Effect of Increasing the water content on the Slope of road embankment, Alsheyab City, NW of Libya

Eng. Anwar Ahmed Abuasara
Faculty of Engineering- Jadu
University of Nalut
Jadu, Libya
AAAbuasara15@gmail.com

Abstract— This paper examines the contrast of water content to the stability of the slopes of a mountain road in the Alrohibat city. As the city is located in Al-Jabal Al-Gharbiy, landslides caused by rainfall have a growing attention for road engineering designers. Hence, comprehensive study for geotechnical parameters is highly needed to propose appropriate approaches that help stabilizing slope embankments.

The Effect of Increasing the Ratio of Water Content on Soil Properties and Stability of Slope Embankment is the subject of this study focusing. This paper starts with estimating important geotechnical parameters that are needed for understanding behavior of slopes. These parameters are then used to estimate the factor of safety using GEO5-Slope software. Although results from the analysis show that the slope is currently stable, increasing water content , that may be caused by climatic changes, can result landslide for the slope embankment..

Index Terms— Keywords— Slope stability, Geotechnical Engineering, Parameters of soil, Soil Mechanical.

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1 Introduction

Slop stability assessment is performed to ensure safe design of natural or man-made slopes. As earth slopes are inclined and ,in general, are not supported, the mass of the inclined earth surface can fail by downward or outward movements, [1]. This movement is only taking place when the force required to resist movement is less than forces that can cause failure by sliding or collapse. The failure of slopes is affected by several factors such as rainfall , groundwater and erosion activities, [2].

One of the main key factors of slope stability is the soil shear strength which is responsible for maintaining the soil mass in equilibrium conditions. This shear strength is strongly affected by moisture conditions. Practically, laboratory sample, which is used to determine the shear strength, is usually prepared without respect to the fact that water conditions in the future may not be the same. Accordingly, unstudied water contents for designed slopes are likely to result slope deformations. This was the case, for example, in the catastrophic events of the failure of the Vaiont dam, where the ground collapse abruptly emptied the reservoir, [3]. Water exerts control over most physical, chemical and biological processes occurring in the soil. Water in soil acts as a lubricant and as a binding agent between soil particulate matter, thus affecting structural stability, soil strength and geological material, [4].

Shear strength of soil is characterized by cohesion (c) and friction angle (Ø) [5]. The two parameters are the target of this study, define the soil maximum ability to resist shear stress under defined load with respect to the amount of water content in the sample.

The stability of the Slopes is assessed by the values of FOS, which can be defined as a ratio between negative "forces", which prevent soil mass sliding (cohesion, friction angle) and "active" forces, which cause slippage of the soil mass (transverse forces), [6][9].

2 Objectives

A. Studying a real problem to a road embankment slope, which have been designed and constructed without taking into account slope stability design of filling material.

B. Gain a better understanding of factors that cause slope instability such as water content and their importance in the geotechnical analysis.

C. Evaluate the effect of using advanced slip surface searching techniques on the selection of the most critical slip surface.

3 Methodology

The methodology of this study focuses on the approach shown in the following figure:

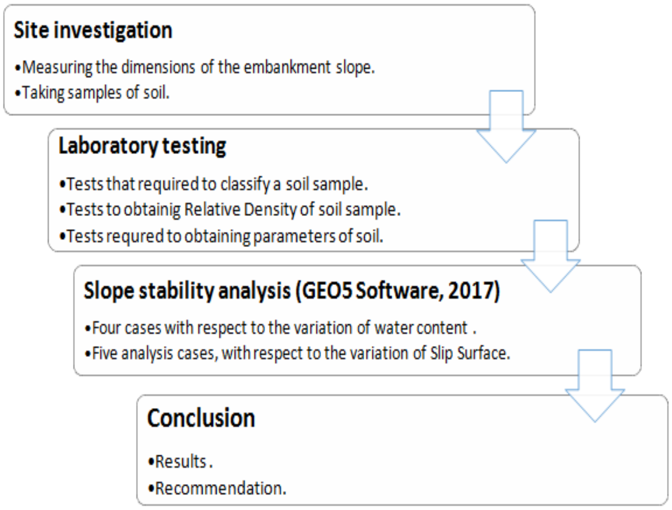


FIGURE (1) SHOWING PROCESS OF STUDY METHODOLOGY

FIGURE (2) PICTURE SHOWING SLOPE OF EMBANKMENT ROAD OF STUDY AREA

4 MATERIALS AND METHODS

The soil samples used in this study were taken from filling material of a embankment road, located in a research area in Alsheyab city. Soil was classified according to USC & AASHTO Systems. Tests performed on the soil included Sieve analysis, Atterberg limits. The Proctor standard test according to AASHTO T180-74, was used to determine the maximum dry density and optimum moisture content. Soil specimen were compacted using the Proctor hammer and the optimum moisture content was identified at Wc = 13.3%. Direct shear test had to be established in four cases of water contents at Wc = 7.7 %, 13.3%, 17% and 18.65%. Shear strength was determined according to AASHTO T 236-90. Factor of safety (FOS) and the location of the shear plane were calculated with use of software GEO5-slope 2017.

5 LOCATION OF STUDY AREA

The study area is located at Alsheyab area north-western of Libya about 200Km south-western of Tripoli as shown in Figure 3. Area is located in coordinates:31°53'28.13" N, 11°48'4.60"E. Location of the study area by satellites is shown as following:

FIGURE (3) ILLUSTRATED LOCATION OF STUDY AREA

6 LABORATORY TEST.

This study involves laboratory tests that are required to classify soil sample and determine internal angle friction(Ø), cohesion of soil(C), Specific gravity(Gs), maximum and minimum dry density (γ_{dmax} , γ_{dmin}), Optimal water content (OMC)). As illustrated in the following table (1).

TABLE (1) ILLUSTRATED A LIST OF TESTS THAT HAVE BEEN CARRIED OUT IN THIS STUDY

Name of test	*The Aims of this test*	*Type of test*
Atterberg Limits tests	Classification of soil	Lab. Test
Sieve analysis test	Classification of soil	Lab. Test
Specific gravity test	To determined the G_s Value	Lab. Test
Standard Proctor test	OMC , $\gamma_{d\,max}$ + $\gamma_{d\,min}$	Lab. Test
brass ring	Field Density$\gamma_{d\,field}$	Lab. test
Direct shear test	C & Ø	Lab. Test

A. Classification of soil.

The classification of soil in this study is carried out using (USC & AASHTO Systems). These systems have substantial acceptance worldwide, as well as in Libya.

In classifying soils for engineering purposes based on laboratory determination of particle-size characteristics, liquid limit and plasticity index, As mentioned above in this study used two methods (USC & AASHTO Systems).

According to ASTM D 2487-00 Volume 04.08, Standard Practice for Classification of Soils for Engineering Purposes, to classify the sample of soil and that depend on the plastic limit, liquid limit and plasticity index as well as percentage of passing and retained from sieve no 200 (0.075mm) and Sieve No 4 (4.75mm). tables and charts that have been used to classify a soil.

According to the both Methods of classification soil and to apply the result of laboratory tests of soil sample to the AASHTO & USC tables and Plasticity charts, the soil sample identified as (*Silt Sandy Soil*, *Low Plasticity and Poorly Graded*). The following table (2) illustrated conclusion of classification.

