International Journal of Natural and Engineering Sciences 5 (3): 49-51, 2011
ISSN: 1307-1149, E-ISSN: 2146-0086, www.nobel.gen.tr

Assessment of Soil Stability and Rupture in Forest Roads

Sepideh NAZARI[1] Seyed Ataollah HOSSEINI[2] Majid LOTFALIAN[2] Mohammad Reza POURMAJIDIAN[2]

[1] Department of Forestry, Faculty of Natural Resources, Mazandaran University, Sari, IRAN

[2] Department of Forestry, Faculty of Natural Resources, Sari Agricultural Sciences and Natural Resources University, Sari, IRAN

***Corresponding Author**

e-mail: Ata_hosseiny2002@yahoo.com

Received: July 23, 2011
Accepted: August 01, 2011

Abstract

This research presents the characteristics of soil stability and rupture in forest road of Sbilarg forest ecosystem. Three segments of road including landslide, consolidated and control areas were selected for stability analysis. Six samples were collected from each area and the Plastic Limit (PL), Liquid Limit (LL), Shrinkage Limit (SL) and their indices as well as soil moisture, texture and direct shear were determined at soil mechanics laboratory. Results indicated that the soil texture in both areas was sandy clay. According to direct shear test for landslide area, the safety factor against mass movement was less than 1 which indicates that this area is unstable. For consolidated area the safety factor was equal to 1 which indicates that this area is stable.

KeyWords: Soil stability . Atterberg limits . Safety factor . Road . Sbilarg forest

INTRODUCTION

Forest roads planning and building is an expensive part of the harvesting project of Hyrcanian forests. Therefore, various choices of road network should be evaluated and the least costly one with highest technical efficiency should be selected [5]. Road constructions without according to environmental aspects lead to mass wasting or landslide. Hillside rupture is created by gravity performance of earth on the mass of materials, which can slowly crawl, freely downfall, and slip along the rupture surface slide or course such as slush. Thus, recognizing positive and negative points and analysis the geological factors for road bed such as stability stone and bedrock type, sill, gradient of beneath layers, probability of mass wasting, land slide and subside of beneath layers are the main factors in network planning of forest roads. Nowadays the GIS techniques have been suggested to design the optimal forest road density based on environmental factors [10]. In this method the best area is selected to plan forest roads with effective factors such as geological maps, maps of soil, slope, direction of slope, and bedrock and trees volume per hectare. The influence of moisture content and density of the fill and the change over time of the material on slope stability and settlement has to be evaluated [4]. Dennehy [1] indicated that for most cohesive soils, except those of low plasticity, which are placed at undrained shear strengths of between 40kN/m^2 and 60kN/m^2 no problems, neither self settlement nor slope stability of embankments placed on hard foundation arose. The safety factor is low and if with surface and depth draining, groundwater surface was sent to lower depth, the safety factor is became more than allowable minimum.

Slope stability depends on the equilibrium between the driving and restoring forces that act on a potentially unstable soil mass. The driving forces acting on slope material, including gravity, result in a shear stress that must be counteracted by the available shear strength. This concept forms the basis of the safety factor, which is the ratio of the maximum available shear strength over the shear stress [6]. The prediction of stability involves many uncertainties and the computed safety factor represents only an estimate based on the engineer's best choice of input for the computations [7 and 8].

The material properties of soils are very variable and are determined by the constituents and control hill slope stability, landslide potential, and ground shaking potential during earthquakes [3]. Atterberg limits are used to derive indices, e.g., index of plasticity and index on consistency, and obtain the basic index information about the soil used to estimate its strength and settlement characteristics [9]. The main objective of this research was to analyze the soil stability and rupture in a forest road of Hyrcanian ecosystem.

MATERIAL AND METHOD

Site Description

Sbilarg forest with an area of 1921 hectare is located in watershed number 51 in Mazandaran province, Iran. The latitude, longitude and elevation ranges of this forest are 36° 16′ 30″ to 36° 20′ 30″ N, 52° 14′ 40″ to 52° 17′ 30″ E and 400-1950 meter at sea level, respectively. The forest site has three types of soil consisting of brown soil, washed brown soil and calsimorf. The soil depth is 70-100 cm. The bed rock is calcareous sandstone and limestone. The general aspect of the hillside is east and its average slope is 30%. The main woody species in Sbilarg are Carpinus betulus, Alnus glutinosa L. Ulmus glabra Huds, Acer velutinum Boiss, Parottia persica. The overstory and understory canopy cover percentage are 70% and 50% respectively. The climate is moist with average temperature ranging from 29.2˚C in August to 1.9 ˚C in February. Mean annual air temperature is 15.7 ˚C. The region receives 827.4 mm of precipitation annually. The growing season lasts 240 days from April to November.

