Landslide hazard in central Zagros region in Iran

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1. Abstract

Mass movement is considered an important land degradation event which occurs in different areas under the influence of climate, topography, soil, plant cover, geology and tectonic factors. In recent years 250 landslides in the Chahar Mahal Bakhtiari Province has occurred. The purpose of this study was to investigate some parameters that could affect landslide occurrence in the study area. Two kinds of marl formations known as Oligomiocene 1 (OM_1) and Oligmiocene 2 (OM_2) which are susceptible to landslides were chosen. After morpho-genetical description of soils and underlying regolite, samples were taken along two transects on slide cuts exposure of OM_1, OM_2. Results show that the texture of marl formations was mainly silt-loam and amount of silt increased to downwards. On the other hand the porosity in deep layers decreased which leads to reduction of matric potential and infiltration rate. Upper horizons of soils in both formations showed good infiltration rate. Mineralogical study indicated that about thirty five percent of clays in soils consist of Smectite and expanding minerals which show an increasing trend downwards. Although Smectite and expanding minerals are inherited, we can conclude that increase of those minerals on depth may occur due to water table. In addition to geological formations, active tectonic of the area and relatively high precipitation influence landslides occurrences. Human activity was also important factor in mass movement in the study area.

2. Introduction

Nowadays extensive scientific study about landslide is investigated world wide. This shows importance of this subject for researchers and governments. Baldassarre et al., (1996) investigated Basilicata landslides in Southern Italy. The results of tests on Varicolour red clays formation and landslide deposits showed that the clayey component mostly Smectite, remarkably affect the geotechnical behavior of Varicoloured clays and landslide deposits. It increases their susceptibility to water. Mohamed (2000) studied the role of clay minerals of marly soils on their stability. The results showed that formation of expansive mineral, ettringite, as a transformation product of Palygorskite increase the swelling potential of the stabilized soils.

3. Method

Location and climate of the region

Doab Samsami has an area of 275 square kilometers in the western part of Chahar Mahal and Bakhtiari province, in Kohrang town. It is located between 50 ^{O} 11´ and 50 ^{O} 26´ longitudes and 32 ^{O} 10´ and 32 ^{O} 8´latitudes. The average slope is 17 ^{O} and its altitude from the sea level is 2553 m. The dominant climate of the area is considered cold steppe, the average rain fall is 1200 mm and the average temperature is 9.5 ^{O} Celsius.

Field and lab studies

Using a topographic map with the scale of 1:50000 and a geological map with the scale of 1:250000, the areas exposed to landslides were recognized. Two kinds of marl formations known as 1 (OM_1: Conglomerates, marls and shale with intercalations of lime stones) and 2 (OM_2: Fossiliferous marly limestones with intercalations of marls and sandy limestone Eq. Upper Part of Asmari Formations) were chosen (figures 1 and 2). After morphological description of soils and underlying formations, samples were taken from four profiles in a slide cut exposure in OM_1 and also five profiles in OM_2. The samples were analyzed for physical properties in terms of texture (pipette method), infiltration rate (double ring) and porosity using Soil Survey Laboratory Methods Manual (1996). The clay mineral samples prepared according to Kittrick and Hope method (1971). The clay fraction of soil and parent rocks were treated to prepare the following oriented slides: Mg-saturated, Mg-saturated and glycerol-solvated, K-saturated, K-saturated and heated at 550 ^{O} C. These slides were scanned using an X-ray diffractometer (philips PW – 1830), Cu lamp and operated at 40 kV and 40 mA.

Figure 1 Landslide in marl formation No 1 (OM_1)

Figure 2 Landslide in marl formation No 1 (OM_2)

For semi quantitative estimates of the content of different clay minerals, the area under the peak method was used (maximum half of the width's peak multiple in intensity) Khademi et al., (1998).

4. Results

The described profiles in the marl formations show a high degree of profile development and clay and lime congestion horizons can be seen in the two marl formations. In general, it can be said that horizon C in OM_2 formation begins at a higher level. In fact, the depth of the horizons formed as a result of soil forming factors is less than OM_1. Furthermore, mottling in horizon C of OM_2 are more than that of the other which suggests the level of underground water as well as its fluctuation is more in this area. Another difference is in the abundance of gravel in OM_1 mounting to 80% in comparison to 27% in OM_2. The reason for this difference is that OM_1 contains not only marl and shale but also conglomerates which will change into gravels after destruction.

