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ALUMNI SEMINAR

DAAD Deutscher Akademischer Austausch Dienst
Serviço Alemão de Intercâmbio Acadêmico

Natural Hazards – Research on natural disasters, civil defense, disaster prevention, and aid

Teresópolis / Rio de Janeiro - Brazil, June 15th to 17th, 2012

Aspects of Movement of Coluvium in the Mountain Areas in Tropical Region

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Abstract
This article presents a study of movements of natural slopes coluvium, taking as example the situation of “Coroa Grande” in the state of Rio de Janeiro. The analysis considered results of instrumentation with inclinometers and piezometers in the area between 1986 and 2004. It was observed that the slope is moving slowly by “creeping” with displacement speed strongly influenced by rainfall.

Keywords: Natural Slopes; Creeping; Instrumentation; Displacement

Introduction
The natural slope, object of this work, is located in the coastal part of Serra do Mar in Coroa Grande, municipality of Itaguaí, state of Rio de Janeiro. At the foot of the hill is the BR-101 highway. A PETROBRAS oil pipeline lies on that area, which carries oil from a terminal located near the city of Angra dos Reis-RJ to a terminal located in Guanabara Bay, as shown in Figure 1. Thus, knowing and monitoring the hillside movements with a view of taking appropriate measures in case of impending landslides that could endanger people who live or travel in the region and harm the environment is of crucial importance.
The average inclination of the instrumented slope area is approximately 17%, being the subsoil consisted of two soil layers over rock: the first and most superficial layer is colluvial, consisting of clayey sand with gravel. The second layer of residual soil is silty clay and sandy with the presence of gravel. The deep bedrock is composed of sound gneiss rock, being altered in some nearby parts of the residual soil.
This article brings an analysis of the slope displacement from instrumentation data obtained between 1986 and 2004.

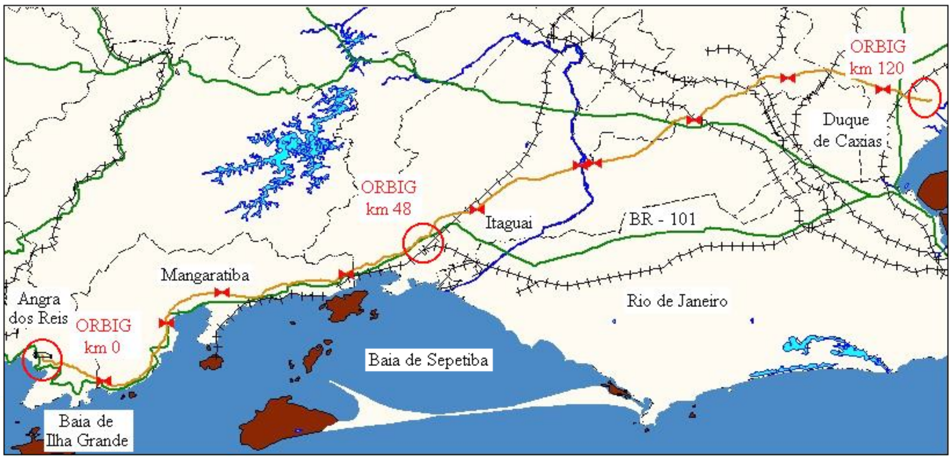

Fig. 1 - Location of the study area, Rio-Baía Pipeline at Ilha Grande - ORBIG and the BR – 101 highway.

Materials & Methods

An observational analysis of movements was conducted in the “Coroa Grande” hillside through instrumentation performed from 1986 to 1999 and from 2000 to 2004. The instrumentation considered in the study, from 1986 to 1999, was composed of 7 inclinometers, 1 Casagrande-type piezometer and 1 water level meter. The rainfall data used here were provided by the State Superintendent of Rivers and Lakes of the State of Rio de Janeiro, SERLA-RJ, for the rain gauge stations of Mendanha and Santa Cruz, the closest to the instrumented area and located about 50 km away.