Data Collection

Segments of road in compartments of 19 and 20, which landslides had occurred on steep slopes were selected for this research. The landslides area in compartment of 19 has been consolidated thorough drainage culverts. A control area was selected near the landslide and consolidated area. In order to investigate the mechanical properties of soil, six samples were collected. The Plastic Limit (PL), Liquid Limit (LL), Shrinkage Limit (SL) and their indices as well as soil moisture, texture and direct shear for each sample were determined using the drop cone penetrometer method at the Soil Mechanics Laboratory.

The shrinkage limit (SL) is the water content where further loss of moisture will not result in any more volume reduction. The test to determine the shrinkage limit is ASTM International D4943. The plastic limit (PL) is the water content where soil transitions between brittle and plastic behavior. A thread of soil is at its plastic limit when it begins to crumble when rolled to a diameter of 3 mm. The liquid limit (LL) is the water content at which a soil changes from plastic to liquid behavior. The original liquid limit test is mixing a pat of clay in a round-bottomed porcelain bowl of 10-12cm diameter.

RESULTS AND DISCUSSION

Results showed that the liquid index in landslide area was more than that in consolidated and control areas, while inverse ratio was observed for plastic index(Table 1). Forest covers generally help to protect the land against mass movements partly through the cohesive effect of the tree roots. Soil strength is increased by the adhesion of soil particles to the roots. Rapid establishment of a grass or legume cover is essential on embankment and cut slopes to minimize surface erosion and enhance slope stability [8]. Results indicated that the soil texture in both areas was sandy clay (Table 2).

According to direct shear test for landslide area, the safety factor against mass movement was less than (1) which indicates that this area is unstable. Due to the unsuitability of the soil drainage flow, soil shear resistance to its shear stress has decreased and mass movement has been created in this area. For consolidated area the safety factor was equal to 1, which indicates that this area is stable (Table 3). Indeed drainage operation of soil in consolidated area caused to increase shear

Table 1. Mechanical characteristics of soil in study area

Sample	Depth (cm)	Plastic limit (%)	Liquid limit (%)	Shrinkage limit (%)	Plastic Index	Liquid Index	Moisture (%)
Landslide	20-30	11	29	29	18	1.43	36.97
	70-80	13	32	30	19	1.29	37.60
Consolidated	20-30	13	38	27	24	0.64	29.19
	70-80	15	39	27.45	25	0.66	29.17
Control	20-30	12.8	36	26	23.2	0.62	27.38
	90-100	13	38	26.3	25	0.64	27.23

Table 2. The texture of soil samples in the study area

Sample	Depth (cm)	Coarse elements (%)	Fine elements (%)	Soil texture
Landslide	20-30	46	54	SC
	70-80	48	52	SC
Consolidated	20-30	49.3	50.7	SC
	70-80	51.6	48.4	SC
Control	20-30	67.06	32.94	CL
	90-100	68.8	31.2	CL

Table 3. Summary of direct shear test for landslide, control and consolidated area

Shear strength parameters		Shear strength (t)	Vertical stress (P)	Shear stress at fraction time (F/A)	Safety factor (FS)
Q Degree (°)	C (Kg cm^{-2})				
26	0.18	0.30	0.30	0.35	0.85
		0.42	0.60	0.45	0.93
		0.54	0.90	0.56	0.96
29	0.19	0.34	0.30	0.34	1
		0.49	0.60	0.49	1
		0.64	0.90	0.64	1
31	0.21	0.39	0.30	0.38	1.02
		0.57	0.60	0.56	1.01
		0.75	0.90	0.74	1.01

