Intense rainstorms and ground slides

Pluies intenses et glissements de terrain

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SYNOPSIS: The role played by intense rainstorm either isolatedly or in association with previous periods of continuous rains, as activating mechanisms for ground slides, have been dealt with by several authors, namely Vargas, M. (1971), Guidicini, G. & Iwasa (1977), Brand, E.W. et alii (1984), and others.
Whichever the rainfall characteristics, however, due consideration has to be given to the ground type for a full understanding of the occurring slides. Besides its grain size, also the intervenning soil cap thickness and the quality of the deep seated material are factors that comand the subsequent slide failure. These aspects only now are becoming better known and a discussion of their influence on ground slides is the theme of this paper.

1 INTRODUCTION

During the 1988 summer, there occurred once more, in February, very heavy rainfalls on the city of Rio de Janeiro and on the mountainous city of Petrópolis, about 60km from downtown Rio de Janeiro.

A summary of the rainfalls is reported in the paper by SERLA (1988).

There occurred three unrelated blocks of events which are summarized as follows:

1. Rainfall on the 2nd of February, achieving a day rate of 230mm. This highest rate was observed by the Pluviometric Station of Campo Grande, with a reccurrence period figured at 100 years.

This phenomenon caused floods in the downflowing area to Sepetiba Bay.

2. Heavy rainstorms on Petrópolis on the 6th, achieving a total rainfall rate of 145mm, according to the Petrópolis Pluviometric Station, with a reccurrence period figured at more than 20 years. For the time between January 31st and February 6th, it reached 414mm, when the average monthly rainfall for February is 234mm. The area ravaged by landslides was very large, including nearly 25km along the access roads.

Besides the floods in the city, there were important landslides in the city itself and on the access roads.

3. Heavy rainstorm from the 19th to the 21st, mainly over the Tijuca Massif.

The afore mentioned paper by SERLA (1988) quantifies properly the phenomenon.

In Rio de Janeiro, the phenomenon was much less destructive than it was in 1966-67, certainly due to nearly 3000 stabilization works accomplished by the Geotechnics Department since it was founded in 1966 (Costa Nunes, 1986).

In 1966-1967, the number of casualties due to the landslides in the city of Rio de Janeiro was over 200, whilst in last February this number was about 80, 21 out of which came from one single place (Santa Genoveva Hospital).

It is important to remark that the behaviour of Rio's slopes was normal until the eighth day of rainfall, i.e., until February 9th, 1988, and the large and more destructive number of accidents only took place on the 19th.

The great majority of the accidents accurred with unstable constructions of the shanty house type ("favelas"), which were hit by rock boulders and blocks, land erosions, collapsed dumps and garbage placed on the slopes (the most characteristic example was that of Dona Marta Hill Shantytown, in Botafogo - Rosa & Lacerda, 1988).

In Petrópolis were counted more than 200 deaths, most of them victimized in unstable constructions.

The senior author has published, in the 7th Conference (1969), a contribution regarding the phenomenon characteristics of the intense rainstorms that affected Rio de Janeiro and neighbouring cities in 1966 and 1967.

Since then, valuable contributions have been presented by other authors, regarding the correlation between rainfall characteristics and the ensuing ground slides.

This work discusses the subject, face newly-acquired experiences.

2 THE INFLUENCE OF GROUND TYPE ON RAINFALL-INDUCED SLIDES

Due to a series of geologic, topographic and climatic features, several ground slides accur throughout the world, that are connected to rainstorms of an exceptional nature, which once affecting urban developments result in greatly damaging catastrophes.

There is general agreement between the various authors that the phenomenon, when related to a high number of slides, depend upon the superposition of various factors:

a) Rainfall intensity

Some authors, like Vargas, M. (1967, 1977) and Brand (1984) correlate the phenomenon exclusively to rainfall intensity, disregarding as important the previous rain duration for the slides.

For example, Vargas, M. (1971) concludes that, when rainfall intensity overcomes 100mm/day, slide probability is very high.

Other authors, as Guidicini & Iwasa (1977), present correlations in which two factors are considered important: the influence of previous rains for ground saturation and the rainfall intensity that will trigger, finally, the slide.

b) Ground nature

Ground characteristics have a decisive influence, in our opinion, both in the slide type that is induced and the influence end product of the previous rain duration.

In schematic fashion, to be quantified by boring logs and soil tests, we could distinguish ground nature, face its behaviour in slide, in the following types:

b.1) Relatively thin (up to 5 meters) coluvial or residual soil caps overlying rock.

In this case, the soil cap slides over rock, suddenly, without any previous warning, if the material is predominantly silty-clayey (Fig. 1).

Figure 1. Cap slide over rock (Lugano Street, Petrópolis-RJ).

Water seepage pressures seem decisive for this soil class (Vargas & Pichler - 1967).

If the ground is mostly sandy, the slide over rock mechanism is as much apt to occur as erosion, which ensues a "hydraulic excavation" of the ground cap.

b.2) Thick, highly weathered residual or collapsible coluvial (or talus), over more resistant ground, with pronounced slope angle (Fig. 2).

