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RESEARCH ARTICLE

Characteristic of soil with seasonal change and their effects on slope stability

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The slope stability affected by wetting and drying of the soil is investigated in Zuangtui Local Council Area, Aizawl, and the study was performed by determining soil mechanical properties for two cycles of wetting and drying. Engineering properties of soil like liquid limit, plastic limit, plasticity index, liquidity index, consistency index, and shear strength are used for comparing the behaviour of soil. Samples were collected during the dry season from two locations (L1 and L2). The second sampling was done during the wet season after completing two wet-dry cycles. Slope stability analysis of the investigated area was carried out to compare the Factor of Safety in two complete cycles. Based on the analysis, the parameters of Atterberg's limit except for the liquidity index decrease during the wet season after completing the cycle in both locations. Cohesion and angle of internal friction reduce in the wet season. The Factor of Safety is below unity in both locations during the wet season and above unity in the dry season.

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Introduction

Mizoram is a sedimentary terrain where rock beds are covered by soil in most of the area. A landslide triggered by rainfall is the most common disaster occurred in Aizawl, the capital of Mizoram. It is common, especially in those areas with a steep slope, incoherent soil with fined grained and residual soil.[1] More than 50% of Aizawl is under a slope angle of more than 20 degrees which could greatly contribute to slope instability. Besides the slope angle, the behaviour of the soil under wetting-drying conditions could be one of the main triggering factors of the landslide as the ground movement mostly occurred during the middle and end of monsoon season.[2] When weathered soil in highly steep terrain is exposed under hot and dry conditions for a prolonged period followed by heavy rainfall, slope stability is highly reduced due to a decrease in the strength of the soil.[3] This paper aims in understanding the mechanical properties of soil under wet-dry conditions, especially in hilly terrain. This paper presents the changes in the behaviour of the soil in determining slope stability under two cycles of wet and dry seasons. The study was carried out in Zuangtui local council area where ground movement has been experienced since 1987. Recently, a ground movement of 30.48cm was observed (Fig.1) during September 2022 which is relatively stable during the dry season.

Materials and Methods

Samples collection

The undisturbed soil samples were collected by using a core sampler during the dry season from two locations of the sliding zone. After the two cycles of wet-dry season, sampling was done

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Figure 1: Field photographs of ground displacement at Zuangtui Area

during the wet season from the same two locations (Fig.2). The samples were kept in a sample bag so that soil moisture is not lost before testing in the laboratory. The geometry of the slope and slope angle was recorded for slope stability analysis using Limit Equilibrium Method (LEM).

