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Geotechnical Studies to Assess the Stability of Large Granite and Gneiss Boulders Occurring on Hill Slopes at Katabari, Gorchuk in Guwahati, Assam, India

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Abstract

Hills of Guwahati are composed of Granite gneiss, Porphyritic Granite, Fine-grained Granite with inclusion of schist, amphibolite, pegmatite, quartzo-feldspathic veins. The Granite Gneiss and the Granites present in the area are highly jointed, through which water can percolate within the rocks. The percolation of water within the rocks cause weathering and erosion along the joint planes which increase the aperture between the joint planes. This led to the formation of giant boulders and rock fragments which are disintegrated from the basement rock. These boulders and rock fragments are than placed within the hill slopes of the region in a metastable condition and are likely to fall, roll or slide down. Falling, rolling or sliding down of these boulders and rock fragments causes loss of life and property of the inhabitants in the valleys of these hill slopes. From the slope stability study, it can be infer that almost 67% of the boulders in the region are unstable and only 33% of the boulders are stable. Geotechnical investigation of the soil in the hill slope brought to a result that the liquid limit of the soil in the hill slope, as calculated is 38.35%. Thus, if the water content of the soil in the hill slope exceeds 38.35%, the soil is likely to behave as a fluid and flow down and this situation is most likely to occur during the rainy season.

Keywords: Stability study, Boulders, Geotechnical study, Guwahati

INTRODUCTION

Guwahati, the capital city of Assam and gateway to seven north eastern states of India, has witnessed many landslide causing death and destruction particularly during last few decades. However, in spite of the fact that among all natural hazards landslide has caused maximum loss of life during the last few decades, comprehensive study taking into account of all aspects of landslide hazard are not yet available in public domain.

Prolonged percolation of surface runoff into the ground leads to chemical weathering of the bedrock. This is particularly evident on hills composed of igneous and metamorphic rocks. The initial stages of weathering involves removal of the soil cover, which is followed by widening of joint planes and finally the formation of boulders of varying dimensions. Often these boulders are found critically lodged on hill tops and hill slopes, thus posing as hazards to life and property. A similar type of situation exists at various locations in the hills within Guwahati City, Assam, particularly in terrain composed of quartzo-feldspathic gneiss and porphyritic granites.

GEOLOGY OF THE STUDY AREA:

The Guwahati city is characterized by unique geological and geomorphological setting of verdant hills and intermountain valleys. Geologically it is a part of Meghalaya Precambrian Province or the Shillong Plateau, which is the eastern most extension of the Indian shield, separated from the rest by the Garo-Rajmahal Graben.

The present study area is situated in the Katabari hill, Gorchuk, Guwahati. The terrain is composed of Precambrian Gneiss and Porphyritic Granite intruded by Metabasites and pegmatite veins of later ages. These rocks are capped by recent overburden formed by weathering of the Gneisses and the Granites and colluvial sediments.

Table 1. A generalize stratigraphy of the study area has been summarized below.

Age	**Group**	**Formation**	**Lithology**
Phanerozoic (Neogene)		Regolith and Collovium	Fresh deposited, easily friable
Unconformity			
Late Proterozoic / Early Cambrian		Porphyritic Granite	Quartz, Feldspar and Biotite with preferred orientation of feldspar grain
Unconformity			
Paleoproterozoic	Basement Gneissic Complex		Banded, migmatised and affected by multiple episode of deformation

