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FIELD MEASUREMENT OF SOIL SUCTION

DETERMINATION IN SITU DE L'EFFET DE SUCCION DANS LE SOL

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SYNOPSIS The field instrumentation for measurement of soil suction and related parameters carried out on a highway slope are presented. The soil suction data related to antecedent rainfall is presented and discussed. The suction values and suction changes due to rainfall decreases with increase in depth. The suction decrease due to rainfall and suction recovery can be predicted reasonably well.

INTRODUCTION

When failure of a residual soil slope is brought about by rainfall, the mechanism of failure is that water infiltration causes a reduction of matric suction in the unsaturated soil, resulting in a decrease in the effective stress reflected in a decrease in the soil strength to a point where equilibrium can no longer be sustained in the slope.

The equation for unsaturated shear strength τ , is written in terms of the stress state variables for an unsaturated soil and is an extension of the form of equation used for saturated soils. (Fredlund D.G. et al, 1978)

$$\tau = c' + (\sigma - u_a) \tan \phi' + (u_a - u_w) \tan \phi^b$$

- where,
- c' = effective cohesion
 - σ = total stress
 - u_a = pore-air pressure
 - ϕ' = effective angle of friction
 - u_w = pore-water pressure
 - $(u_a - u_w)$ = matric suction, and
 - ϕ^b = friction angle with respect to changes in $(u_a - u_w)$ when $(\sigma - u_a)$ is held constant

It can also be presented in the form of the familiar shear strength equation as follows:

$$\tau = C + (\sigma - u_a) \tan \phi' ; \quad \text{where,}$$

$$C = c' + (u_a - u_w) \tan \phi^b$$

SITE GEOLOGY

The site investigated is an exposed profile of a cut slope along the Kuala Lumpur - Karak Highway, Malaysia. The weathering profile is developed over a porphyritic biotite granite bedrock. The distribution pattern of the different stages of weathering profile is very distinctive and figure 1.0 shows the lateral extensions of the

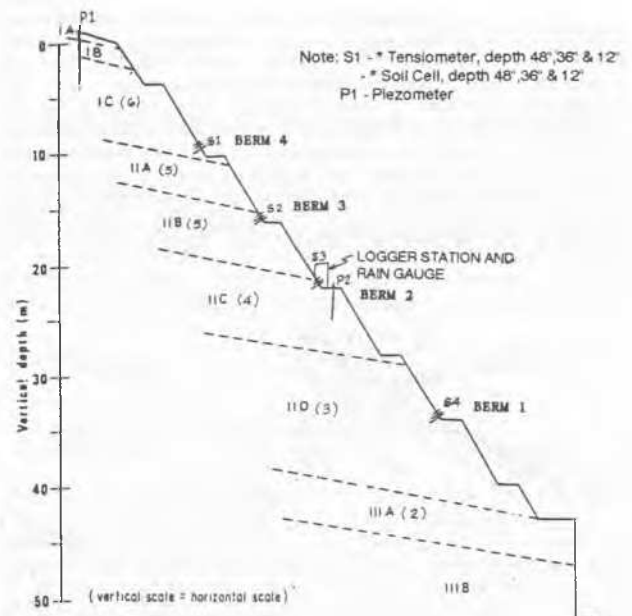


Figure 1.0 Profile of Slope Under Study

...morphological horizons, within the weathering profile and the relevant grading. The distribution of the different stages of weathering of bedrock material within, and the morphological features of the weathering profile over the porphyritic biotite granite is as shown in figure 2.0.

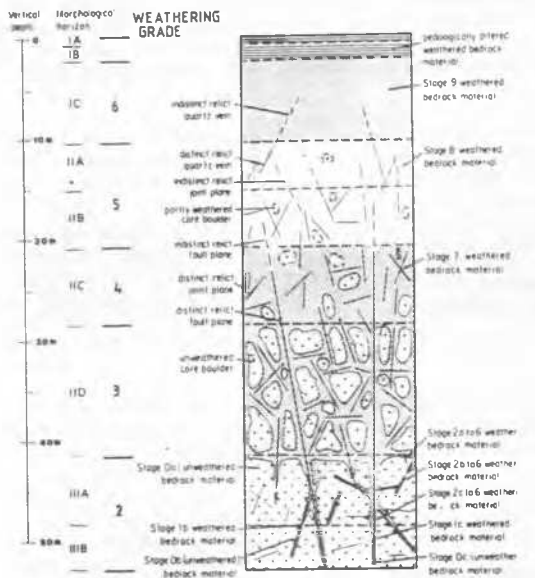


Figure 2.0 Schematic Sketch of Weathering Stages

FIELD INSTRUMENTATION

Instrumentation system for the study on tropical residual soils is for an automatic continuous measuring of soil suction, soil moisture, rainfall and other ancillary parameters. The most recent development in such instrumentation in Malaysia has been the introduction of an automatic system of measurement and recording of rerading from tensiometers, soil moisture cells, piezometers and rain gauges. The instrumentation adopted in the study is schematically presented in figure 4.0, while the detailed instrumentation at one location for tensiometers and soil moisture cells are as shown in figure 3.0.

