Evaluation of Underground Water Level on Slope Performance

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Abstract

The liquefaction could be change due to level and availability of underground water. In this research to understanding slope failure mechanism computerized modeling employed and base on that capability of underground water on slope stability has been evaluated. The result revealed pore water pressure has direct influence on slope factor of safety and types of slope failure. The failure of slope and types of that could predict if accurate slope modeling developed. The essential concept in any soil structure mitigation is proper understanding of failure type.

Keyword: Slope Modeling, Pore Water Pressure, Slope Failure

1. Introduction

In the area of geotechnical engineering to understanding problem and solve of that computerized modeling provide sufficient knowledge.

There are several investigations on slope stability base on determination factor of safety and stability of slope which could be finding as per soil mechanical properties and laboratory analyses in order to provide necessary engineering geological data for further site development and urban planning [1-8]. The stability of slope is one of the most important problems in geotechnical engineering to solve of that in a scientific attempt the limit equilibrium method used and it is taken as 2-D plane strain problem with no variation in geometry and material of the slope [9-10]. The characteristics of 10 mixed soils under compacted optimum moisture condition (OMC) in the laboratory has been determined and using computer modeling several slopes have been developed, the computerized slopes analyzed and result compared with manually calculation.

2. Methodology and Experiments

The best and safe method in slope design is using combination of manually and computerized methods for avoiding any disaster and failure of soil structure. The author made an attempt to find possibility in improvement of soil structure in general and slope in the particular, to the achieving goal base on soil mechanical properties, assumption of underground water level, the slope geometry and type of slope failure the slope stability have been evaluated. The 10 mixed soil types from red plastic soil and black, green, dark brown, yellow and light brown non plastic soils, sand, and two types of gravels 2 mm, 4.75 mm developed, and also from previous investigation (Table 1) angle of friction, unit weight and cohesive of mixed soils sample for computerized model have been used, the Geo-Slope and origin software for calculation and identification of models behavior employed.

The formulas for calculation of normal stress, shear strength, shear stress and factor of safety by manually are the following

1) $\sigma = \gamma H \cos^2 i$
2) $\tau_f = (\gamma H \cos^2 i)\tan\Phi$
3) $\tau = \gamma H(\cos i)(\sin i)$
4) $F_s = \tau_f / \tau = [\tan\Phi / \tan i]$

Table 1 Mixed soil models [11]

Sl. No	% of Red Soil	% of Sand	% of Gravel 4.75 mm	% of Gravel 2 mm	% of Black Soil	% of Green Soil	% of Dark Brown Soil	% of Yellow Soil	% of Light Brown Soil
1	100	0	0	0	0	0	0	0	0
2	55	45	0	0	0	0	0	0	0
3	55	0	45	0	0	0	0	0	0
4	55	0	0	45	0	0	0	0	0
5	55	15	15	15	0	0	0	0	0
6	55	0	0	0	45	0	0	0	0
7	55	0	0	0	0	45	0	0	0
8	55	0	0	0	0	0	45	0	0
9	55	0	0	0	0	0	0	45	0
10	90	0	0	0	2	2	2	2	2

Fig. 1 Landslide at Kwun Lung Lau in 1994 [12]

3. Results and Discussion

The base of any construction activities is accurate design and analysis, it could be done by manually or computerized method or combination of both. This is possibility to finding best slope geometry and material by using laboratory result and numerically development of slope geometry base on site requirement and characteristics to avoid of slope collapse or landslide (Fig 1).

To understanding of slope failure type, best option is computerizing modeling which is manually not possible. The table 3 and figure 2 indicating manually result of slope model with different inclined angle. The tables 4-6 and figures 3-5 shown factor of safety and slope failure types, to mitigation and support of model it is requirement understanding slope failure types this is lead to accurate improvement of critical area. The change of slope failure type is possible by modification of slope geometry and soil mechanical properties. The level of underground water imposed in design of slope geometry and failure type. The understanding all factors, which effected to the soil, could be starting new way of the improvement of any soil. Some characteristics of soils have linear and some of them nonlinear effect on soil foundation bearing capacity [13]. Proper selection of mixtures made of suitable material could significantly improve soil bearing capacity. It is possible for liquefaction mitigation to employ the soil mixing method. Soil mixing technique could seriously improve the ability of soil resistance if it is faces shear failure [14]. Soil Mixing is an applicable, easy and cost effective method to improve soil characteristics, increasing soil bearing capacity, reduction of unsustainable deformation, differential settlement and increasing stability of soil foundation [15].