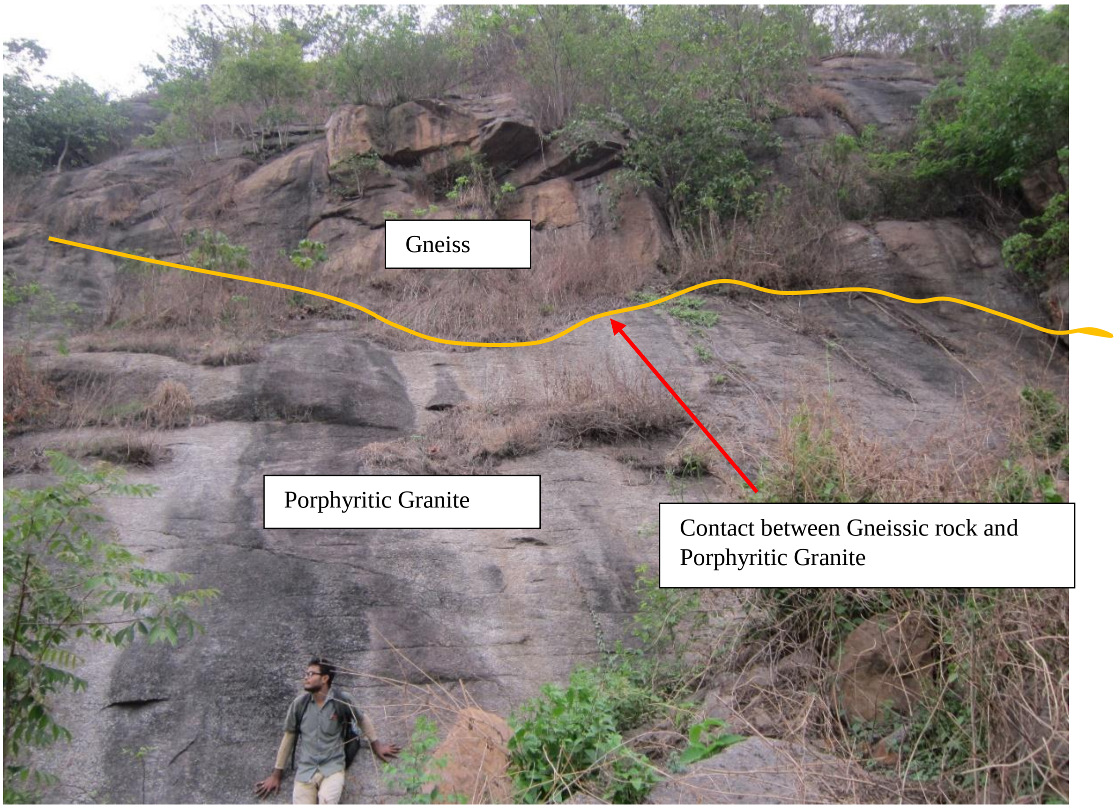


Fig. 1: Photograph showing Contact between Gneissic rock and Porphyritic Granite.

METHODOLOGY:

The Limit Equilibrium Method (E. Hoek and J.W. Bray, 1981; D.C. Wyllie and C.W. Mah, 2004) has been use in this project work for the determination of the stability of the boulders in the hill slope.

The stability of a boulder in a hill slope depends on the shear strength generated along the sliding surface. For all shear type failures rock can be assumed to be Mohr – Coulomb material in which the shear strength is expressed in terms of the cohesion ‘c’ and friction angle ‘ϕ’. For a sliding surface on which there is an effective normal stress σ’ acting, the shear strength τ developed on this surface is given by

$$\tau = c + \sigma' \tan\phi \qquad \text{-----------} \qquad (1)$$

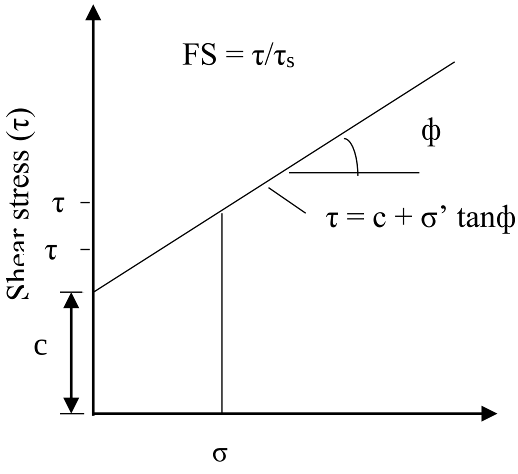


Fig. 2: Mohr diagram showing shear strength define by cohesion c and friction angle ϕ.