Figure 2. Thick, highly weathered residual or collapsible coluvial (or talus) over more resistant ground, with pronounced slope angle.

In this case, conchoidal surface ruptures predominate, specially if the ground is silty clayey.

If the ground is mostly sandy, superficial and deep erosion ("vossorocas") effects are as much apt to occur as conchoidal slide surfaces.

b.3) Thick silty clayey coluvial soils with low slope angle (Fig. 3).

In spite of the slope low angle, an important fluency effect has been observed, which promotes high lateral displacements, leading to damages to nearby structures, without any evidence of ground rupturing.

Further new data has recently been acquired about deep coluvial deposits that show high SPT values (above 15), in spite of which have a tendency to flow during prolonged rainy periods. That is a new condition to be dealt with (Fig. 4).

b.4) Expansive soils, specially those of the Salvador Bay region, whose behaviour has been discussed in the work edited by Barry Voight (Costa Nunes, Couto e Fonseca & Hunt - 1979).

This ground type has its shearing resistance totally dependent on the moisture content and the degree of weathering dictates the slide pattern.

When the ground (calcareous shale) is only

Figure 3. Thick silty clayey coluvial soils with low angle.

slightly weathered, ruptures surface are planar, following clivage or structural discontinuities (as in shales).

As weathering degree progresses, rupture surfaces turn to be conchoidal and, finally, occur as viscous displacements and mud flows.

3 CLOSURE REMARKS

3.1 Consequences of the ground type on the relative importance of two factors regarding rainfall characteristics as in Guidicini & Iwasa (1977)

In sandy grounds, with moderately intense rainfall, one can observe water seeping through the slope material and the cumulative effect with peak rainfall intensity, as foreseen by Guidicini and Iwasa, does not occur in large scale.

On the contrary, if the ground is predominantely silty-clayey, intersticial drainage is slow and pore pressure from previous seepages add their effects to those of intense later-occurring rainfalls.

3.2 The basement rock role

In mountainous regions, as those related to neighbouring cities of Rio de Janeiro, like Petrópolis, Teresópolis and Friburgo, to name only the best known, the role represented by the deeply seated rock massif, as a permanent water reservoir, is poorly understood.

The naturally fractured rock, that underlies the widespread regolith, has an abrupt boundary seawards, at which elevations jump from about 0 to more than 1000 meters in a relatively short horizontal distance.

The rock that bounds this physiographic feature has several water seeps throughout the year; since fractures can reach several kilometers in length, water kept-in permanentely may reach thousands of cubic meters in spite of the milimetric, even less so, fracture widths. Therefore, the regolith base interface has a low shearing resistance due to the high pore pressure, although the material itself may yield high cohesion and friction angle in lab shear tests.

This is an obvious source of slope instability, albeit often deep seated, that would not require severe rainpours or long rainy periods to reach dangerous pore pressure levels. This is a new evaluation that is being applied to the special physiographic conditions related to some of Rio de Janeiro's neighbouring cities.

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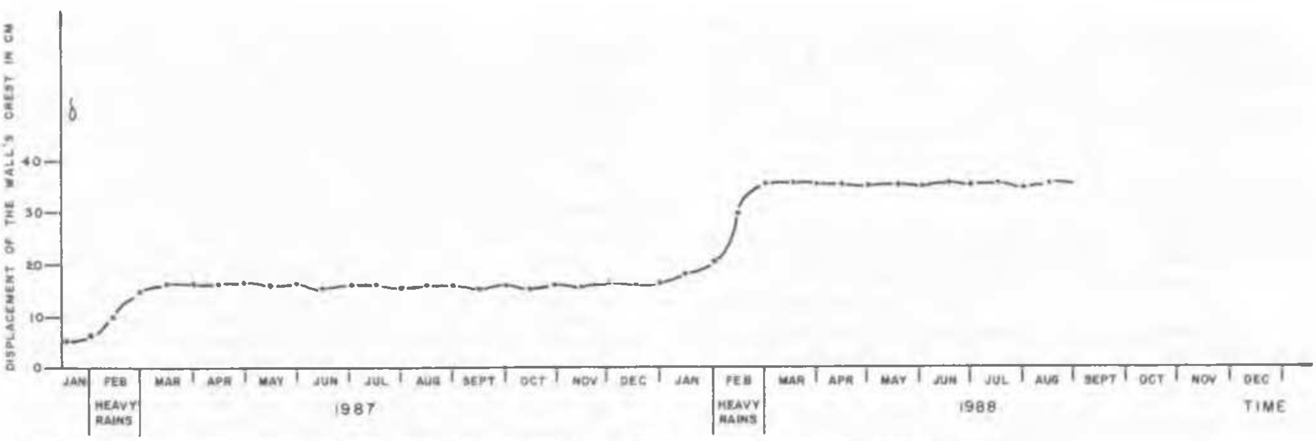

Figure 4. Displacement of the retaining wall's crest during heavy rains.

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