Geophysical Research Abstracts
Vol. 14, EGU2012-6719, 2012
EGU General Assembly 2012

A research of phase velocity of roll waves for debris flow

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This research is phase velocity of roll waves on debris flows. Phase velocity of roll waves has different characteristics with mean velocity. Using the momentum and mass conservation equations in a coordinate system moving with velocity c for a homogeneous fluid are as follows

$$c\frac{\partial U}{\partial \xi} - \beta U \frac{\partial U}{\partial \xi} + c\left(1-\beta\right)\frac{U}{A}\frac{\partial A}{\partial H}\frac{\partial H}{\partial \xi} = -g\,\sin\theta + g\,\cos\theta\frac{\partial H}{\partial \xi} + \frac{f'}{2}\frac{U^2}{R} \tag{1}$$

$$\left(U-c\right)\frac{\partial A}{\partial H}\frac{\partial H}{\partial \xi} + A\frac{\partial U}{\partial \xi} = 0 \tag{2}$$

here, $v(x,t) = U(x-ct) = U(\xi)$, $h(x,t) = H(x-ct) = H(\xi)$, $\xi = x - ct$, v : cross-sectional mean velocity, h : depth of flow, A : cross-sectional flow area, g : acceleration due to gravity, θ : slope angle of the channel, R : hydraulic radius, β : momentum correction factor, f' : friction factor, x : coordinate axis of flow direction, t : time, the occurrence condition of roll waves is obtained. From other way to obtain the occurrence condition, the ratio $\frac{U_0}{c}$ which U_0 is mean velocity at control section and c phase velocity (velocity of a coordinate system moving) is obtained, and under the condition that the channel is rectanglar and the width B of channel is much wider than the depth ($B \gg H$), the ratio of $\frac{U_0}{c}$ is led as follows,

$$\frac{U_0}{c} = \frac{\beta - \sqrt{\beta\left(\beta-1\right) + \dfrac{S}{B}\dfrac{1}{{F_r}^2}}}{\beta - \dfrac{S}{B}\dfrac{1}{{F_r}^2}} \tag{3}$$

here, $F_r = \frac{U}{\sqrt{gH\cos\theta}}$: Froude number, S : wetted perimeter.

Experiments have been conducted in an experimental flume of 28m in length, 10cm in width and 10cm in depth. In a circulation system the tested material is pumped from the extit of the flume back to the inlet, providing a constant discharge upstream. The material used consisted of non-cohesive coal particles with a d_{50} of 0.67mm, a density σ of 1.41g/cm^3 and polypropylene particles with a d_{50} of 2.9mm, a density σ of 1.06g/cm^3.

The experimental results and theoretical result (equation (3)) are correspondig well on $\beta = 1.02$.