Remedial measures in tropical soils

Mesures pour l'amelioration dans les sols tropicaux

A.Carrillo-Gil – *P.E.,MSCE., Director, School of Civil Engineering, Ricardo Palma University, Lima, Peru*
A.Carrillo-Acevedo – *MSc, Member of AC Consultant Engineers S.A.C., Lima, Peru*

ABSTRACT: This paper describes the developing of a different method of slide stabilization carried out in the riverbanks of the Amazon River and in the Peruvian jungle. This method uses sand-cement bags as another form of reinforcement by confinement, erosion protection and emergency repair. Many cases of this slide stabilization method have been successfully implemented, and the performance monitoring of one of these repairs is discussed, along with, a history of the slide, description of the tropical soils, and the mechanism of failure. The application of this method of slide stabilization is also evaluated.

RÉSUMÉ: Ce travail décrit le developpment d'une méthode differente de stabilization des Talus réalizé dans les berges de I'Amazone et dans la forét Péruvianne. Cette méthode utilise des sacs du sableciment comme une autre forme de renforcement par emprisonnement, de protection contre l'erosion et de réparation d'emergence. Beaucoup de cas de cette méthode de stabilization des Talus ont été utilisé avec succés. et on discute la performance observéé pour un de ces cas, dés l'histoire de Talus, la description de sols tropicaux et le mécanisme d'effondrement. On évalue aussi l'application de cette méthode de stabilization.

1 INTRODUCTION

An empirical correlation has been established between the plasticity of tropical soils of the Peruvian Amazon and their plausible classification for design. Carrillo-Gil (1997) applied geomorphology, climatic pedologic information together with a consideration of the type of mother rock underlying the soil to provide the basis for a first attempt to classifying the tropical soils in Peru and placing them into distinct generalized geographical zones.

These hypothesis have been established pursuant to statistical analyses of thousands of data from tests performed in connection with road and airfield construction, as well as from building foundation, ports, and landslides in the main river shores of high jungle and the amazon plains.

Laboratory and field experimental data were obtained for this study. CIU and UU triaxial compression tests were performed to obtain saturated shear strength soil data. In-situ results also provided data that are considered to be more reliable than the laboratory results.

Average values from field and laboratory test results were selected as representative of field conditions. The effect of soil suction was also take into account.

2 SITE CONDITIONS

The general description of the geomorphology of the Amazon region indicates that the low jungle is substantially flat and its height varies between 80 to 400 meters above the mean sea level. Due to this small difference of elevation, rivers flow slowly, getting in dry season the appearance of lakes. This region of the Amazon plain can be indicated as advance erosion type. The Amazon plain is characterize by its great humidity and soil covered by dense tropical vegetation.

Studies establish that in the high jungle and in the limits of the low jungle are found so much igneous rocks as sedimentary, while in the low jungle prevail saprolitic soils originated by the sedimentary rocks of the tertiary, and quaternary and they are formed mainly by sandstones, shales, and clays (Carrillo-Gil, Dominguez, 1996).

The general geology considers that a large part of the Amazon region has stayed covered during the interglacial periods of the quaternary by an interior sea of shallow water when the level of the oceans had 100 meters above of the existing now (330,000 years ago) it also to fluctuate during several glacial and interglacial periods forming terraces throughout the water courses, dropping to 100 meters below of the original level during the last Glacial Era (17,000 years ago) and remaining in these deep channels the large rivers, between then the Amazon river, raising afterwards to the current level (6,000 years ago).

3 SLOPE FAILURE MECHANISM

The most common slope failure in the Peruvian jungle occurs along the riverbeds of the large rivers. The slope failure is due to the fluctuation in the water level. During the dry season the water level lowers. The rivers form meanders over a soft soils of different depths. The meanders flow down the river producing erosion and sedimentation. The continuous change of the meanders up the river, changes the river course and produces change in the river beds that contribute to the occurrence of landslides.

The statistical analysis of the movement of the Amazon River between 1991 and 1996 shows that landslides predominantly occur during low water level periods. The landslide triggering mechanism is considered to be rapid drawdown of the water table within the sliding mass. The lowering of the water level in the river produces that. The river level drops 12 meters in a very short time period. (Carrillo-Carrillo, 1999).

This rapid drawndown is interpreted as a process that increases the undrained deformation of the saturated zone in the affected banks. In others words, the reaction of the stability of the banks to the rapid movement when the water level decreases is similar to the response occurred in an open cut in which is produced a forced alleviation, due to material that previously was offered as lateral support and the was suddenly removed. In this case, as a consequence of the imbalance produced by the rapid drawdown of the river, there is water that remains within the porous structure of the soil, since its level does not decrease to the same speed that the water level. This phenomenon causes an increase in the weight of the bank body, as in the pore pressure with the soil. This effect reduces the shearing strength of the soil, which, together with the effects of the river, causes the land