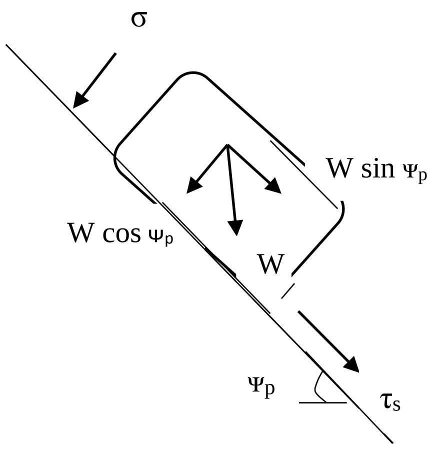


Fig. 3: Resolution of force W due to weight of the block into components parallel and perpendicular to the sliding plane (dip Ψ_p).

Normal stress, $\sigma = \dfrac{W\cos\Psi_p}{A}$ *and*

Shear stress, $\tau_s = \dfrac{W\sin\Psi_p}{A}$ ——— (2)

Equation 1 can be express as,

$$\tau = c + \frac{W\cos\Psi_p\tan\phi}{A} \qquad (3)$$

$\tau_s A = W\sin\Psi_p$ *and*

$\tau A = cA + W\cos\Psi_p\tan\phi$ ——— (4)

Or,

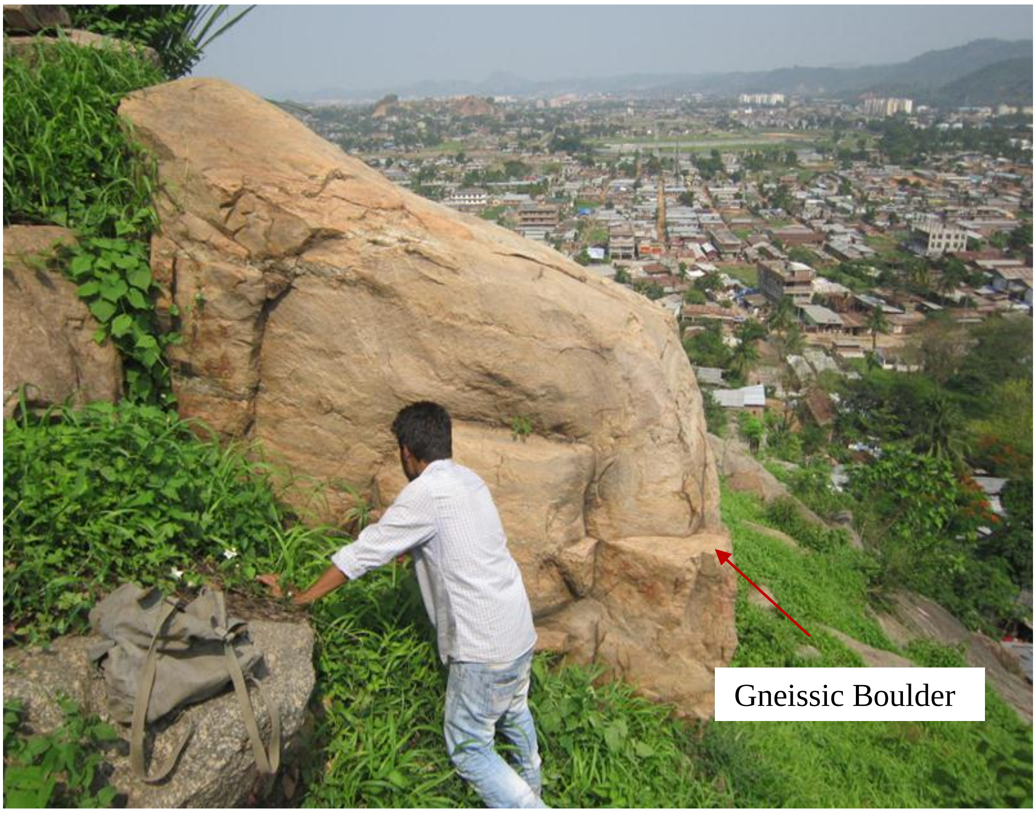


Fig. 4: Photograph of a large gneissic boulder in the hill slope.

