui a étudié l'landslide de Doreghanlu. Un certain nombre de borings exploratoires avec la profondeur maximum de 30 m étaient descendus et des sols calmes et dérangés ont été prélevés et examinés dans cette recherche. Vu les résultats des trous d'alésage, on l'a constaté que la surface de glissade serait plus profonde que le niveau souterrain de 15 m. Les paramètres de résistance au cisaillement des résultats d'essai ont été exécutés pour analyser le mouvement d'landslide. Les analyses de stabilité ont été effectuées en utilisant la méthode modifiée Bishop de tranches.

INTRODUCTION

Landslides often occur at specific area under certain topographic and geologic conditions. In recent years, the population growth and the expansion of settlements over hazardous areas have increased in Kesbayer area in northeast of Iran. Landslides form major natural hazards in hilly train in this area, and caused extensive damages to roads, human dwellings, agricultural lands and forests.

Landslides occur on sloping terrain in all kinds of soil, soil-rock and rock materials. A slide, especially in soil, defined as downward and outward movements of a portion of the soil masses. The movement is in response to gravity, generally the weight of the slope material that decreases the stability of the slope. The Kesbayer area needs to be kept under constant observation even if it is at rest for the moment. In all cases, water is present at the slip surface. The pore water pressure is the main cause for the slides. Landslides mostly set in during or after heavy rainfall or during melting of snow. It is obvious that this sudden inflow of such large quantities of water strongly increased pore water pressure. This paper summarizes the findings of a study that has investigated the Dorghanlu landslide. A number of exploratory borings with the maximum dept of 30 *m* were sunk to explore subsoil conditions and to investigate the causes for the landslide. Undisturbed and disturbed soils were sampled and tested in this research. The shear strength parameters from test results were used to analyze the landslide movement.

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GEOLOGY

Interaction between local geology and long term climatic conditions will result different landforms with varying degree of susceptibility to land sliding. Fooks et al., (1985) have most illustrated the interrelation between wide range of landforms produced and the slope stability problems encountered, and diversity of topography, geology and climate in a mountainous region. It is necessary to understand the topographic characteristics of the site slopes and the regional geology and geological structures of the area.
The Kopet-Dogh basin in northeast Iran is about 600 km long and about 200 km wide. It was established after mid Triassic orogenic movements, when the Iran and Turan plates had apparently joined (Berberian and King, 1981). From mid Jurassic, a widespread Mesozoic epicontinental sea invaded the basin. No important orogenic movements took place after early Jurassic until the area was folded late in the Alpine Orogeny along southeast to northwest lines. Through Kopet-Dogh basin some formations such as Kashafrud, Chamanbid, Shurijeh, Sarcheshmeh, Abderaz, Abtalkh and Pestehleigh, with special lithology, have great effect on the occurrence of Landslides (Ghafoori, 1998).
The study area is located to the northwest of Bojnord between latitude 37 and 39 N and longitudes 57 and 58 E. The general sratigraphy of the Kopet-Dogh basin in this area comprises 3 different formations of lower Cretaceous age (Afshar Harb ,1970, Kalantari,1987). The Doreghanlu village situated in an area underlain by the Sarcheshmeh Formation. The Sarcheshmeh Formation consists of a sequence of gray marls and pencil-shales with subordinate Orbitolina-bearing limestone intercalation, developed as a conformable cover of the limestone of the Tirgan Formation throughout the Kopet Dagh Ranges. The black shale of the Sanganeh Formation overlies the Sarcheshmeh Formation. The thickness of the sarcheshmeh formation increases from some 100 m in the southeaster most Kopet Dagh to more than 500 m in the central Kopet Dagh.