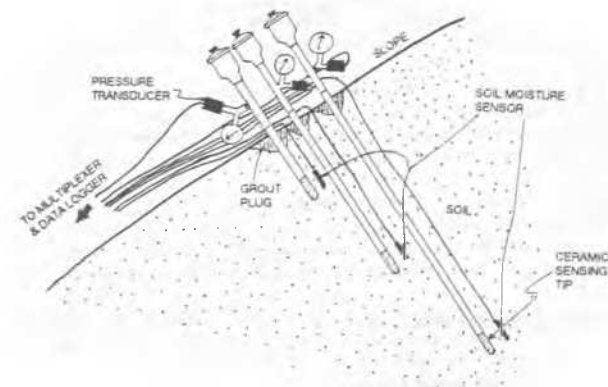


Figure 3.0 Typical Instrumentation Details

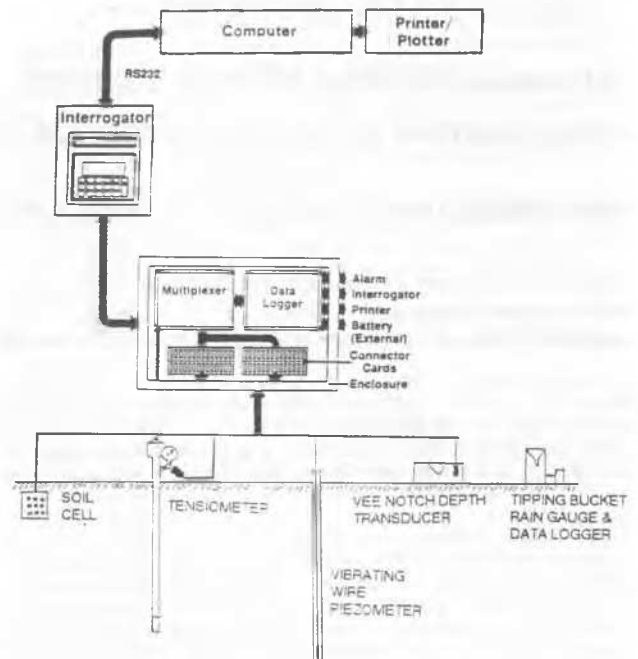


Figure 4.0 Schematic Arrangement of Instrumentation

Some of the soil properties (average values) for the various berms are as follows:

Berm	S.G.	Bulk Density g/cc	Dry Density g/cc	Moisture Content (%)
1	2.6	1.51	1.39	9.1
2	2.55	1.33	1.19	12.1
3	2.6	1.47	1.32	11.6
4	2.62	1.84	1.64	12.5
Berm	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
1	1.5	26.7	52.25	19.5
2	2	27	53	18
3	4.3	30	57.3	8.7
4	9.1	32.5	42	14.5

DATA COLLECTION AND ANALYSIS

The data from a total number of 27 sensors are periodically down loaded and transferred into office computer using an interrogator. In this paper only data pertaining to soil suction is presented and discussed. A typical analysed data for suction against rainfall for berm 4 is shown in figure 5.0.

SUCTION VARIATION FOR BERM 4
01/03/92(00:00) TO 31/03/92 (23:30)

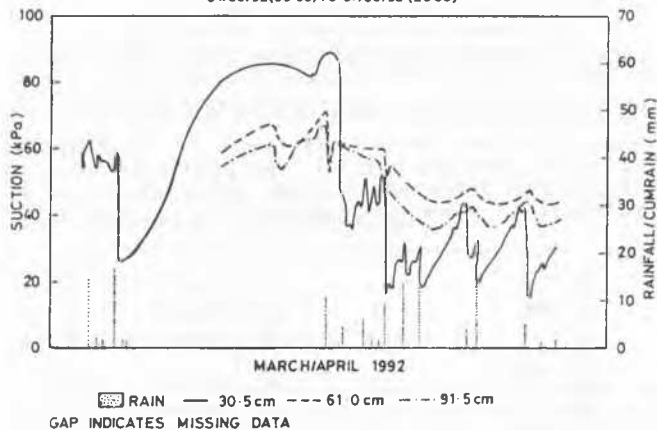


Figure 5.0 Suction Variation for Berm 4

The suction reading for the shallower depth seems higher than that of the deeper locations. Furthermore, the response due to rainfall is less pronounced as the depth is increases. There seems to be a limiting value for suction at various depths. The suction values levels up to certain value, depending on the depth, after a spell of dry weather. The largest drop in suction value due to a rainfall intensity of is from a high value of 89.2 kPa to 35.4 kPa.(depth 30.5 cm)

These drop in suction decreases as the depth increases. Similar behaviour is experiences in studies conducted on residual soils in Hong Kong.

