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Occurrence condition of roll wave and flow model on muddy debris flow

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This is discussed about relationship between occurrence conditions of intermittent surges of muddy debris flow and it's flow model. The occurrence condition is obtained by instability of the flow and the phenomenon of intermittent surges have been know as roll wave. It has individual occurrence condition on difference flow model. Three flow models which are particles collision and turbulent flow model (Arai M. and Takahashi T. 1983), Dilatant flow model of Bagnold and Bingham flow model are discussed. Theoretical each occurrence condition of intermittent surges by instability of flow are as follows,

1) Particles collision and turbulent flow model

$$F_r \geq \frac{1}{\sqrt{\left\{\Phi + \left(\frac{3}{2} - \beta\right)\right\}^2 - \beta\left(\beta - 1\right)}} \tag{1}$$

here [U+FF0C]

$$\Phi = \left[\sqrt{1+\phi^2} - \phi\right] \times \left[\sinh^{-1}\left\{\frac{1}{\phi}\right\} - \sinh^{-1}\left\{\frac{Y_0}{\phi}\right\} - \sqrt{1+\phi^2} + \phi\right]^{-1} \tag{2}$$

$$\begin{aligned} \beta \;=\; & \left[\left\{\sinh^{-1}\left(\frac{1}{\phi}\right)\right\}^2 - 2\left\{\sqrt{1+\phi^2} + \sinh^{-1}\left(\frac{Y_0}{\phi}\right)\right\} \cdot \sinh^{-1}\left(\frac{1}{\phi}\right)\right. \\ & \left. + 2\left\{\sqrt{1+\phi^2} - \phi\right\} \cdot \sinh^{-1}\left(\frac{Y_0}{\phi}\right) + \left\{\sinh^{-1}\left(\frac{Y_0}{\phi}\right)\right\}^2 + 2\right] \\ & \times \left[\sinh^{-1}\left(\frac{1}{\phi}\right) - \sinh^{-1}\left(\frac{Y_0}{\phi}\right) - \sqrt{1+\phi^2} + \phi\right]^{-2} \end{aligned} \tag{3}$$

F_r : Froude number, $\phi^2 = \lambda^2 \frac{a_i \sin\alpha}{\kappa^2}\left(\frac{d}{h}\right)^2$, $\lambda = \left\{\left(\frac{C_*}{C}\right)^{\frac{1}{3}} - 1\right\}^{-1}$: linear concentration, h : depth of flow, d : particle size, $Y_0 = \frac{y0}{h}$, y_0 : roughness , β : momentum correction coefficient, $a_i \sin\alpha$: Bagnold coefficient, κ : Karman constant, σ : dencity of solid particle, ρ_m : mean density of flow, C_* : concentration of packed solid particles, C : mean concentration,

2) Dilatant flow model

$$F_r \geq \frac{2}{\sqrt{5}} \simeq 0.894 \tag{4}$$

3) Bingham flow moldel

$$F_r \geq \frac{1}{\sqrt{\frac{36 - 33\,a_\eta + 9\,{a_\eta}^2}{\left(a_\eta - 3\right)^2}}} \tag{5}$$

$a_\eta = y_\eta/h$, y_η : yield point from bottom of the flow.

Experimental results and observation data of Mt. Sakurazima in Japan indicate the particle collision and turbulent flow model.