DESCRIPTION OF THE SLOPE MATERIALS

The residual soils at Doreghanlu village was formed by the in-situ weathering of the marl and shale of the Sarsheshmeh Formation. An accumulation of this sort gradually thickens as a layer that covers and conceals the remaining bedrock. Chemical weathering is the dominant process in developing of a weathering profile on these rocks. Residual soil profiles retain many of the physical features of the solid rocks over which they form the regolith. The bedding planes in the sedimentary rocks such as shale will persist in the residual soils along which the present slip is most probably occurring. More commonly the regolith is found to be layered in three zones. The upper zone contains highly weathered and leached residual soils usually reworked by biological agencies. The intermediate zone contains less highly weathered residual soils often exhibiting the relict structures. The lower zone contains disintegrated and little altered materials merging into the original parent rocks. Fine materials leaching from the upper zone are deposited somewhere near the intersection of the upper and intermediate zones forming a sort of barrier to water percolation. During rainy spells, the saturated top zone becomes very heavy, the thin leached zone becomes soapy, shear strengths being very low due to pore water pressures, lead to the landslide.

Of greatest relevance to the unstable slope is the profile of residual soil that has developed due to the chemical weathering of the marl and shale of the Sarcheshmeh Formation in Kesbayer area. The most important chemical process in this area is the production of clay minerals. Clays are the weakest and most unstable slope materials. Undisturbed clays can stand in steep temporary slopes due to the cohesion, pore water suction and peak frictional strength. The likely distribution of these deposits is shown in Figure 1. Referring to Figure 1, in particular the steep slope having large potential energy with large slope angle. The hill slopes at Kesbayer are found to be in a continuous state of readjustment. In this area some old landslides also were reactivated by the development activities involving blocking of natural drainage ways, loading the head of the slide by building house on them and cutting of the toes especially by water flow. Figure 2 shows the old and recent landslides in this area.

The main body of the slide consists of two layers, an upper layer of brown clay that followed by a thick layer of dark-gray clay. The mass of soil involved in this slide is several tens of square meters demolishing the dwellings situated on this slope. At another place in the village, a slide with the visible crack has occurred. In this case the sliding is aggravated by the weight of the building. The building with developed cracks, became slightly tilted. The tree nearly originally straight becomes slant. The waters rushing to this village from higher points of the hills fill the cracks exerting more lateral pressures, eroding the soil and causing the mass to slide farther. The watercourse continuously erodes the soils at the foot of the hill and carries it through thus removing the toe support. The toe of the slope moves downward through the action of water streaming in the sub soils. In this case the best measure is to protect the toe, either by a carefully carried out rockfill or by a wall. This is a major cause of many of the slides that have occurred. The sliding is irritated by the weight of the buildings. The cracks are developed in tilted buildings. The Doreghanlu village is thus seen to be in a very bad situation with many landslides having occurred in the past. The villagers are gripped by the constant fear of a landslide anytime and anywhere.