The influence of rainfalls in variations of water level meters and piezometers was verified. Similarly to that reported by [1] also for slopes from the “Serra do Mar” mountain, there is a relationship between rainfalls, piezometric and water table levels, as well as horizontal displacement speed on the slope. It was also verified, in most situations, that the piezometric load and water levels values increased with increasing the amount of rain. It can be considered through relationships verified by [4] and [3] that in “Coroa Grande”, the amount of rainfall is 50% higher than that in “Mendanha”.

When considering the relations between the results of the displacement speed of inclinometers and the amounts of rainfall recorded at “Mendanha” and “Santa Cruz” stations, it could be verified that the rainfall peaks are close to the displacement speed peaks on the slope, as will be shown in the analysis of the results of inclinometers.

With the instrumentation results obtained with inclinometers, the sliding surface was identified and through the displacement speed, it was possible to classify the movement and analyze the stability of the “Coroa Grande” slope.

To reach the critical sliding surface, the depth equivalent to the maximum distortion was identified from the results of inclinometers for each inclinometer profile. According to the instrumentation results in the region, throughout the monitoring period, it appears that the critical or sliding surface was verified at different depths, ranging from 4.5 m to 11.5 m in relation to the ground surface level. Although several critical depths at different inclinometers were found, there is no evidence of two sliding surfaces in the same horizontal displacement profile. We assume, then, that this is the same surface, and it was possible viewing it through graphical representation in three dimensions or in topographic plant, by drawing the contour lines based on results obtained from the inclinometers. The sliding surface, recorded in the period, is located in the saturated soil even in the dry period, and very close to the contact of the colluvial soil layer with residual soil layer.

The study on the displacement speed in the period from November 1986 to August 1999 showed that the movement occurred in the study region ranges from very slow to extremely slow [2]. Analyzing each interval between measurements individually, it was observed, even in the worst situation, that the soil mass movement is by creep [6]. However, considering the entire observation period, there are variations in the horizontal displacement speed, which according to what was presented here, are influenced by rainfall, then, it is concluded that the soil mass moves by “creeping”. Significant accelerations were recorded for the water table levels observed in a water level meter, above 97.05 m

Despite changes verified in horizontal displacement speeds, in the situations studied, the behavior of “horizontal displacement speed x time” curves and the speed levels achieved indicated no trends of rupture. The speeds had small oscillation around average equivalent to 0.05 mm / day. Accelerations of the displacement speeds are checked only during rainy seasons, reaching a maximum of 0.66 mm / day in November 1998.

The movement observed in the case shown is considered its worst situation, of low destructive power [2]. Some permanent structures may remain intact during the movement. Proven cases show situations of movements within the same speed range and without significant damage [7]. According to [5], for cases of residual and coluvionar soils, speeds from 2 to 5 cm / day during periods of heavy rain indicate imminent collapse.

Results & Discussion

According to the results of inclinometers, throughout the monitoring period, one could observe that the sliding surface was predominantly verified on the contact surface of the colluvial with the residual soil. Considering the results of the water level meter in the study period, it was found that the sliding surface is located in saturated soil, even in the dry season.

The study of the displacement speed proved that the movement occurred in the studied region is by “creeping”. The increase in the amount of rain, according to what was observed in inclinometers, piezometers and water level meters in the period from June 1988 to June 1991, seemed to cause increases in piezometric hydraulic loads and horizontal displacement speeds, as well as elevation on water table. Despite changes in the horizontal displacement speeds, in the situations studied, the trends in the behavior of “horizontal displacement speed x time” curves did not indicate rupture.

Acknowledgement

The authors would like to thank FINEP / CTPetro for their support in the initial phase of this research, TRANSPETRO-PETROBRAS for providing data for instrumentation, to the general financial support provided by Pronex / MCT, Faperj and CAPES for the scholarship awarded to the first author.

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