

Geological and geomorphological characteristics of basins with debris flows in Rio de Janeiro, Brazil

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1. Introduction

Since the severe disasters caused by mass movements in January 2011 in the Mountain Region of the State of Rio de Janeiro, the Federal Government of Brazil has been making investments in strengthening the capacity for prevention and response to natural disasters. In order to solve these problems by engineering projects and Sabo dams, two municipalities were chosen to be worked: Nova Friburgo and Teresópolis.



Picture 1. Landslides and debris flows after the heavy rainfalls in Nova Friburgo, 2011 (Dantas river basin).

One of the main measures implemented by the Ministry of Integration and Regional Development concerns the improvement and updating of scientific knowledge on the subject. The Brazilian government, focusing on structural solutions capable of promoting total prevention of damage and maximizing the ability to minimize damage caused by debris flows, has signed a technical cooperation agreement with the Japan International Cooperation Agency - JICA, called the Project for Improving Technical Capacity in Structural Measures against Gravitational Mass Movements with a Focus on Building Resilient Cities - Sabo Project. The partnership aims to transfer knowledge and technology for the development of a technical guidelines manual for engineering projects for the construction of debris flow retention works (Sabo Dams), implementation of works, construction management plans, and maintenance of structures. In the first stage, the construction of two Sabo dams will be carried out as pilot projects for two municipalities: (i) Teresópolis, where a permeable dam was decided to be built, and (ii) Nova Friburgo, where an impermeable dam is being designed. For each municipality were chosen one mountainous forested catchment affected by large debris flows that were the

main cause of the destructions: Duas Pedras basin in Nova Friburgo and Príncipe Basin in Teresópolis. Besides, in a second stage, the development of two engineering projects to be built in the states of São Paulo and Santa Catarina is expected.

2. Methods

Taking into account the technical aspects of the Technical Cooperation Agreement, the studies on debris flows are based on the Sabo Manual. Topographic maps at the 1:10,000 scale have been prepared for the Príncipe basin (Teresópolis) and the Duas Pedras basin at the São Lucas Hospital (Nova Friburgo), associated of satellite images to define land use and vegetation cover. The grain size for each basin was determined by geometry and dimensions of the rock blocks. In the case of Teresópolis, a total of 312 blocks were measured due to the greater availability of rock blocks, while in Nova Friburgo, the number was limited to the minimum recommended in the Japanese method, which was 200 blocks, given the smaller amount of rocks to be measured. The activity was carried out using a manual tape measure, where the major and minor axes of each block were measured.



Picture 2. Field method for measuring the axes of the rock blocks at Duas pedras basin in Nova Friburgo.

The results were plotted in graphs relating the A and C axes (in meters), subsequently determining the percentage granulometric distribution for the following ranges: $<0.5\text{m}$, $0.5\text{m} \leq X < 1.5\text{m}$, and $\geq 1.5\text{m}$.

3. Results

The geology of both basins has predominance of granite that under tropical humid climate generate residual soils with rounded blocks due to spheroidal weathering (Photo 2). After shallow translational landslides and debris flows, these materials are

deposited in the valley bottoms and generate colluviums with rounded blocks of different sizes.

In the upper course of the Príncipe River basin, there is significant forest cover, predominance of very steep slopes ($>25^\circ$) and occurrence of colluviums and residencies in the valley bottoms. The rock blocks are slightly ellipsoidal ($A>C$), with dimensions larger than 1.5m (8%), from 0.5 to 1.5m (48%), and less than 0.5m (44%). Figure 1. It means that D95 is around 2.0 meters in diameter at the this basin.

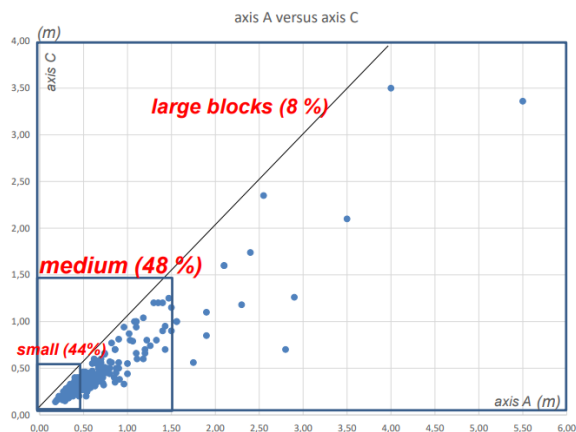


Figure 1. Distribution of the rock blocks size at the Príncipe basin in Teresópolis.

On the other hand, the Duas Pedras basin has a wide area of granite rock outcrops, with even steeper slopes ($>35^\circ$), and a valley floor containing many rounded to slightly ellipsoidal rock blocks ($A\sim C$ or $A>C$), colluvium, and residual soil, where the hospital buildings are located. The measured rock blocks showed dimensions larger than 1.5m (7.5%), from 0.5 to 1.5m (22.5%), and smaller than 0.5m (70.0%). Figure 2. Considering these results we assume the D95 is around 2.5 meters in diameter at the this basin.

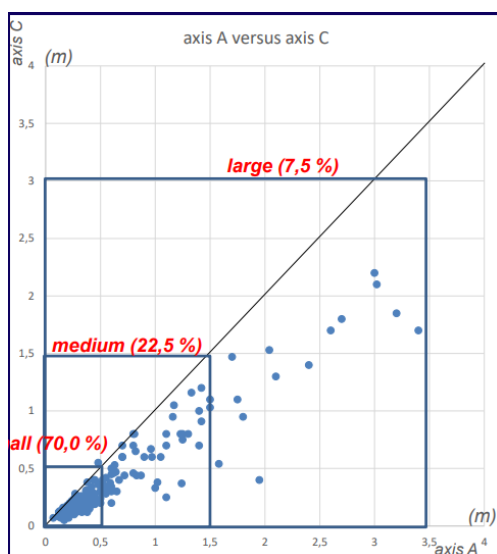


Figure 2. Distribution of the rock blocks size at the Duas Pedras basin in Nova Friburgo.

4. Conclusions

The results indicate that both basins are highly susceptible to debris flows, as occurred in January 2011. These flows are highly destructive due to the high kinetic energy involved, tending to transport sand, silt, and clay downstream and leaving deposits dominated by rock blocks in the upstream of the basins. Therefore, reference points for barriers were predicted in locations where the steeper slope (upstream) transitions to a gentler one (downstream).

The two basins have distinct characteristics regarding the granulometric distribution of blocks from susceptible rock masses that may move and be incorporated into debris flows.

The Príncipe Basin has a greater number of rock blocks scattered along the main channel and its tributaries. During the basin's evolution process, there was a more efficient distribution of large boulders.

In the case of Nova Friburgo, the granulometric distribution favored the concentration of sediment below 0.5m (70%). This distribution was evident in the greater difficulty in finding blocks for measurement, compared to the Príncipe Basin.

These results corroborate the decisions to implant a permeable barrier in Teresópolis, considering the greater need for retaining rock blocks, and the construction of an impermeable barrier in Nova Friburgo, emphasizing the need to retain fine sediments.

Such results will also assist technical committees in sizing the metal structure intended to integrate the permeable barrier.

Keywords: Debris Flow, Sabo Dam, Sediment Retention, Natural Disasters.