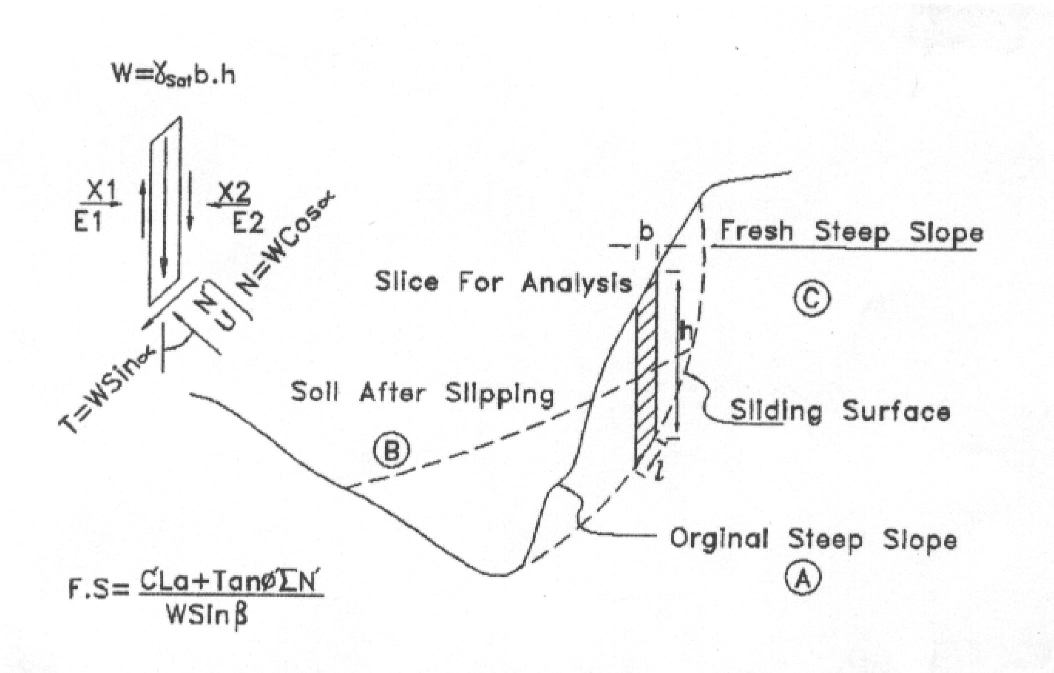

Figure 1. Possible mechanism of landslide

Figure 2. The old and recent landslides in this area.

It is noted that the slopes with grape trees are surprisingly stable. This is due to the root system of the trees binding and holding the soil together. The roots, acting as reinforcing elements, are preventing the slope from slide. In Doreghanlu village where the landslide is occurring, there are hardly any trees. Because of the lack of deep root trees, capillary tensions removed from the soil water. These results reduced stability and increased rates of creep. Also decay of trees and their roots may cause strength reduction but the weight

of trees may aid sliding. So it is necessary to take selective trees such as grape trees having possibly deep root system and relatively long life and also being light.

Leaching of the slopes by seepage may cause changes in soil chemistry affecting slope stability. Removal of materials from the toe of the slope, as in the present case, can cause a previously stable slope to become unstable.

Most natural slopes exist in an unsaturated condition and their margin of safety depends on the capillary tensions that exist in the pore water that enhance the strength of the soil. Infiltration during prolonged rainfall can reduce capillary tension to a point where the slope becomes unstable. The increase in density caused by the increased water content aids sliding.

Due to changes in soil-water regime of a slope such as partial or complete inundation, instability may occur. The waters rushing from higher levels of hills inundate the village and cause slides. Discontinuities, joint and fissures control the strength of the residual soils. Anisotropy behavior either as a result of in-situ stresses or as a result of features such as bedding planes affects the strength. The shear strength parallel to the laminations or bedding planes may be as small as 1/3 of the peak strength of a homogeneous and isotropic soils.

The new location where it proposed to shift the village on hilltop seems to be relatively stable with no slide reported during the past 2 to 3 years. The foundations of buildings, being built there, made with random masonry. This may not be an appropriate foundation type for the buildings (although the buildings are light) in view of the possibility of land movement. A rigid beam column frame with intersecting strip footing or individual footings with beam is the kind of foundation that is appropriate to this situation.

LABORATORY TEST

Six exploratory borings revealed to a depth 20 to 30 m. Many undisturbed and disturbed samples were taken from the holes at different depths. A series of laboratory tests was carried out on these samples. Apart from classification tests, unconsolidated-undrained and consolidated-drained triaxial tests were carried out to investigate the shear strength parameters. The tests were carried out with different confining pressures. The test results summarized in Table 1.

Table 1. The shear strength parameters

B. No.	UU	CD	UU	CD
	$\phi°$		c kg/cm^2	
1	29	9	0.25	0.29
2	8	13	0.48	0.36
3	21	_	1.25	_
4	27	19	0.82	0.13
5	22	11	1.08	0.23
6	26	_	0.25	_

STABILITY ANALYSIS

The slope described in this paper situated at Doreghanlu area. Figure 3 shows a typical section through part of the slope. There are numerous factors that affect slope stability analyses. In order to back analyze the slope stability, it was necessary to establish the failure plane geometry, tension cracks, soil characteristics, dynamic loading or earthquakes and water pressure of the sliding mass. The geometry of the ground surface was stabilized by a land survey. Considering the results of boreholes, it was found that the slip surface would be deeper than 12 and 30 m below ground level. The unit weight (γ) and shear strength parameters(c and ϕ) are the main soil characteristics that required for the analysis. Seed (1966,1967) for evaluating slope response to earthquakes and design procedures related to earthquakes gives suggested methods. To study the behavior of a slope, the accelerations of 0.1g and 0.15g and the average values of ϕ=16° and c=3 ton/m^2 were used to these analyses.