Figure 6 (a), (b) and (c) shows plot of suction against cummulative rainfall for various depths (30.5, 61.0 and 91.5 cm). The plot of suction values at 30.5 cm depth for various berms shows that the response for the various grade of granite behaves differently.

SUCTION VARIATION WITH RAINFALL FOR ALL BERMS
25/01/92(12:00) TO 12/05/92 (14:30)

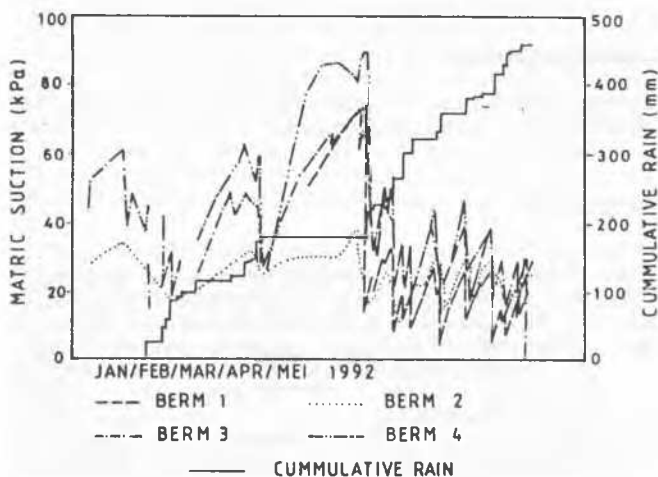


Figure 6a. Suction Variation - 30.5 cm Deep

SUCTION VARIATION WITH RAINFALL FOR ALL BERMS
25/01/92(12:00) TO 12/05/92(14:30)

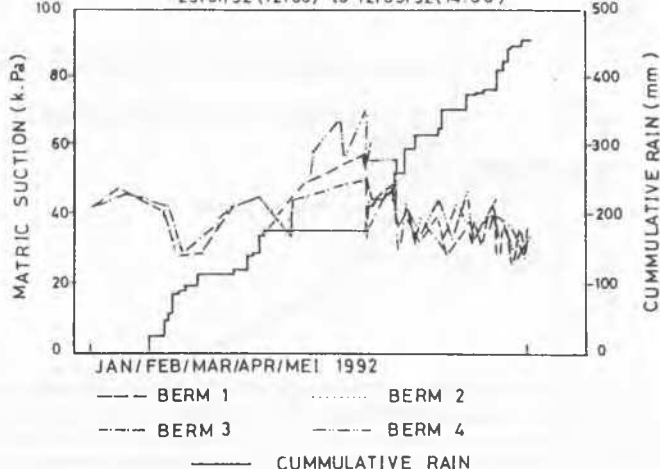


Figure 6b. Suction Variation - 61.0 cm Deep

SUCTION VARIATION WITH RAINFALL FOR ALL BERMS
25/01/92(12:00) TO 12/05/92 (14:30)

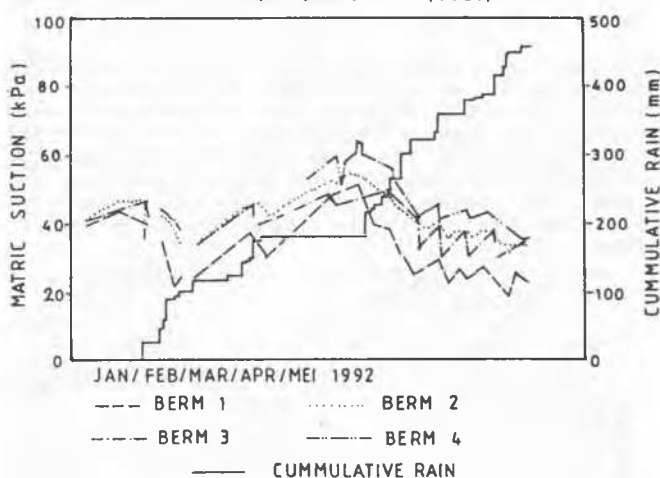


Figure 6c. Suction Variation - 91.5 cm Deep

The suction variation for different berms at 30.5 cm depth is large, while for depths 61.0 cm and 91.0 cm the variation is smaller. The fluctuation of suction values at 30.5 cm depth is from below 10 kPa to above 85kPa. For deeper than 61.0 cm the suction variation is between 25kPa and 65kPa.

