Analyses of a residual soil slope at Addishu area, Tigray, Northern Ethiopia

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Abstract

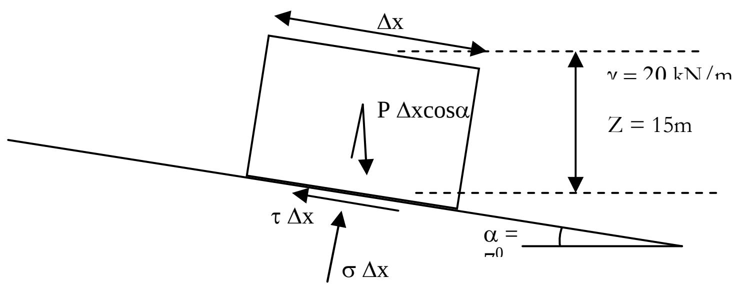
Landslides have been causing major socio-economic problems in the highlands of Ethiopia. Statistics show that rainfall-triggered landslides are common in most of the hilly and mountainous regions of the Ethiopian highlands. Due to population expansion, many rural people are moving into areas which are potentially endangered by slope instabilities, and some towns and cities are expanding into landslide-prone areas without proper risk assessment and mitigation. This has become a serious concern to the general public, planners and decision makers at various levels of the government. Despite this, however, the causes and mechanisms of slope failures remain poorly understood so far and little effort has been made to mitigate them or reduce losses resulting from these landslides.

This project focuses on slope stability problems in Addishu area, southern Tigray, northern Ethiopia. The study area has an estimated size of 70 square kilometres (14 km length by 5 km width). Landslides in this area have displaced about 120 people, destroyed 75 rural houses and caused major damage on about 11 hectare of agricultural land. However, more than 500 people are still living in terrains potentially endangered by slope instabilities.

The slip surfaces associated with natural residual soils are often situated above the ground table and analysis using different models indicated that suction played an important role towards the stability of the slope during dry periods. Therefore, it was important to quantify the contribution of negative pore water pressure to the shear strength of the soils. Hence, the numerical analyses were focused on using the principles of unsaturated soil mechanics, which considers the effect of matric suction. Analyses results reveal several combinations of incidents that could have potentials to cause instability, leading to failure. One such mechanism indicated that the slope has been stable due to high suction resulting from excessive evaporation, typical in tropical areas. Thus during the rainy season, (a) accumulation of water could reduce the matric suction, (b) highly permeable soil layers at the top and middle parts of the slope could ease the way for perched water table formation together with concave plan-concave profile topography, and (c) the active erosion at the river banks could increase the instability of slope. Effects of various combinations of the above processes are likely to have initiated the failure at the toe and propagated it up the slope.

Fig 1 First part of the slide area

A Very simple model



A very Simple equilibrium consideration of a block by neglecting the variation of the interslice forces gives

$\sigma' = (P-U)*(\cos\alpha)^2$

$\tau_f = c + \sigma'\tan\phi$

$\tau = P\sin\alpha\cos\alpha$

From which the factor of safety F = shear strength/shear stress = τ_f/τ

Taking some representative values for the lower section of the slope;

$\sigma' = (P-U)\ (\cos a)^2 = (15*20 - U)*(\cos 7)^2$

$\tau_f = c + \sigma'\tan\phi = 12 + (15*20 - U)*(\cos 7)^2*\tan 17^0 = 102 - 0.3U$

$\tau = P\sin\alpha\cos\alpha = 36\ kN/m^2$

$F = \tau_f/\tau = (102 - 0.3U)/(36)$

For U = 0, F = 2.8

And for F = 1.00 then U = 220 kN/m^2