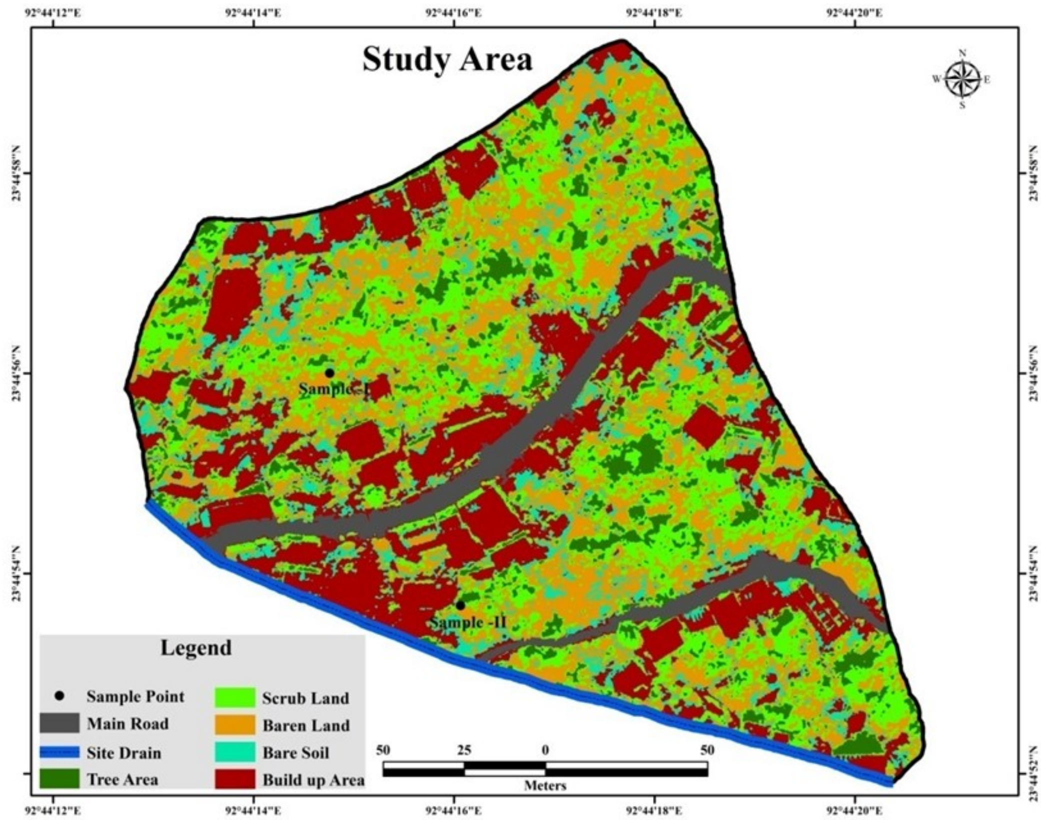

Figure 2: Map of the study Area

Laboratory Methods

Atterberg's limit test was carried out to find out the natural moisture content, plastic limit, liquid limit, liquidity index, plasticity index, and consistency index of the soil.[4,5,6] The natural moisture content of the soil was calculated by drying the samples in an oven at a temperature of (110 ± 5) for 24 hrs. The weight of the sample with the container before and after was recorded to determine the natural moisture content of the soil. The soil sample passing through 425 microns IS sieve size was used for liquid limit test.[7]

The Casagrande apparatus was used for the determination of liquid limit[7]. The moisture content and the number of revolutions were used

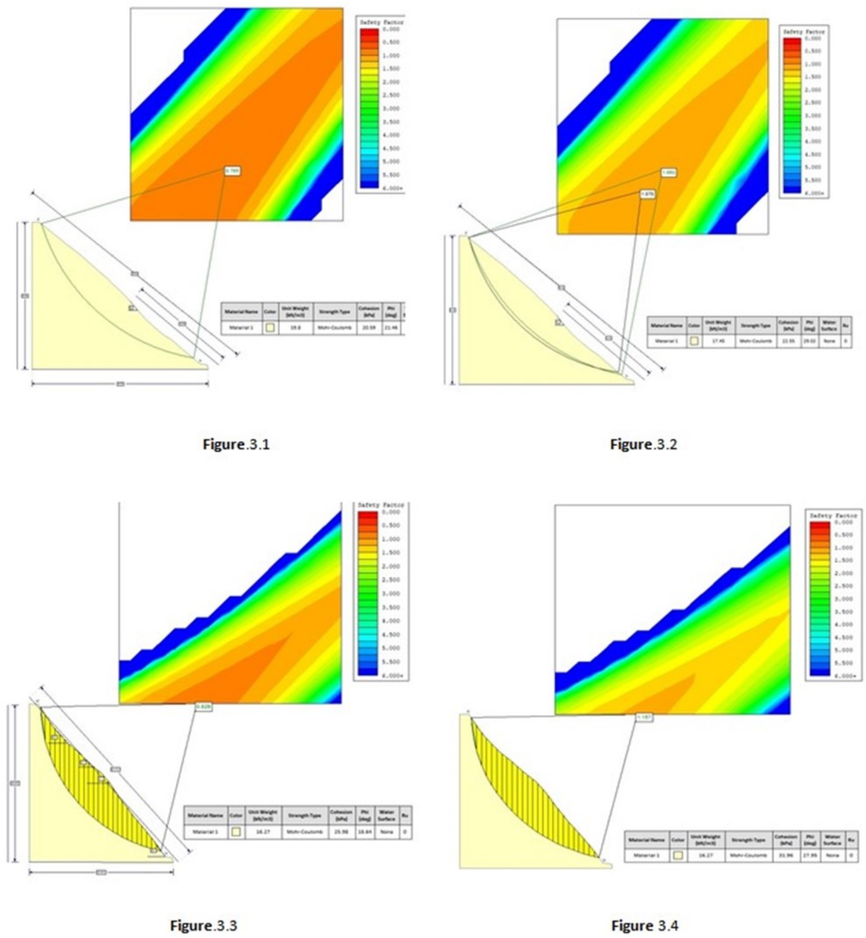

Figure 3: Slope Stability Analysis using Limit Equilibrium Method (LEM).
3.1) Location 1 wet season 3.2) Location 1 dry season
3.3) Location 2 wet season 3.4) Location 2 dry season

Table 1: Value of Atterberg's Limit Test for Location-1 and Location-2

PARAMETERS	LOCATION-1				LOCATION-2			
	Dry	Classification	Wet	Classification	Dry	Classification	Wet	Classification
Liquid Limit	40.70	-	38.31	-	40.22	-	37.05	-
Plastic Limit	27.15	-	24.36	-	25.82	-	23.05	-
Plasticity Index	13.55	Medium Plastic	13.05	Slightly Plastic	14.4	Slightly Plastic	14	Slightly Plastic
Liquidity Index	-1.24	Semi-Solid	-0.11	Semi-Solid	-0.54	Semi-solid	0.13	Stiff
Consistency Index	2.2	Very Stiff (semi-solid)	1.11	Hard (Solid)	1.54	Hard (Solid)	0.86	Stiff (Plastic)
Natural Moisture Content	10.33	-	22.75	-	17.95	-	24.99	-

