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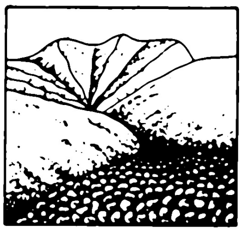

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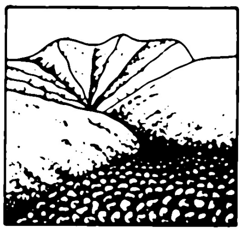

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При создании логотипа конференции использован рисунок из книги С.М. Флейшмана «Селевые потоки» (Москва: Географгиз, 1951, с. 51).
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Debris flow control in Brazilian tropical rain forest mountains

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Контроль селевых потоков в тропической лесной и горной среде Бразилии с большим количеством дождевых осадков

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Твердая органическая и неорганическая фаза в тропических селевых потоках Юго-Восточной Бразилии проанализирована с использованием отдельного коэффициента весовой/объемной концентрации. Неорганическая твердая фаза или обломочный (окатанный) материал удалены при помощи сортирующих устройств, которые задерживают крупные зерна и пропускают более мелкие частицы и воду вниз по течению. Численный пример, в котором использован диаметр Φ Вентворта, представлен с полученным соответствующим сокращением весовой/объемной концентрации. Экономические факторы лимитируют широкомасштабное повторное использование проанализированного процесса, который является относительно дорогостоящей процедурой фильтрования.

The solid organic and inorganic phase present in the tropical debris flows of Southeast Brazil is analysed using separate concentration coefficients by weight/volume. Inorganic solid phase or clastic/granular material is removed by use of sorting devices (structures) that retain the larger grains and transfers the finer grains and water downstream. A numerical example, using Wentworth Φ diameter, is presented with the obtained correspondent weight/volume concentration reduction. Economic factors govern a large and repetitive use of the analysed process, which is limited by a costly filtering procedure.

1 Debris flow's solid phase organic and inorganic components

Debris flows are worldwide phenomena, but in the tropical rain forest scenario they are distinguished among others mass movements by a large organic solid phase presence.

Main debris flows regions of Brazil are encountered in the Serra do Mar and Serra da Mantiqueira ridges located close to the Southern east oceanic coast along a distance of about two thousand kilometers long (Perov et. al. 1997).

The first and lower step is the Serra do Mar of a moderate altitude, only up to 1000 meters height; the second one is the Serra de Mantiqueira with the highest peaks ranging about 3000 meters above the sea level.

An extended and dense tropical rain forest covers as a vegetal mantle both mentioned mountains chains. This vegetal cover is known in Brazil as the Atlantic Forest and represents the main source of organic matter supplied occasionally to the debris flows that occurs frequently in this region.

The Atlantic Forest suffered in past a drastic reduction due to human activities but is still an impressive remnant testimony of a tropical environment. The Atlantic Forest is compound by a large and variable number of specimens represented by high and moderate high trees, bushes, shrubs, herbs and grasses which form the rain forest canopy or the tropical flora.

Such natural milieu represents obviously a formidable source of solid organic material. All described vegetal material, if becoming unstable, is incorporated in the displacing and moving regolitic mass in a greeter or lesser amount. The joint inorganic and organic mass is put in movement and forms a debris flow.

In Brazilian case debris flows are triggered by heavy and/or long duration rainfalls. During the Southern hemisphere rainy month's precipitation remains continuous upon particular meteorological conditions during several days. Observed total mean annual rainfall in the region of Serra do Mar, close to the city of Cubatão, attains 4000 mm/year, some times occurring local daily precipitation of 300 mm (Massad, 2002).

As an unavoidable consequence resulting debris flows represent severe natural disasters and cause serious damages to population and all environments in general.

Tropical debris flows are characterized by the (C_V) volumetric concentration coefficient (adim.) which is written as:

$$C_V = \frac{V_S}{V_T} = \frac{V_S}{V_S + V_A} = \frac{V_{SO} + V_{SI}}{V_S + V_A} = \frac{V_{SO}}{V_S + V_A} + \frac{V_{SI}}{V_S + V_A} = C_{VSO} + C_{VSI} \qquad (1)$$

Where the terms are: V_S, Solid phase volume (m^3); V_A, Liquid phase volume (m^3); V_T, Total, or both phases volume (m^3); V_{SO}, Organic solid phase volume (m^3); V_{SI}, Inorganic solid phase volume (m^3), C_{VSO}, Organic volumetric concentration coefficient (adim.) and C_{VSI}, Inorganic volumetric concentration coefficient (adim.).