It can clearly be seen from table 1 that the soil texture in both formations has a silt loam composition. While the amount of clay decreases downwardly, silt increases.

In both formations, porosity decreases downward. Reduction in porosity and the size of holes causes water to stay between the particles and the penetration rate to decrease. Low penetration rate, water absorption and saturation increases the weight factor in sliding masses; as a result, the power created due to the soil weight makes the mass move in the slope.

Table 1 Some physical charactristics of two marl formations susceptible to landslide

texture	porosity (%)	EC dS/m	pH	Particle size: gravel (%)	Particle size: sand (%)	Particle size: (%)silt	Particle size: (%) clay	depth (cm)	horizon
Pro 2 Marl Formation NO 1 (OM_1)									
Gravely silty clay loam	37.4	0.44	7.3	18.5	12.8	50.1	37.1	0-50	A
Gravely silty clay	41.6	0.43	7.4	20	14.9	42.8	42.1	50-150	Bt
Silty loam	30.4	0.8	7.4	-	30.4	51.9	17.6	150-300	C
Pro 5 Marl Formation No 2 (OM_2)									
Silty clay loam	41.6	0.5	7.4	11.6	17	52.5	30.5	0-30	A
Silty loam	40	0.44	7.4	2	20.8	54.6	24.6	30-90	Bk_1
Gravely silty loam	34.6	0.42	7.4	27.7	19.8	61.6	18.5	90-180	Bk_2
Silty loam	18.8	0.35	7.5	-	12.3	66.5	21.1	180-350	C

As it can be seen in figure 3 cumulative infiltration in soils developed on marl formation No 1 is more than marl formation No 2. Greater cumulative infiltration in soils developed on formation No 1 is due to its depth and higher percentage of gravel. According to the measured infiltration, high annual precipitation of the region and high level of ground water table facilitate the movement of the slopes

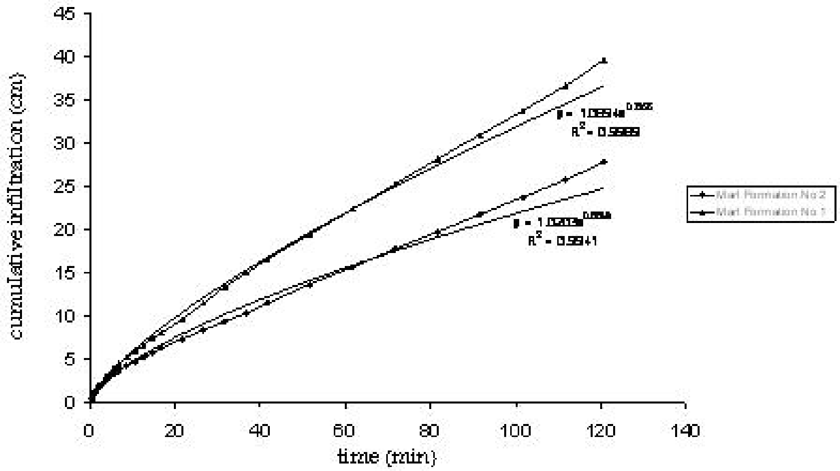

Figure 3 Cumulative infiltration changes on two marl formation's soils

In all Mg-saturated X-ray diffractograms one peak is observed around 1.41 to 1.45 nm that shift to 1.7 nm after saturation with glycerol for 24 hour. It shows the existence of Smectite. The step like changes of 1.61 to 1.73 nm of with glycerol treatment proves the existence of mixed inter layer minerals. The sharper and more clear peaks of lower layers in all profiles prove the improvement of Smectite crystallinity downwardly. Forlati et al., (1996) suggested that the presence of Smectite is a decisive factor in paving the way to sliding phenomena which are then triggered by a sudden increase in rainfall water and ensuing hydration processes.

A peak around 0.99 to 1.1 nm can be seen in all X-ray diffractograms of both marl formations and their soils in Mg-saturated treatment. There are not any changes in the thickness of crystal in K-saturated, Mg-saturated and glycerol-solvated, K-saturated and heated at 550 ^{O} C which shows existence of Mica. The intensive second order peak of Mica in 0.5 nm shows that Mica is diochtahedral (Figures 4 and 5).

