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Impact force of debris flow on filter dam

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Filter dams can be effectively used to block boulders and thus reduce impact on downstream constructions. There are many researches on impact of debris flows and some formulas are presented to measure impact. Field surveys are conducted in Japan, China, and the United States (Suwa and Okuda, 1983; Zhang, 1993; DeNatale *et al*., 1997, 1999). The boulder impact can be 10^2ąã10^4 kN/m^2. We observed that under different conditions the results varied from one to two orders. On the aspect of impact force formulas, present design of filter dams and check dams often refers to the empirical models (Mizuyama, 1979; Yamaguchi, 1985; Lien, 2002). After reviewing the literatures, we found impact force of the boulder is proportion to moving velocity and square of its particle size. Despite of their same variables, we may also notice that the constant coefficients vary greatly. Therefore, different formulas of boulder collision impact application will obtain distinct results. It will be uneconomical if we overestimate impact force, on the other hand, underestimation may lead to security misgivings.

This study applies theory of elastic collision to find a boulder collision impact model. The study of elastic collision is based on the Hertz Law (presented in 1881) and Rayleigh (1906)'s research. In this study, the two balls in collision may represent a concrete dam and a boulder. Assumed that the collision is elastic collision, the impact surface of concrete dam $R_1 = \infty$, and its massm_1 is much bigger than that of the boulderm_2, we can find the impact force

$$F = \left[4/3\pi\left(k_1 + k_2\right)^{0.4}\right]\left(5\rho_s\pi^2/4g\right)^{0.6}U^{1.2}R^2 \text{ where } k_1 = \frac{1-\nu_1^2}{\pi E_1}\text{ąA}k_2 = \frac{1-\nu_2^2}{\pi E_2}$$

Fstands for impact force of boulder(kg),$\nu_1$andν_2 stand for concrete dam and boulder's Poisson's ratio; E_1andE_2 stand for concrete dam and boulder's Young's elastic modulus(kg/cm^2); ρ_s is boulder's density (kg/m^3); $U$is moving velocity of boulder

(m/s)ąF$R$is radius of boulder (m); g is gravity (9.8 m/sec^2).

If the collision is not elastic, we need to add a coefficient Kc for modification, and this study used the flume (Length is 10 m, width is 0.6 m, and its height is 0.8 m.) to experiment on the Kc. First, this study reviewed data of present filter dams, analyzed them, and chose the most appropriate filter dam as the basis of our model. Then, in order to satisfy dynamic similarity condition, this study equalized Froude Number of the prototype and the model. The experimental material in the study is gravel of various sizes, and blended it to different size proportion. Its $D_{50}$is equal to 10.0 mm, and $D_{max}$is equal to 31.1 mm. The instruments we used to gauge flow velocity are radio current meter and electromagnetic velometer. Radio current meter is a non-contact instrument, and is able to measure the flowing velocity of the surface of debris flow and clear water. Electromagnetic velometer is a contact instrument, of which the fragile probe is easily harmed to collision of gravel, therefore can only be used in clear water. Due to the reason, we established the regression formula between surface velocity and flowing velocity at 0.5h (h=water depth) in clean water. Then we used the formula to interpret the average flowing velocity (at 0.5h) of debris flow. The filter dam model of this study is made of acrylic board. It is hollow. We drilled four holes on the impact surface along vertical direction on the tooth. We fixed the load cells in the holes on the model, and linked it to the data logging system.

By conducting flume experiments and using non-contact instruments like radio current meter we are able to measure data of impact force. Then we referred to our experimental (impact force of mixed-sized particles on dams) results to help modify the impact models. A more reasonable and universal model is thus obtained.

$$F = 30.8 \cdot U^{1.2} \cdot R^2$$

where$F$is impact force of boulder (ton),$U$is moving velocity of boulder (m/s), and$R$is radius of boulder(m).

Our flume experiment showed that greater slope will result in higher flow velocity and greater impact force. When dams are empty, we found that the maximum impact force appears at h/3 of the tooth. However, in actual situation, when debris flow impact filter dams , the impact point of the maximum force will vary with the height of deposition. This should be taken into account when designing constructions. Besides, boulder impact force is much greater than fluid dynamic pressure. Therefore, the loading capacity of boulder impact force should be the main consideration of stability analysis of dam, especially in creeks where stony debris flow often occurs.