PREDICTION OF SOIL SUCTION REDUCTION

A curve has been produced using the available data collected from the instrumented site in order to predict the suction reduction after ascertain rainstorm. All soil suction changes due to storm rainfall events were located on an arbitrary established rainfall axis. Upon repositioning the rainfall events and the corresponding suction changes, a curve defining the suction change due to an antecedent rainfall event was established as shown in figure 7.0.

SUCTION PREDICTION CURVE

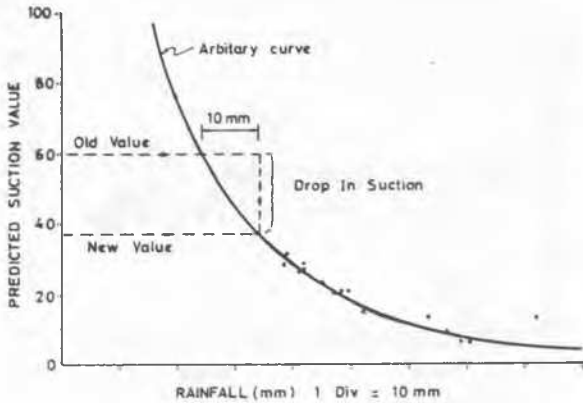


Figure 7.0 Suction Reduction Prediction Curve

The suction values before the rainfall event and the total amount of rainfall can be used to predict the minimum suction resulting from such a rainfall event. The exponentially based curves can be established for various weathering zones.

This method however, does not allow for positive pressures to be established. Furthermore, this method is particularly not satisfactory with regards to physical processes of soil moisture distribution in the unsaturated zone and the continuity between the unsaturated zone and the saturated phase. The predicted data fit reasonably well with the actual values as seen in figure 8.0.

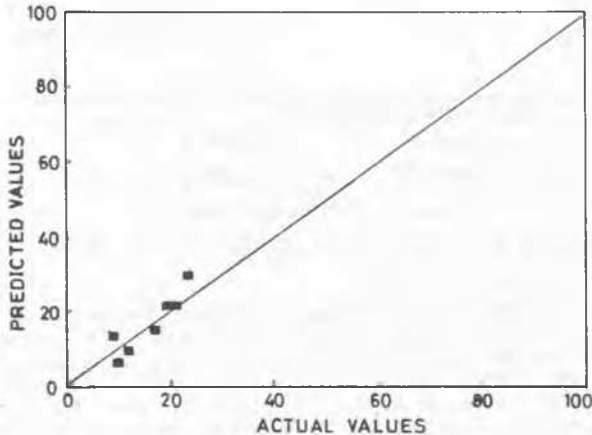


Figure 8.0 Suction Reduction - Actual vs Predicted

SUCTION RECOVERY PREDICTION

Initial analysis undertaken to predict the resulting suction values (S_r) for different period (T) after the cessation of rainfall, and the start suction condition being the lowest suction attained during a rainstorm (S_1) for a berm at approximately 30.5 cm depth is as follows:

$$S_r = 0.183 + 0.97 S_1 + 0.134T$$

where,

S_r = resulting suction value in kPa

S_1 = lowest suction attained during rainstorm in kPa

T = period after cessation of rainfall in hours.

A plot of the suction recovery for the actual value of suction against the predicted suction values for different periods after cessation of rainfall is shown in figure 9.0.

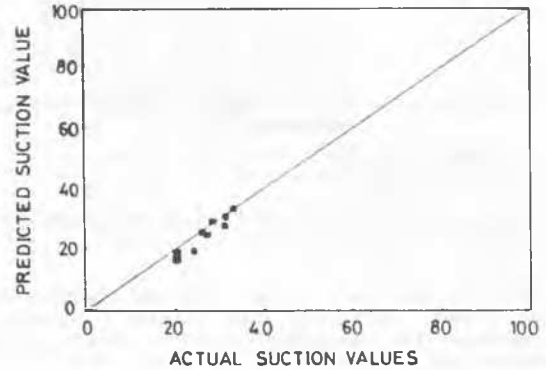


Figure 9.0 Suction Recovery - Actual vs Predicted

CONCLUDING REMARKS

The following conclusions are made with reference to the data obtained from site.

1. The suction changes decreases with increased depth.
2. There seems to be a limiting suction value for different weathering zones.
3. The suction variation is larger at shallower depths and smaller at greater depths for all weathering zones.
4. The suction reduction curve and the suction recovery equation based on the field data can be useful in design and analysis of cut slopes.

ACKNOWLEDGEMENT

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