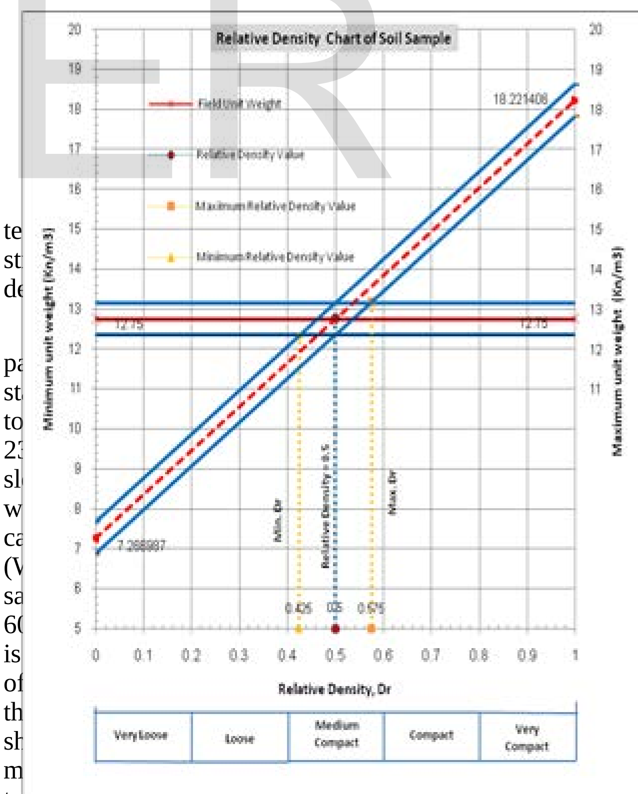
B. Relative density (Dr).

The relative density of a soil reflect its compressibility. for instance, higher values of relative density indicate that the soil is incompressible in regard to low values for soils on the same magnitude. In this study used a chart of approximation of relative density (Dr Chart) to obtained a Relative density of the soil. Relative density can be obtained from maximum, minimum and field density using figure (4) where the limits of relative density are indicated that the soil ccompaction is *(Medium Compact, Dr = 0.5).*

TABLE (2)RESULTS OF TESTS THAT USED TO CLASSIFY THE SOIL SAMPLE AND CLASSIFICATION OF SOIL

Sieve Analysis Test			Atterberg Limits & Consistency indices	
Percentage Passing Sieve No.	No. 4	88.6	L.L	18.3
	No. 10	85.25	P.L	17.89
	No.40	74.9	P.I	0.41
	No.100	24.24	L.I	-7.23
	No.200	8.8	**Natural Water Content**	
Coefficients	D10%	0.08	Wc	7.7
	D30%	0.17		
	D60%	0.24	**Specific Gravity**	
	Cc	1.51	Gs	2.62
	Cu	3		
Classification of soil				

	Systems		Classification
	USCS	***AASHTO***	
Table	SP-SM	A-2-4	**Silty Sand Soil, Low plasticity and Poorly Graded**
Chart	CL-ML	A-2-4	



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displacements, vertical / normal stresses and vertical displacements are transferred to a data and can be read from gauges. Test results are summarized in Table (3) and the results obtained from the plotted graph shown in Figure(5) indicates the Maximum Sheer failure for four samples of difference water content .

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Direct shear test results are presented in table (3) bellow. The Shear failure involved in different cases of changing in load and water content, as well as the parameters of soil sample. Testing consists of determining the maximum shear stresses (Shear failure) for at least three test samples with three different applied normal stresses that are selected to be representative of anticipated field stresses. Since a decrease in the sample void ratio will increase the shear stress of soil therefore increase internal angle of friction and cohesion, test specimens are initially placed to the same density (unit weight). Shear strength parameters C and ϕ are determined by determining a best-fit line (y-intercept and slope) of the σ'_f (abscissa), τ_{max}.

TABLE (3) PRESENTED CONCLUSIONS OF DIRECT SHEAR TESTS IN THIS STUDY.

Load case(kg)/ N. Stress (Kpa)	Shear Failure (Kpa) Water Content %			
	7.7	13.3	17	18.65
4kg / 109kpa	84.783	86.95	77.613	0
8kg / 218kpa	166.897	155.809	155.926	86.366
16kg / 436kpa	298.197	304.908	295.279	173.316
C kpa	20.13	12.401	7.936	0
Ø°	40.15	38.4	36.5	4.36