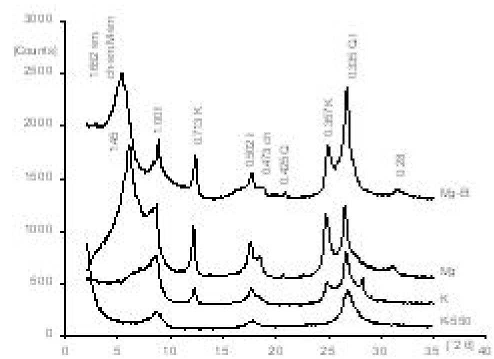

Figure 4 X-ray diffraction patterns of carbonate-free clay fractions of OM_2 Pro. 4, A horizon (0-10 cm)

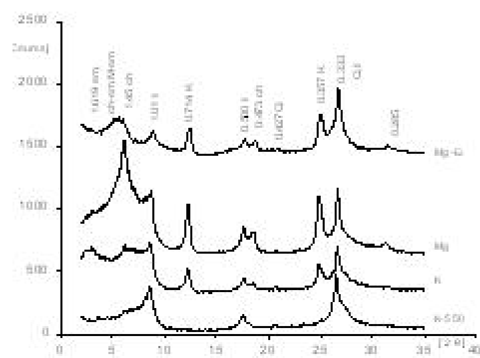

Figure 5 X-ray diffraction patterns of carbonate-free clay fraction of OM_2 Pro. 4, C horizon (400-700 cm)

The d-spacings are in nm. I, Illite; Ch, Chlorite; Sm, Smectite; K, Kaolinite; Q, Quartz; Ch-Sm, Chlorite-Smectite; M-Sm, Mica-Smectite.

The 0.72 nm peak in K-saturated samples which removed when heated to 550 ^{O} C shows the existence of Kaolinite. Also the second order peak of Kaolinite (0.35 nm) is observed.

Figure 6 High level of ground water table in marl formation No 1

Results of semi-quantitative measurements indicate that Illite and Kaolinite are the dominant clay minerals in both formations. About 35 percent of clays in soils are Smectite and expanding minerals which show an increasing trend downwardly. But for Illite and Kaolinite (table 2) it is opposite. On the whole, the existence of Kaolinite, Smectite and Illite in both formations and their soils shows that these minerals were inherited by parent materials. Increase of Illite and Kaolinite on surface shows that these two minerals exist in other geological formation which are transferred to the studied marl formations with runoff. In the other hand, receiving high rain fall on surface cause the changing of 2:1 minerals to Kaolinite. Increase of Smectite in deep layers is related to high concentration of salts, appropriate pH and alternately wet and dry processes duo to fluctuation of ground water (figure 6).

Table 2 Relative abundance of clay minerals in the carbonate-free clay fractions

Pro 2 Marl Formation No 1 (OM_1)						
Quartz	cholorite	Kaolinite	Illite	Smectite & expanding minerals	Depth (cm)	Horizon
tr	tr	xxxxx	xxxxx	xx	0-50	A
tr	tr	xxxxx	xxx	xxx	50-150	Bt
tr	tr	xx	xxx	xxxx	150-300	C
Pro 4 Marl Formation No 2 (OM_2)						
tr	tr	xxxx	xxx	xxx	0-10	A
tr	tr	xxxx	xx	xxxx	400-700	C2
xxxxx = > 40% , xxxx = 35-40 , xxx = 25-35% , xx = 15-25% , x = 5-15% , tr = trace						

5. Conclusion

In studied marl formation, fine texture, reduction in porosity in deep layers and also high precipitation cause soil saturation which leads to decrease of shear strength, increase of water pore pressure and finally provide sliding. Results of mineralogical study indicate that Illite and Kaolinite are the dominant clay minerals in both formations. About 35 percent of clays in soils are Smectite and expanding minerals which show an increasing trend downwardly. Although the amount of Smectite and other expanding minerals are not major, these minerals have high weight when absorb water and reduce the consistency rate of the slope. It is not possible to conclude that slides in these formations occurred only due to characteristics related to geologic formations. Landslides are complex phenomena and a many interrelated factors influence their occurrence. In addition to geological formations, the study area has active tectonics and relatively high precipitation which may influence landslides occurrences. Human activity is also considered one of the most important factors in mass movement in the study area. The obtained information indicates that caution should be used wherever this type of material is encountered during heavy construction. Wherever possible, deep cuts in to material of this type should be avoided.

6. References

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