Table 2 Experiments Results When Soil is in Compacted OMC Condition [11]

Sl. No	Model No 1	Optimum Moisture Content (%)	γ (KN/m^3)	Φ Degree	C (KN/m^2)
1	1	11.2	21.94	38	21
2	2	10.61	21.83	39	12
3	3	10.72	23.46	39	46
4	4	12.15	23.82	36	28
5	5	9.58	23.02	40	8
6	6	22.39	20.09	32	20
7	7	18.86	20.95	32	26
8	8	14.56	23.35	18	44
9	9	14.23	20.96	30	28
10	10	16.83	21.61	36	22

Table 3 manually analytical results of slopes under compacted [OMC] condition

Sl No	Model No	Model with 15degree inclined			Model with 20degree inclined			Model with 25degree inclined		
		τ_f (kPa)	τ (kPa)	F_s	τ_f (kPa)	τ (kPa)	F_s	τ_f (kPa)	τ (kPa)	F_s
1	1	119.87	41.12	2.92	113.46	52.86	2.15	105.55	63.00	1.68
2	2	123.62	40.91	3.02	117.01	52.60	2.22	108.85	62.69	1.74
3	3	132.85	43.97	3.02	125.74	56.53	2.22	116.97	67.37	1.74
4	4	121.03	44.64	2.71	114.55	57.39	2.00	106.56	68.40	1.56
5	5	135.08	43.14	3.13	127.85	55.47	2.31	118.93	66.10	1.80
6	6	87.80	37.65	2.33	83.10	48.41	1.72	77.30	57.69	1.34
7	7	91.55	39.26	2.33	86.65	50.48	1.72	80.61	60.16	1.34
8	8	53.06	43.76	1.21	50.22	56.26	0.89	46.72	67.05	0.70
9	9	84.63	39.28	2.15	80.10	50.50	1.59	74.52	60.19	1.24
10	10	109.80	40.50	2.71	103.92	52.07	2.00	96.68	62.06	1.56

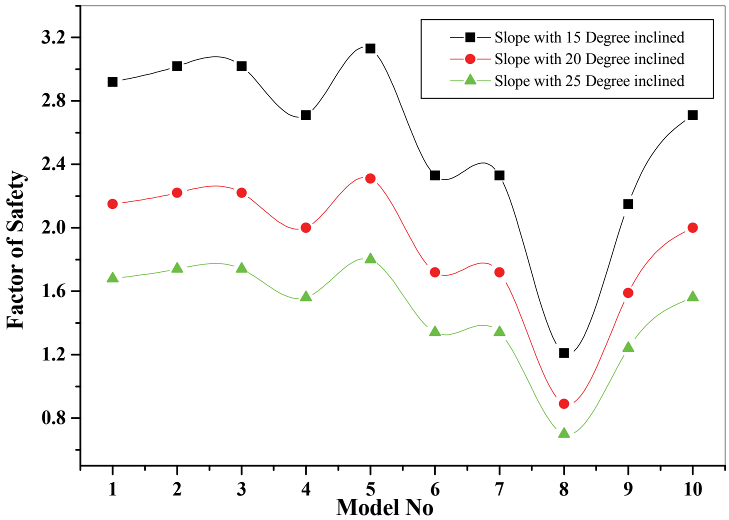

Fig 2 Factor of Safety Vs Model No

Table 4 computerize analytical results of model 1with 15 degree inclined

Sl No	Model No	Model with (OMC) soil		Model with subsoil submerged		Model with fully submerged	
		F_s	Type of failure	F_s	Type of failure	F_s	Type of failure
1	1	5.98	SF	5.51	SF	3.85	SF
2	2	5.37	SF	4.89	SF	3.35	SF
3	3	7.59	SF	7.23	SF	5.52	SF
4	4	5.98	SF	5.65	SF	4.14	SF
5	5	5.04	SF	4.79	SF	3.17	SF
6	6	5.12	SF	4.77	SF	3.25	SF
7	7	5.47	SF	5.15	SF	3.68	SF
8	8	5.64	SF	4.49	SF	3.8	SF
9	9	5.33	SF	5.03	SF	3.67	SF
10	10	5.75	SF	5.35	SF	3.74	SF

Slope failure = SF

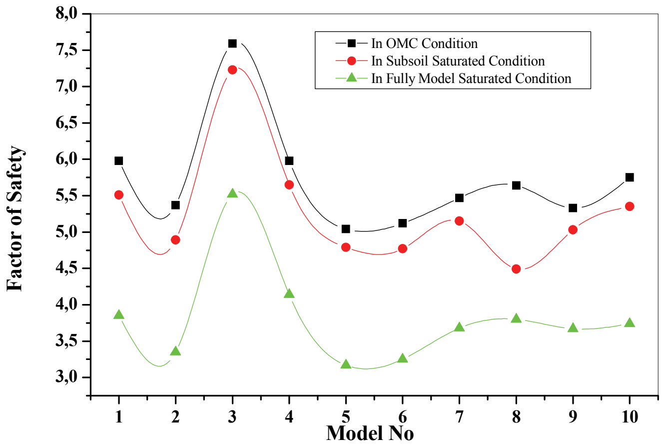

Fig 3 Factor of Safety Vs Model No in Model with 15 Degree Inclined

Table 5 computerize analytical results of model 1with 20 degree inclined

Sl No	Model No	Model with (OMC) soil		Model with subsoil submerged		Model with fully submerged	
		F_s	Type of failure	F_s	Type of failure	F_s	Type of failure
1	1	4.28	SF	3.93	SF	2.77	SF
2	2	3.86	SF	3.5	TF	2.36	SF
3	3	5.59	SF	5.25	SF	4.11	SF
4	4	4.32	SF	4.02	SF	3.02	SF
5	5	3.61	SF	3.32	TF	2.23	SF
6	6	3.7	SF	3.39	SF	2.37	SF
7	7	3.99	SF	3.7	SF	2.71	SF
8	8	3.59	SF	3.44	SF	2.99	SF
9	9	3.91	SF	3.64	SF	2.73	SF
10	10	4.13	SF	3.89	SF	2.71	SF