In equation 4, the term [W sin Ψ_p] defines the resultant force acting down the sliding plane and is termed the "driving force" (τ_s A), while the term [c A + W cos $\Psi_p$tan ϕ] defines the shear strength force acting up the plane that resist sliding and are termed the "resisting force" (τA). The stability of the block in fig. 3 can be quantified by the ratio of the resisting and driving forces, which is termed the factor of safety, FS. Therefore, the expression for the factor of safety is

$$FS = \frac{Resisting\ force}{Driving\ force} \qquad (5)$$

$$FS = \frac{c\,A + W\cos\Psi_p \tan\phi}{W\sin\Psi_p} \qquad (6)$$

Under different geometric condition a boulder or rock block may slide or topple and thus different forms of limit equilibrium analysis is to be use depending on their geometry. Fig. 5 shows the geometry of a block with width Δx and height y of the block, the dip Ψ_p of the plane on which it lies.

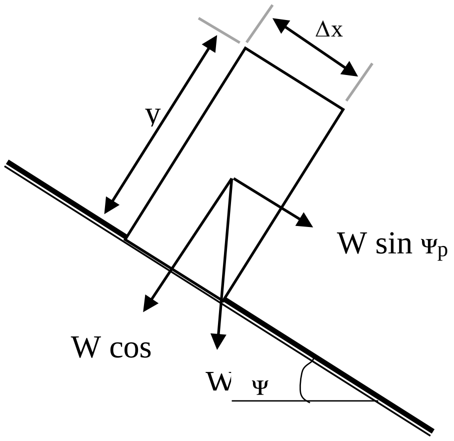


Fig. 5: Geometry of a block on incline plane.

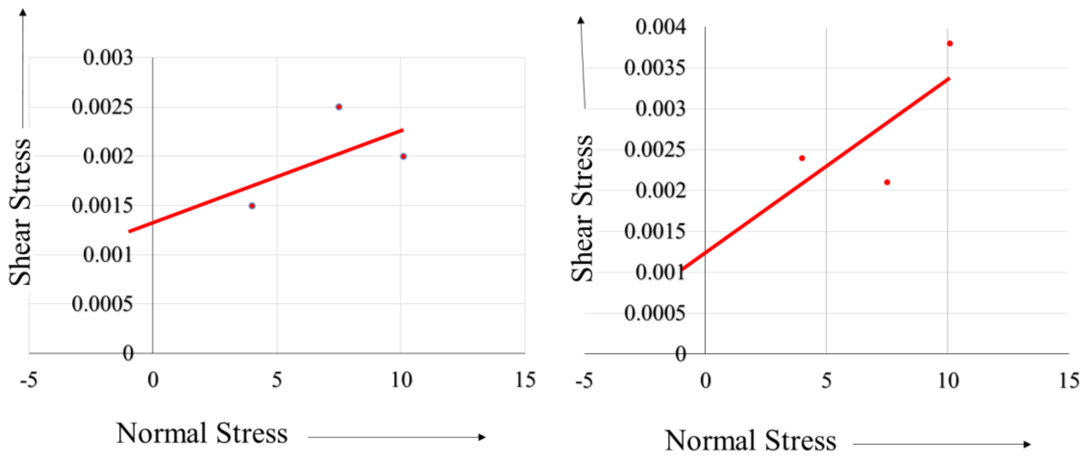
Observations and Calculations:

The densities of the rocks are:

Gneiss = 25900 kg/m^3

Granite = 26700 kg/m^3

The shear strength of the soil samples is measured following the standard procedure of direct shear test.