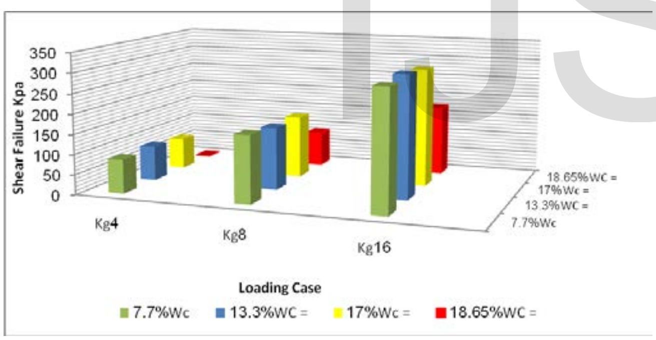

FIGURE (5) SHOWING RELATIONSHIP BETWEEN SHEAR FAILURE AND CHANGING IN WATER CONTENT IN DIFFERENT CASES OF LOADING.

In the figure (5) Showing Comparing between shear failure with considering to water content and different of cases loading. In general the peak value of Shear failure have been recorded in state of water content equal to OMC. In other hand the lease value of shear failure obtained when the water content increased more than liquid limit state, indicts that the parameters of soil are effect by amount of water content in soil as presented in figure (6). That is supporting to, TOPP, G. C., FERRE, P. A., 2002.,"Water in soil acts both as a lubricant and as a binding agent among the soil particulate materials, thereby influencing the structural stability and strength of soil and geologic materials".

In table (3) shows results of maximum shear strength(τ_{max}), cohesion (c) and friction angle (Ø) for each water content. Values of maximum shear strength at 13.3 % water content were slightly higher than those at 7.7 %, but notably higher than those at 17 % or 18.65% water content. Friction angle was the lowest (4.36°)at 18.65 % water content and the highest (40.15°) at 7.7 % water content. Cohesion was descending with raise of water content, as presented in Figure (6), also illustrated that, between7.7 % and 13.3% cohesion diminished from 20.13 kPa to 12.401kPa, between specimen with 13.3% and 18.65 % water content, the values of cohesion exhibited considerable drop from 12.401kPa to 0 kPa. Figure (5) displays development of maximum shear strength for each of the water contents. It is clearly visible, that the most realistic results were obtained at 13.3 % water content, with highest values of maximum shear strength, while at 18.65 % the values were the lowest. At 109Kpa Normal load and 18.65 % the shear strength declined to 0 ° . Values of maximum shear strength for specimen at OMC =13.3 % water content exhibited uncommon behaviour and were lower than those at 7.7 % water content..

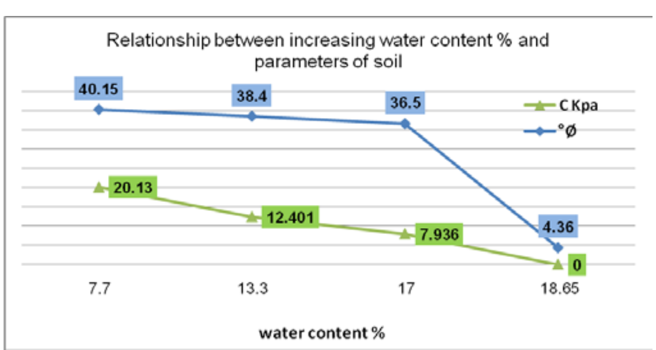

FIGURE (6) ILLUSTRATED EFFECTIVE THE PARAMETERS OF SOIL BY INCREASING WATER CONTENT

7 SLOPE STABILITY ANALYSIS USING COMPUTER'S SOFTWARE

In this paper, slope stability was analyzed using the computer software (GEO5-slope, 2017). GEO5 is a geotechnical software suite developed by Fine s.r.o. (Czech Republic). First programs were written by Jiri Laurin in 1989 in cooperation with the Faculty of Civil Engineering of CTU in Prague. The software is used in the field of geotechnical engineering to analyze slope stability, shoring excavations structures, retaining walls, foundations (piles, spread footing or mats) and tunnels.

Input data that required to analysis slope stability using GEO5 Software are presented in the following .

