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Application of dimensional analysis to predict the performance of rockfall barrier

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Natural hazards involving rocks or rock slopes are responsible for loss of life and damage to infrastructure and are consequently widely studied. Rock fall barriers are a common type of protection structures that is usually designed on the basis of total impact energy. However, the systems are usually tested in free fall where the predominant component of energy is kinematic and it has been shown that there is not a unique relationship between the response of a barrier and the kinetic energy of the impacting block. In particular, recent studies have discussed the so called "bullet effect" i.e. relatively small blocks traveling at high speed can perforate the barriers yet having acceptable level of energy. This effect compromises the use of kinetic energy as an adequate design criterion since there is not a threshold value defining clearly acceptable and unacceptable values of energy. This issue can be addressed empirically by using different block sizes when it comes to test a system. However, the literature still lacks a characterization of a rockfall barrier performance regarding the bullet effect.

This note presents the results of the application of dimensional analysis to the physical problem of the bullet effect. This latter has been formulated as a function involving eight key variables:

$v = f(\rho, K, \sigma_y, H, A, D_b, D_w)$

where v is the minimum speed of a given block to break the barrier, ρgs the density of the block, $K$is the stiffness of the system, σ_y is the strength of the wires, H is the height of the barrier, A is the aperture of the mesh, D_b is the dimension of the block and D_w is the diameter of the wire. Applying the Buckingham Pi theorem allows reducing the equation above to a simpler problem involving only three dimensionless parameters:

$E^*=F(S^*, G^*)$

Where $E*$ is the performance parameter, $S*$ is the strength-stiffness parameter and G^* is the geometrical parameters defined as:

$E*= (\rho.v^2.H)/K$

$S^*=K/(H.g\sigma_y)$

And $G^*=A^{-0.25}.D_b^{-0.75}.D_b$

F in the simplified equation is referred to as the Rockfall Barrier Performance, or RoBaP, Model. Results suggest that the dimensional analysis can satisfactorily be used to assess the performance of a barrier when impacted by variable block size. A calibration-prediction exercise has been conducted using data form the literature to assess the predictive capability of the RoBaP model. It has been found that the RoBaP model gives satisfactory results. In particular, the progressive loss of performance of the rock fall barrier as the block size diminishes has been well captured.