Table 2: Shear strength parameters for Location-1 and Location-2

LOCATION-1			
		Dry	Wet
Sl. No.	NORMAL STRESS σ(kg/cm2)	SHEAR STRESS AT FAILURE τ(kg/cm2)	SHEAR STRESS AT FAILURE τ(kg/cm2)
1	0.5	0.517347222	0.51199
2	1	0.772	0.77736
3	1.5	1.104388889	1.06686
Cohesion (kg/cm2)		0.23	0.21
Dry Density (UnitWeight)g/cm^3)		2.02	2.2
Angle of internal friction(°)		30.41 ϴ′=21.46	26.74 ϴ′=18.64
LOCATION-2			
		Dry	Wet
Sl. No.	NORMAL STRESS σ(kg/cm2)	SHEAR STRESS AT FAILURE τ(kg/cm2)	SHEAR STRESS AT FAILURE τ(kg/cm2)
1	0.5	0.58704	0.53075
2	1	0.86582	0.7371528
3	1.5	1.11779	1.0346944
Cohesion (kg/cm2)		0.326	0.263
Dry Density (Unit Weight)g/cm^3)		1.66	2.2
Angle of internal friction(°)		27.9571	26.74 ϴ′= 18.64

Table 3: Factor of Safety (FoS) shown by different methods

Location-1		
Method	Factor of Safety (Dry)	Factor of Safety (Wet)
GLE/ Morgenstern-Price	1.060	0.779
Ordinary/ Fellenius	1.009	0.744
Janbu Simplified	1.001	0.738
Janbu Corrected	1.001	0.782
Bishop Simplified	1.083	0.785
Spencer	1.065	0.783
Location-2		
GLE/ Morgenstern-Price	1.940	1.335
Ordinary/Fellenius	1.150	0.835
Janbu Simplified	1.179	0.868
Janbu Corrected	1.235	0.924
Bishop Simplified	1.157	0.829
Spencer	1.221	1.152

to estimate the liquid limit of the soil.

The plastic limit test was done by using a flat glass plate, the soil sample was rolled on the glass to obtain a size of 3mm at which the soil is showing failure or crack, and the weight of the wet and dry samples was then recorded for plastic limits.[8]

For each sample passing through a sieve size of 4.75mm, the direct shear test was conducted three times for determining the angle of internal friction and cohesion of the soil following Mohr-Coulomb failure criteria. The test was conducted in consolidated undrained test method.[9]

Analysis of soil data

Rocscience Slide_6.020 software was used for analyzing the stability of the slope. The Limit Equilibrium Method was used to estimate the factor of safety. In this analysis, a probabilistic approach was used that accounts for spatial soil variation of soil strength.[10] The factor of safety was calculated from the shear strength parameters of the soil taken during the wet and dry seasons. The analysis was done using the Ordinary/Fellenius, Bishop Simplified, Janbu Simplified, Janbu corrected, Spencer, GLE/ Morgenstern-Price method for calculating the factor of safety.

Results

Effects of wet-dry cycles on Atterberg's limit

The mechanical properties of soil shown by the soil samples collected from the same location varied depending upon the season. Samples collected from the location1 during the dry season show a liquid limit of 40.70%, a plastic limit of 27.15, a plasticity index of 13.55, a liquidity index of -1.24, and a consistency index of 2.2. Except for the liquidity index, there is a decrease in the other properties of the soil after completing two cycles of wetting and drying (Table 1). This decrease in the strength of the soil after two wet-dry cycles is also similar for location 2.

Effects of wet-dry cycles on shear strength parameters

In location 1, the cohesion value and angle of internal friction under direct shear test decreased from 0.23 to 0.21 and from 21.46° to 18.64° respectively after completing two cycles of wetting -drying in the monsoon season. This reduction in the shear strength parameters is also observed in location 2 as well (Table 2).

Based on the analysis of slope stability using the Limit Equilibrium Method (LEM), the average Factor of Safety as indicated by different methods is 1.5 and 1.9 respectively in both locations during the first wet-dry cycles in the dry season (Table 2). It has been observed that a lowering of Factors of Safety below unity in both locations (Fig 3) can be attributed to the decrease in the shear strength parameters in the last cycles of wetting and drying of soil (Table 3).

Discussion

Due to the cycles of wetting and drying of the soil with seasonal change, there is a reduction in the nature of soil expansion that increases slope instability.[11] In the present study, it has been noticed that the rate of weathering increases after the completion of two wet-dry cycles which in turn reduces the strength of the soil. This reduction in strength of the soil results in lowering the Factor of safety (Fig.3), and making the area more prone to slope failure. This is practically observed as evidenced by 30.48cm of ground displacement (Fig.1) in the study area during monsoon season. Therefore, there is a chance of more slope failure during the monsoon season due to a decrease in the strength of the soil after continuous wet-dry cycles.

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