A. Material Properties.

The properties of the soil sample material are presented in Table (4) outline of laboratory result. The slope of embankment will be analyzed for four cases at varying water content. These characteristics were obtained from the soil sample taken from the study area and tested in the Soil Mechanics Laboratory at Faculty of Engineering - Jadu.

B. Dimension of slope Surface.

From site investigation to calculate some variables such as slope height, for example, to provide all the inputs required in the study, especially the field measurements. The height and angle of slope, road width and shoulders were measured, as indicted in Figure (7), slopes dimensions of road embankment.

TABLE (4) ILLUSTRATED THE PARAMETERS OF SOIL FOR FOUR STAGES OF CHANGING WATER CONTENT VALUE.

Parameters of soil	Stage 1 (Water content = 7.7 %)	Stage 2 (Water content = 13.3 %)	Stage 3 (Water content = 17 %)	Stage 4 (Water content=18.65 %)
C Kp_a *	20.13	12.40	7.94	0.00
Ø° *	40.15	38.40	36.50	4.36
Υ_b gm/cm³ *	1.30	1.30	1.30	1.30
W_c %	7.70	13.30	17.00	18.65
Υ_d gm/cm³	1.40	1.47	1.52	1.54
Gs	2.62	2.62	2.62	2.62
Υ_w gm/cm³	1.00	1.00	1.00	1.00
[illegible]	0.87	0.78	0.72	0.70

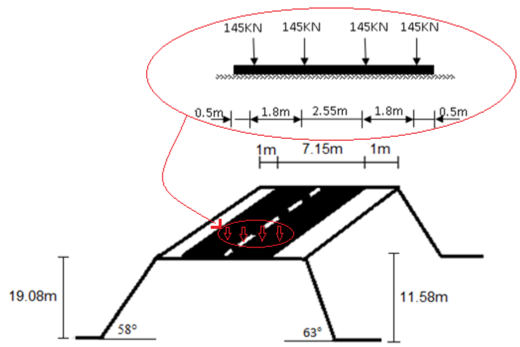

FIGURE (7)SHOWING THE SLOPE DIMENSION OF ROAD EMBANKMENT (FILLING MATERIAL)

C. *Model Traffic Surcharge.*

The slope stability analysis takes into account even the surcharge caused by neighboring structures. The surcharge can be introduced either as a concentrated force or distributed load acting either on the ground surface or inside the soil body. In this study is taking into consideration the critical situation as described in AASHTO LRFD (HL-93). The distance between axle is 6' (1.8m), that of two rear axles weighing 32kip (145 kN), can be obtain the worst design force when two trucks considering using the road in same time as illustrated in Figure (7)

After collecting slope configuration and the soil parameters and all required details to obtaining FOS of Slope embankment of road, the staged construction approach intends to simulate the various stages throughout the slopes construction are divided in two approach as constant inputs and variation inputs.

1) Constants inputs.

The geotechnical model adopted in this analysis is illustrated in the following, kept constant throughout all analyses in different stages.

- ***Coordinates of interface;***

The shape of road embankment in this analysis is obtained from on-situ investigation measurements, and this dimensions are presents the interface of road embankment as illustrated in figure (7) is kept constant.

- ***Coordinates of Surcharge of traffic:***

According to AASHTO LRFD (HL-93) the worst design load force have been applied in this simulation as mentioned previously and kept constant during all analysis cases of this study.

- ***Slip surfaces.***

In this study tacked in to account a five analysis of slip surfaces and kept constant throughout all analyses of different stages, as in figure (8).