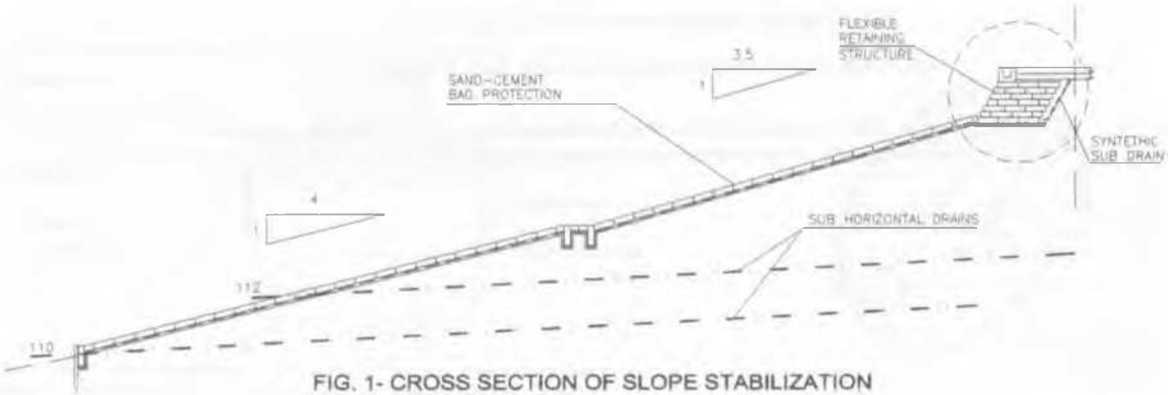

FIG. 1- CROSS SECTION OF SLOPE STABILIZATION

slides (if it has not been possible to evacuate the water tricked within the soil of the bank).

4 LANDSLIDE INVESTIGATIONS

Geotechnical instrumentation was installed in the most critical landslide prone areas. Data obtained has aided in the study of the phenomena described above. Data gathered between 1996 and 1997 and between 1998 and 1999 show that, on the average, movement has not been very significant. These data have been compared with fluctuations of the water level in the river. As a result, it is concluded that drawdown is produced by forces that push the sliding mass towards the river. During raising of the water level of the river the opposite is true.

The above suggests that if a stabilization and slope protection system is to be buiit, the system should be designed to be sufficiently flexible, and not rigid, because the latter will be too costly.

Piezometric readings indicate that, in general, pore pressure dissipation occurs when the river water level lowers. Good behavior has been observed for the drainage system installed in the critical slopes. Slope stability analysis for high pore pressure conditions renders a safety factor less than one. On the other hand, when an adequate internal drainage system is installed in the slope, the pore pressures drop uniformly, and a relatively high safety factor is obtained. These clearly indicates that the best solution should not necessarily include a retaining structure. Instead, an adequate internal drainage system must be included Carrillo-Gil (1998)

5 CASE STUDIED

Some slope stability problems were solved through the use of various methods, ranging from the uses of rigid earth retaining structures (40 million dollars) to geotextile reinforced earth walls (10 million dollars). To arrive to the most appropriate solution, the author used his vast experience from all his previous studies. The method finally adopted was the safest and most economical solution for the problem in question (0.5 million dollars).

The use of flexible retaining structures for improving the stability and surface erosion resistance of slopes is entirely viable in the tropical regions of Peru. The system does not require the use of special equipment, and contributes to the use of local non-skilled hand labor.

The sand-cement bags are placed one on top of the other, thus forming a flexible wall. Analysis and design for this type of wall follows the same general principles used for conventional retaining structures.

The project included 20 sub-horizontal drains, spaced every 5 meters, and placed in two rows. The minimum embedment length used was 30 meters.

These drains are installed in order to dissipate the pore pressures that alter the stability of the saturated soil in the slope, when as a result of the lowering of the water level in the river a rapid drawdown condition is generated. The system helps increase the slope stability by promoting faster drainage, and lower drawdown forces in the slope, thus increasing its sliding stability. See Figure 1.

Because there are permeable natural materials near the site, the design includes the instaliation of synthetic drainage behind the back of the wall. The drain is formed by two layers of geotextile with a layer of geonet in between them. The geotextile allows water to pass across its in plane direction (filtration) and into the geonet, while at the same time preventing the soil travel with the water. The geonet allows water to flow in its in plane direction (drainage). Together, the geotextiles and the geonet constitute a synthetic drainage geocomposite. The geonet includes a network of perforated drainage pipes that collect and discharge drainage water to the drainage channels provided at each end of the protected area.

Polypropylene Bags filled with cement and sand were used to protect the slope against erosion due to the river flow. These bags are placed over the slope following a special pattern where one sac is piled against the other. Three eighths of an inch steel rods were used to anchor the bags to each other. The anchorage system does not allow movement. An advantage of this type of slope protection is that it does not require ancillary reinforcement, and the use of other costly geosynthetics.

6 FINAL COMMENTS

In summary, on the basis of acquired experience in previous projects (some successful and other not), a solution to the stabilization of riverbank slopes is proposed for used in tropical regions. The system consists in placing sacks filled with cement-sand mixture to protect the slope from erosion and to form a retaining wall. The author has obtained good wall behavior in all of the projects where the described system has been applied. It is suggested that systems similar to the one proposed are convenient for projects where local weathering, soil, and other conditions are similar to those prevailing in the Peruvian jungle.

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