Slope failure = SF BF = Base failure TF = Toe failure

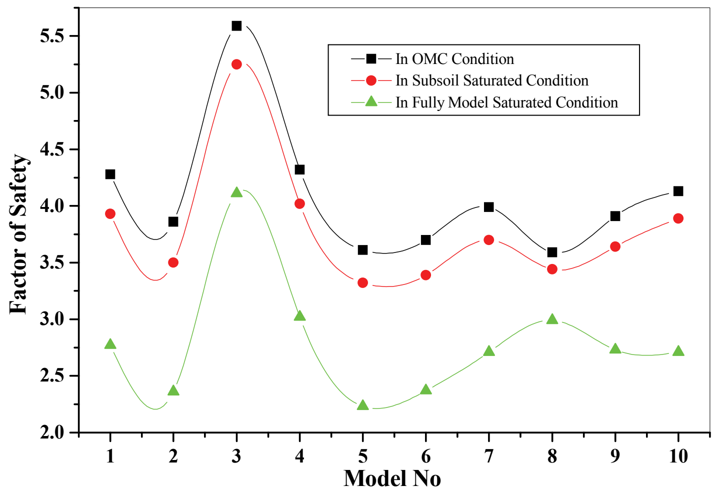

Fig 4 Factor of Safety Vs Model No in Model with 20 Degree Inclined

Table 6 computerize analytical results of model 1with 25 degree inclined

Sl No	Model No	Model with (OMC) soil		Model with subsoil submerged		Model with fully submerged	
		F_s	Type of failure	F_s	Type of failure	F_s	Type of failure
1	1	3.54	SF	3.25	BF	2.32	BF
2	2	3.00	TF	2.89	TF	1.87	SF
3	3	4.74	TF	4.43	BF	3.49	BF
4	4	3.63	TF	3.35	BF	2.54	BF
5	5	2.76	TF	2.67	TF	1.7	TF
6	6	3.11	TF	2.82	BF	1.99	BF
7	7	3.37	SF	3.09	BF	2.96	BF
8	8	3.07	SF	2.96	TF	2.49	TF
9	9	3.39	TF	3.06	BF	2.32	BF
10	10	3.46	SF	3.15	BF	2.26	BF

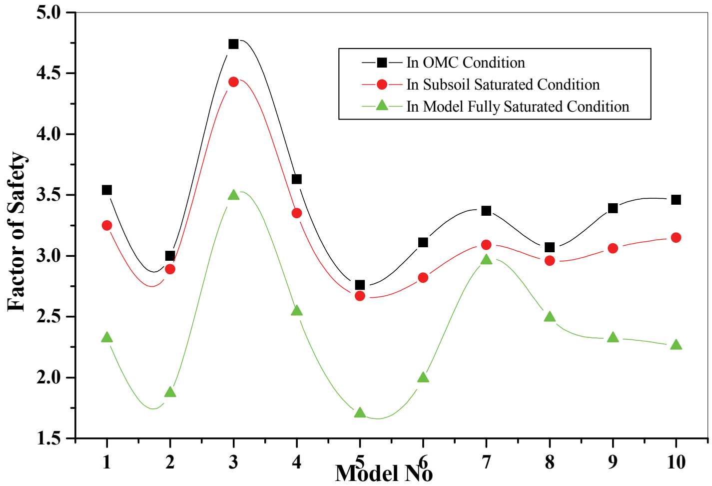

Fig 5 Safety Vs Model No in Model with 25 Degree Inclined

4. Conclusion

- Type of slope failure In the manually calculation method could not be recognized it is possible only by computer modeling
- The slope inclined angle controls type of slope failure and in a slope with high inclined angle time stability is decreased
- The underground water level has direct correlation with slope failure and type
- If the factor of safety decreased the type of failure could be change
- The soil mechanical properties could has better function if suitable slope geometry designed

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NOMENCLATURE

Φ [°] = Friction Angle
C [kN/m2] = Soil Cohesion
OMC % = Optimum Moisture Content %
SBC [kN/m2] = Safe Bearing Capacity
γ [kN/m3] = Unit Weight
Slope failure = SF
Base failure = BF
Toe failure = TF
σ[kPa] =Normal Stress
τ[kPa] =Shear Stress
τ_f[kPa] =Shear Strength