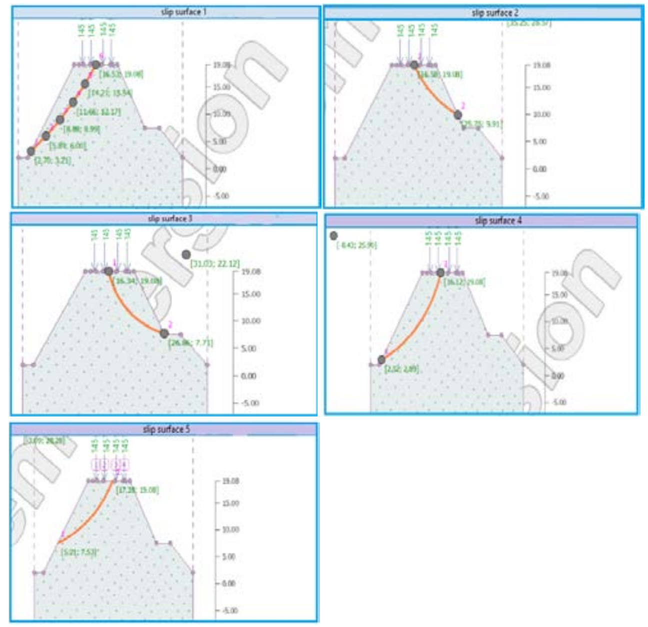

FIGURE (8) COORDINATES OF SLIP SURFACE.

2) Variation Inputs.

The material properties need to be created and assigned for each analysis case, they are presented in profiles such as in figure (9) Soil profile of Case (1) at water content 7.7% .

- ***Case 1:-Water content = 7.7%***

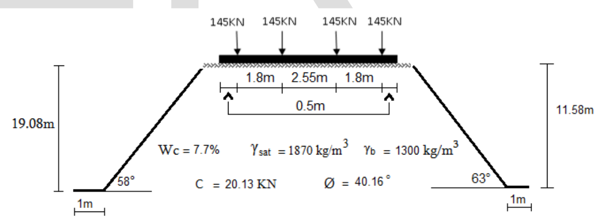

FIGURE (9)PROFILE OF SOIL IN CASE 1:- WATER CONTENT = 7.7%

- ***Case 2:-Water content = 13.3%***

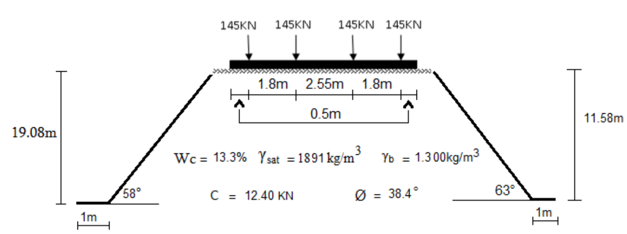

FIGURE (10)PROFILE OF SOIL IN CASE 2:- WATER CONTENT = 13.3%

- ***Case 3:-Water content = 17%***

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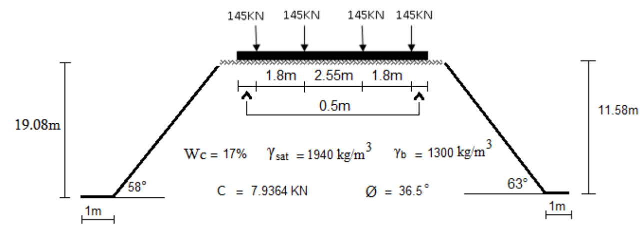

FIGURE (11)PROFILE OF SOIL IN CASE 3:- WATER CONTENT = 17%

- ***Case 4:- Water content = 18.65%***

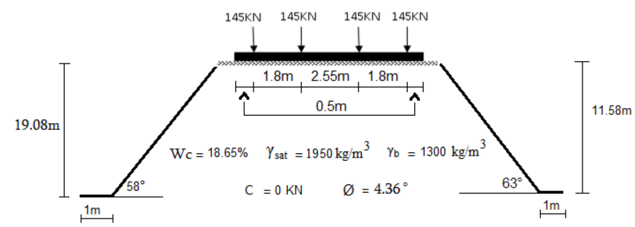

FIGURE (12)PROFILE OF SOIL IN CASE 4:- WATER CONTENT = 18.65%

The safety factor was also taken into account in this study and was considered 1.5. According to the following conditions:

- If Factor of safety greeter or equal to1.5, acceptable case. (FOS $\geq$1.5).
- If factor of safety greeter or equal to 1 and smaller or equal 1.5, not acceptable but stable. ($1 \leq$ FOS$\leq$ 1.5).
- If Factor of safety less than 1, not acceptable and unstable. (FOS <1).