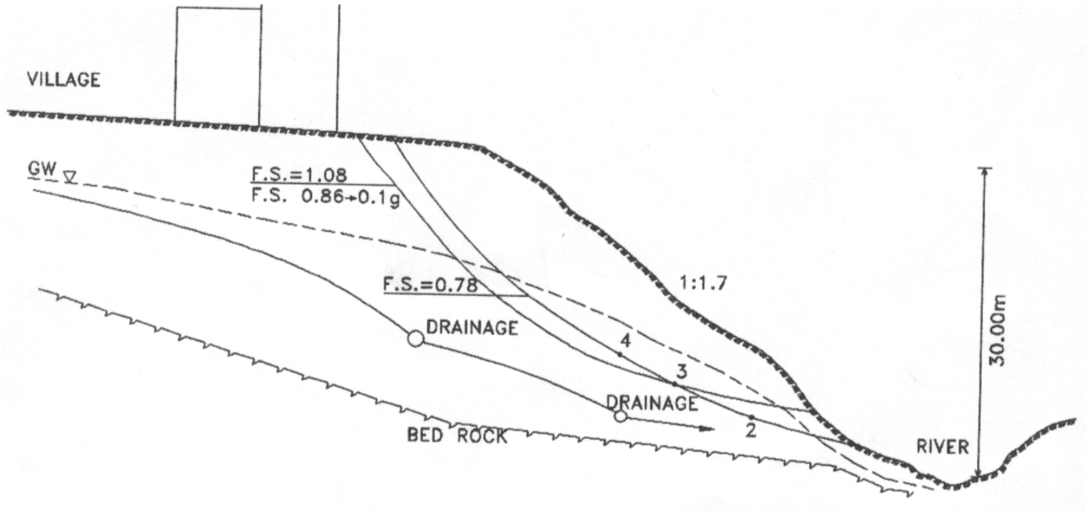

Figure 3: A typical section through part of the slope.

The stability analyses were carried out using the modified Bishop method of slices with irregular slip surfaces. These analyses were performed, using a computer program for different conditions. Two possible slip surfaces with and without drainage systems and different accelerations of earthquake were used to determine the factor of safety for slope. The complete results are presented in Table 2.

Table 2. Analysis results

Analysis No.	Condition	F. of safety
1	Without drainage	1.13
2	W. drainage and a=0.1g	0.92
3	W. drainage and a=0.15g	0.81
4	With drainage	1.3
5	With drainage and a=0.1g	1.18

The rate of change of the safety factor is evaluated by varying significant parameters in turn while keeping the values of other parameters constant. This rate of change indicates the importance of the parameters for the stability of the slope. As Table 2 and Figure 3 show, the influence of water on the safety factor is clearly evident. The safety factor changes from 1.08 to 1.3. As table 2 shows, the earthquake response on factor of safety is also evident.

In order to stop soil movements, the following stabilization measures were carried out to reduce water pressure in the soil. From exploratory borings it was found that the water-bearing layer was about 12 m below ground surface. A number of pits were excavated. A series of horizontal filter pipes and drainage pipes were made. These horizontal filters and drainage pipes were connected in shafts.

CONCLUSION

Ground conditions consisted of fill overlying residual soil derived from the underlying marl and shale bedrock. The action of water in the soil is predominantly responsible for landslides. Mass movements occurred when water levels in the slope rose above a certain value. From observations and local knowledge of the area, it was concluded that the mass movements have been taking place over many years previously and was still continuing.

The effect of changing the water table level by drainage system within the slope was investigated by calculating the factor of safety for different situations. It was found that drainage system and the acceleration of earthquake have significant effect on the factor of safety. To raise the factor of safety, the head of the slope must be drained as much as possible by surface and subsurface drainage. The slope surface must be made as impermeable as possible by filling up the largest tension cracks.

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