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Dynamic impact of granular material on a vertical obstacle

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Debris flows are rapid to very rapid flows, made up of a high concentrated mixture of water and sediments. These types of flow are catastrophic natural phenomena affecting mountain areas and causing several property damages and loss of lives. The mitigation of these phenomena is then fundamental: the check dams are among the main structural countermeasures. A crucial aspect in the definition of the design criteria for these structures is the analysis of the impact force exerted by a debris flow on them.
From a scientific point of view, the state of art in this field still has aspects that are not fully clear. There are two main approaches adopted: the first one considers the force of dynamic impact exerted on a structure proportional to the hydrostatic pressure. However, from a theoretical point of view, this approach is not so reliable, since the hydrodynamic nature of the phenomenon probably induces pressures on the structure higher than the hydrostatic values. On the other hand, the second approach assumes the force of the dynamic impact proportional to the square of the velocity of the flow, considering the dynamic nature of the impact.
According to Armanini and Scotton (1992), two main types of impact may occur. The first type is characterized by the formation of a reflected wave after the impact, which propagates upstream. A convincing theoretical solution of this problem is achieved through the application of the conservation of mass and momentum equations with respect to a volume control that moves with the reflected wave (Armanini 2009) under the hypothesis of homogeneous fluid.
The second type of impact consists of a complete deviation of the flow along the vertical obstacle, assuming a jet-like behavior. The previous theoretical scheme cannot be applied in this situation, but it must be suitably modified.
In order to better understand the kinematic characteristics of the phenomenon, the debris flow dynamic impact against a vertical wall has been studied in the Hydraulic laboratory of the University of Trento. The phenomenon has been reproduced in a channel of variable slope, by releasing a certain volume of fluid and measuring its impact force on a gate situated at the end of the channel. Several slopes of the channel and concentration of the solid fraction have been investigated.
The results have shown that the pressures distribution along the gate during the dynamic impact cannot be represented, as expected, by a linear distribution.When the flow crash into the gate, it is deviated along the vertical obstacle and forms a vertical jet. In the lower part of the gate, this behavior is characterized by very high pressures values, which tend to zero as soon as the streamlines become parallel to the gate (in the upper part).
Furthermore, the total impact force experimentally measured against the gate has been compared with a theoretical curve, derived from the momentum balance. The experimental data are in good agreement with the theoretical curve, showing the importance of the hydrodynamic term proportional to the square of the velocity.