The same formulation is also obtained using the (C_P) weight concentration coefficient (adim.) which is figured as:

$$C_P = \frac{P_S}{P_T} = \frac{P_S}{P_S + P_A} = \frac{P_{SO} + P_{SI}}{P_S + P_A} = \frac{P_{SO}}{P_S + P_A} + \frac{P_{SI}}{P_S + P_A} = P_{VSO} + P_{VSI} \qquad (2)$$

The terms in (2) have the same significance as presented before in (1), only changing the volume parameter by the correspondent weight parameter; relation between the two moods of concentration coefficient is easily established and is not presented here.

Organic solid phase concentration coefficients depend on the vegetal cover density, on and on vegetal cover type. The mentioned factors are also related to the debris flows source altitude, to hypsometric coefficient of the debris prone basin, to valleys steepness and local rainfall parameters (precipitations' amount/intensity, area and duration).

Tropical specimens of trees are encountered in lower altitudes, ranging from the sea shore level until approximately 1500 meters elevations above the sea level.

In higher altitudes arboreal vegetation is gradually substituted by bushes, shrubs, herbs and grass and is encountered until 3000 meters altitude correspondent to the highest peaks elevation in Brazilian territory.

It is observed that if large trees logs are incorporated in the debris flows, they are transported by the water/solid mixture (matrix) as floating bodies mostly on the flows surface. They present two sort of behavior, or namely:

- Velocity close to the matrix flow velocity, when the tree logs acquire their maximal moment or quantity of movement and offer a very high destructive potential during possible shocks and collisions with obstacles in their way (Spears or Darts effect);

- Velocity close to zero value, when tree logs are jammed and result in a temporary stable random structure, which dissipates flows' kinetic energy and reduce matrix' discharge velocity. As consequence a flows level heightening occurs (Beavers or Damming effect).

Breaching of such structures occurs in a random way, what origins in this case some debris flow's secondary snouts or wave peaks.

The retention of the organic solid phase (tree logs) is strongly recommended in any one of the above mentioned cases. It is a normally adopted procedure as the first control measure seeking the debris flow control.

2 Grain size sorting or selection

The next control step consists in arrests the larger inorganic solid phase components removing them from the solid/liquid mixture. There are several types of well known structural solutions that achieve the proposed goal: (Flow breakers, Sorting dams, Discharge controllers, Tyrol weirs, Clauzel-Poncet dams, Watanabe-Ikeya separating devices, Flexible net barriers and others).

The listed structures act some time as kinetic energy dissipaters, or as flow discharge regulators, but, all of them promote simultaneously in a proper grade the grain size selection. The final result of a grain size selection process is: a less sediment charged (clearer) flow and an easier maneuverable liquid material with a smaller inertia amount to be handled (quantity of movement or momentum).

With this purpose, the well known AGU (American Geophysical Union) sediment classification chart (Gottschalk, 1964), was adopted by Znamensky & Gramani (2000) for the debris flow grain size analysis and classification, that allows separate the whole grains universe in 3 large groups or domains, Namely they are:

- Macromeritic or macrogranular and clastic domain (M), associated with the rocky or clastic debris flows, also known as "Sturzströme" or "Rock Avalanches".
- Mesomeritic or mesogranular domain (m), represented by the incohesive sandy mudflows.
- Micromeritic or microgranular domain (μ), that encompasses the cohesive loamy/viscous clay flows.

Grain size selection is more effective in the macromeritic or macrogranular (M) domain, as figured in the next presented numerical example based on employ of Φ diameter (Wentworth 1922).

3 Numerical example of grains sorting

Analyzing as an example the observed grain size distribution curve from the Sierra do Mar 1994 debris flows, measured by Kanji et al. (1995), and assuming an initial volumetric concentration coefficient $C_V = 0,53$, obtained grains distribution is presented in the Table 1, as the correspondent Φ diameters accumulated percentages values.