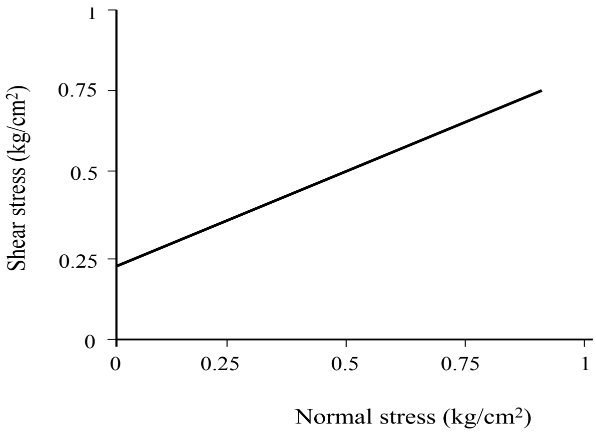

Fig.1. Rupture for control area

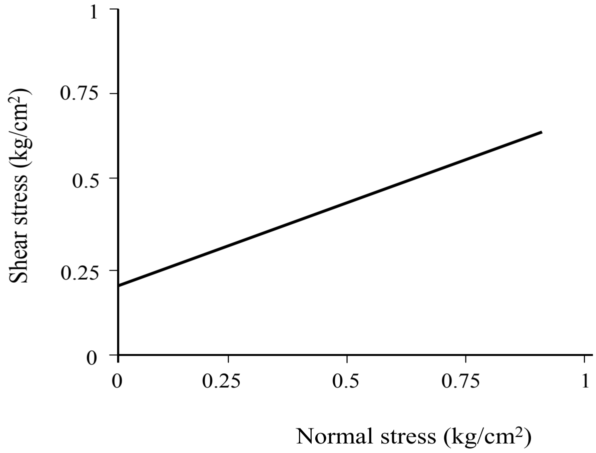

Fig.2. Rupture for consolidated area

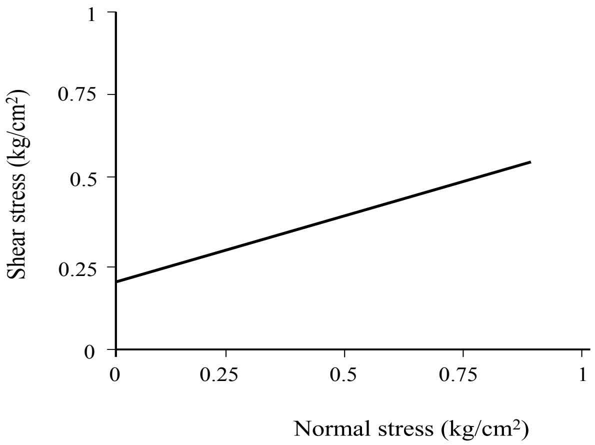

Fig.3. Rupture for landslide area

resistance against shear stress and consequently the safety factor increased (Fig. 1, 2 and 3). It was proved that the construction and maintenance cost of forest road in stable area is less than that of unstable areas [2, 3 and 6].

Landslides occur when a large amount of rock, earth, or debris move down a hill. Landslides may be very small or very large, and can move at slow to very high speeds. The Atterberg Limits define the ranges in moisture content that a soil will behave as a solid, plastic and liquid. Zung (2008) showed that certain soil characteristics may be useful tools for assessing landslide frequency in forest lands.

Examination of local cuts can provide valuable information about cut slope stability. Often, small slope failures can be symptoms of larger slope stability issues. Forest management practices may alter both physical and biological slope properties that influence slope stability and the occurrence of landslides. Most physical alterations are the result of roads, skid trails, and landings [2].

CONCLUSIONS

In this study, the soil texture in both areas was sandy clay. According to direct shear test for landslide area, the safety factor against mass movement was less than 1 which indicates that this area is unstable. For consolidated area the safety factor was equal to 1 which indicates that this area is stable. In drainage basins of the northern part of Iran, acombination of natural and human factors have caused numerous landslide-related damages. One of the main strategies for restricting the damage caused by the activity of landslides is to avoid these regions. To accomplish this, landslide hazard zonation map of the area should be prepared.

REFERENCES

[1] Dennehy JP. 1978. The Remoulded Undrained Shear Strength of Cohesive Soils and Its Influence on the Suitability of Embankment Fill, Clay Fills, Institution of Civil Engineers, London, pp. 87-94.

[2] Dutton AL, Loague K, Wemple BC. 2005. Simulated effect of a forest road on near-surface hydrologic response and slope stability. Earth Surf. Proc. Land. 30: 325–338.

[3] Kusky T. 2008. Landslides, Mass Wasting, Soil, and Mineral Hazards. Library of Congress Cataloging-in-Publication Data. 145 p.

[4] Limsiri C. 2008. Very Soft Organic Clay Applied for Road Embankment: Modelling and Optimization Approach. Published by Taylor & Francis. ISBN 978-0-415-38487-2. 153 p.

[5] Majnounian B, Abdi E, Darvishsefat AA. 2007. Planning and technical evaluating of forest road networks from accessibility point of view using GIS. Journal of the Iranian Natural Res., 60(3): 907-919.

[6] Norris JE, Stokes A, Mickovski SB, Cammeraat E, van Beek R, Nicoll BC, Achim A. 2008. Slope Stability and Erosion Control: Ecotechnological Solutions. Published by Springer, ISBN 978-1-4020-6675-7 (HB), 290 p.

[7] Morgan RP, Rickson RJ. 1995. Slope stabilization and erosion control: A bioengineering approach. Published by E & FN Spon, an imprint of Chapman & Hall, 2–6 Boundary Row, London SE1 8HN, UK. ISBN 0 419 15630 5 (Print Edition), 306 p.

[8] Morgan RPC. 2005. Soil erosion and conservation, Third edition. Black well Publishing, National Soil Resources Institute,Cranfield University.304 pp.

[9] Poršinsky T, Sraka M, Stankić I. 2006. Comparison of two approaches to soil strength classifications. Croatian Journal of Forest Engineering, 27(1): 17-26.

[10] Sessions J. 2007. Forest road operations in the Tropics. ISBN-10 3-540-46392-5 Springer-Verlag Berlin Heidelberg New York. 170 p.