8 CONCLUSION OF STABILITY ANALYSES RESULTS

The results from the stability analyses with the software GEO5 slope2017 are presented in Figure (13). The road embankment is 19 m high and declines in a ratio 1:4.5 as presented in figure (7). FOS for Case of 7.7% water content is acceptable result because of FOS $\geq$1.5 and that in all slip surface analysis approximately the same values. Marked drop was observed at 18.65 %water content, where FOS reached only 0.09 which indicates critical condition. Indicts that, the slope of embankment road is relatively stable, but it is not safe to be suitable in all cases because the slope will go to failure in case of increasing the water content of the soil.

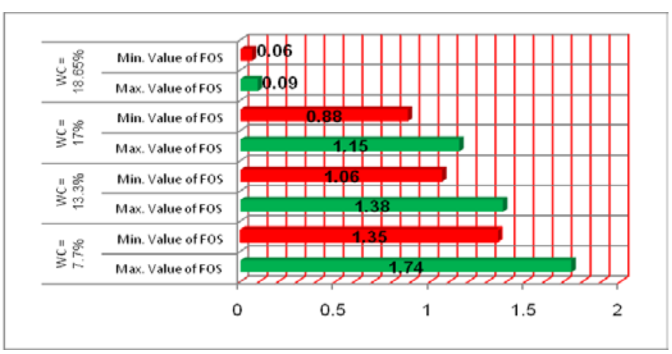

FIGURE (13) ILLUSTRATING THE EFFECTIVE WATER CONTENT IN TO VALUES OF FOS.

9 SUMMARY

The cohesion and angle of friction are the an essential parametric properties to understand the behavior of soil. In this study, a Direct Shear Test was conducted to estimate these parametric properties according to (AASHTO T 236-90). The main aim of this study is to find out the degree of stability of slope embankment in respect to changing the water content. Therefore, the direct shear test was performed four times, with the water content ratio varying each time, to obtain the variance of the values (C & Ø), as shown in Figure (6). The parameters obtained from these tests were used for stability analyzes with the GEO5 SLOPE 2017 program. The results of slope stability are presented in Figure (13). The conclusion of this study can be expressed in the following points.

- The maximum value of shear strength (τ_{max}) 304.908Kpa, is obtained from sample with (OMC) 13.3% water content were, under normal stress of 436 kPa.
- Decreased cohesion with increased water content, a significant reduction was found between 13.3% and 18.65% water content, where the cohesion decreased from 12.4kPa to 0kPa, respectively.
- The development of friction angle values showed an exceptional behavior, with values at 7.7% of water content (40.15 °) higher than that of 18.65% (4.36 °).
- Soil cohesion is affected by ratio of water content in the sample more than angle friction as illustrated in figure (6).
- In general, the Factor of Safety (FOS) is depends on the values of (C& Ø) also the Unit weight of Soil.
- Figure 13 shows the variation of FOS with the amount of water content and gradually decreases from 1.74 as the maximum value in 7.7% of the water content to 0.09 FOS registered under 18.65% of the water content. That indicates critical condition of the tested slope embankment, Result obtained in this study show the necessity of taking moisture conditions into account. Usually the laboratory specimen, which are used to determine shear strength of the soil are prepared at water content and dry density same as in the field conditions, without respect to the fact, that the conditions in the future might not remain the same.

10 RECOMMENDATIONS

Based on the findings of this study, it is recommended that:

- Redesign and construction of the embankment in engineering ways and under the supervision of specialized engineers taking into account the climatic conditions, terrain and traffic in the area.
- Attempt to protect the slope from failures in modern engineering methods such as (concrete injection method, Shotcrete Surface Method,....etc).
- The reduction of the use of this road during the rain, especially in the case of trucks carrying large weights, including these signs and using media and Internet.
- Try to prevent the increase of water content of the soil and under the supervision of a specialized engineer.

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