If a determinate sorting device is introduced in the flow with the purpose of retaining particles with the Φ > -7 (or >128 mm) diameter or larger, than the obtained result are two complementary grain curves, precisely as:

- Retained grains curve, with the particles size ranging from diameter Φ = -11 (max.) to diameter Φ > -7 (min.);
- Downstream transferred grains curve, with the larger particles size corresponding to Φ ≤ -7 (max.) until Φ ≥ +11 (min.) diameter, or even smaller diameter if it is measured, represented in the Table 2.

Table 1. Grain size distribution original curve before the sorting procedure

Φ	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1
Σ %	0	100	99	90	80	70	65	60	55	50	47	44
Φ	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10	+11
Σ %	40	32	24	15	13	10	7	5	3	2	1	0

Table 2. Grain size distribution curve after sorting or the downstream transferred solid material

Φ	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1
Σ %	0	0	0	0	0	100	92,3	84,6	76,9	72,3	67,7	61,5
Φ	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10	+11
Σ %	49,2	36,9	23,1	20,0	15,4	10,8	7,7	4,6	3,1	1,5	0	0

Applying the SEDISOMA algorithm, obtained summations result corresponds to the original grain size curve as figured in the Table 1 (Znamensky, 2000).

The result is a substantial reduction in flows' solid concentration, beside other marginal benefits such as: impacts damage reduction, large size sediments stock (construction material) and availability of more easily manageable clearer liquid phase (water and fine sediments).

Proposed procedure can be of course repeated a certain amount of times, retaining every time larger solid grains and removing them by sorting from the downstream transferred mixture. In a broad sense the described procedure tends to behave at the limit as a filtering process. A large and repetitive use of the sorting devices is obviously controlled by the different economic factors which, in the last instance, govern the feasibility of the adopted sorting procedure.

Performing the respective volumetric and/or weight concentration calculations of the exposed numerical example, their results are summarized in the next Table 3.

Table 3. Initial and final solids concentration values.

Solids concentration	By weight	By volume
Initial concentration	0,75	0,53
Final concentration	0,66	0,42

The grain sizes curves, obtained before and after the sorting processes, using the Wentworth Φ diameter are shown in the Figure 1 (Znamensky & Tamada, 2003).

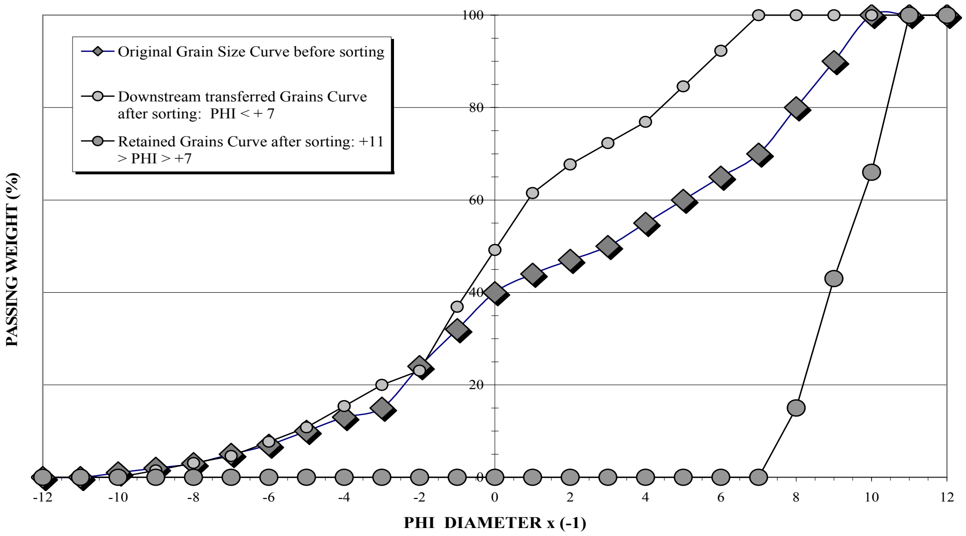

Fig. 1. Graphical representation of the grain size curves before and after sorting.

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