Graph 1&2: Shear stress versus Normal stress plot of soil sample set – 1 and 3

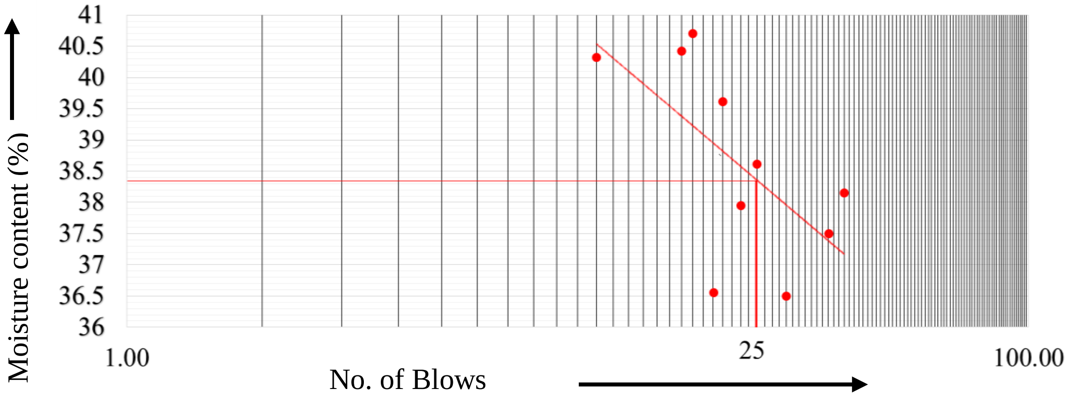
The average cohesion and friction angle from the above two graph are:

Cohesion (c) = 0.001275

Friction Angle (ϕ) = 26.5°

The water content of the soil sample determined by oven drying method (BIS code no. : IS2720-2) = 17.13662352

The liquid limit of the soil sample has been measured using Casagrande apparatus (BIS code no : IS2720-5)



Graph 3: Water content versus no. of blows plot in a semi logarithmic scale.

Thus the liquid limit of the soil sample collected from the study area is 38.35%.

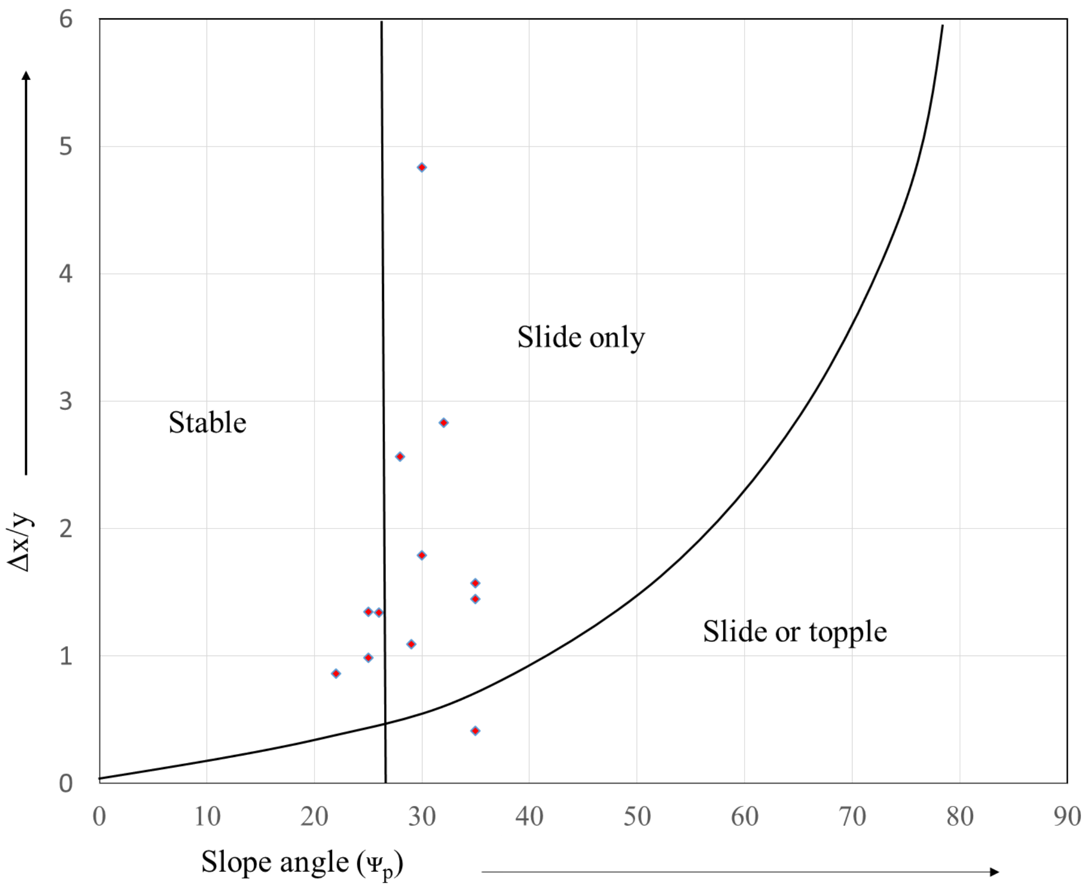
Measurement of Stability:

Table 2: Measurement of factor of safety of the boulders in the hill slope.

Boulder No.	Area (m^2)	Weight (kg)	Slope angle (Ψ_p)	Cos Ψ_p	Sin Ψ_p	Tan ϕ	factor of safety (FS)	Remark
1	1.483	1536.388	30	0.866	0.5	0.499	0.8642704	Unstable
2	0.674	3002.535	35	0.819	0.574	0.499	0.7119883	Unstable
3	6.78	34769.19	29	0.875	0.485	0.499	0.9002582	Unstable
4	0.521	828.5254	25	0.906	0.423	0.499	1.0687820	Stable
5	0.912	1114.901	26	0.899	0.438	0.499	1.0242055	Stable
6	1.294	2557.163	25	0.906	0.423	0.499	1.0687816	Stable
7	0.515	960.372	22	0.927	0.375	0.499	1.2335298	Stable
8	0.38	527.592	35	0.819	0.574	0.499	0.7119894	Unstable
9	0.748	1256.213	35	0.819	0.574	0.499	0.7119891	Unstable
10	2.194	7732.533	30	0.866	0.5	0.499	0.8642687	Unstable
11	4.367	15740.85	28	0.883	0.469	0.499	0.9394826	Unstable
12	1.567	2631.666	32	0.848	0.53	0.499	0.7984014	Unstable

Mode of Failure:

The mode of failure of the boulders in the hill slope is estimated by the Δx/y versus slope angle (Ψ_p) plot on a graph



Graph – 4: Δx/y versus slope angle (Ψ_p) plot of boulders in hill slope of the study area (based on Hoek and Bray, 1977).

INFERENCE AND CONCLUSION:

- From the situation encountered in the above study, it can be infered that almost 67% of the boulders in the region are unstable and only 33% of the boulders are stable.
- From the plot of Δx/y versus slope angle (Ψ_p) almost 58% of the considered boulders in the slope are likely to slide down, 8% of the boulders in the slope are likely to slide or topple down while 33% of the boulders are stable in the slope.
- Geotechnical investigation of the soil in the hill slope brought to a result that the liquid limit of the soil in the hill slope is 38.35%. Thus, if the water content of the soil in the hill slope exceeds 38.35%, the soil is likely to behave as a fluid and flow down, giving an inertial force to the boulders in the slope to slide down.

This situation is most likely to occur during the rainy season, due to intense rainfall causing an increase in the water content of the soil in the hill slope.

- Considering the above values and factors, the boulders in the slope of Katabari hill are not stable. The base of the slope is inhabited by human population, and thus it is a highly risk zone. So necessary measures to mitigate and prevent the loss of life and property is strongly recommended in the area. Necessary protective measures should be taken in the area for the well-being of the inhabitants of the Katabari area.

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