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A research on solutions of a wave equation of shallow water for roll waves of debris flow

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Intermittent surges of debris flow are observed in mountains region in Europe, Aisia and others. A purpose of this research is to obtain characteristic of wave equation on shallow water for debris flow surges.

Considering a flow in a rectangular straight channel, where the width is very large compared to a flow depth, momentum correction factor $\beta = 1$, constant friction factor over mean depth h_0, a channel slope $\tan\theta < 1$, Froude number $F_r > 1$, and a long wave condition by results of observations and experiments, a wave equation is obtained with

$$\frac{\partial \eta'}{\partial \tau'} + a_1 \eta' \frac{\partial \eta'}{\partial \xi'} - a_2 \frac{\partial^2 \eta'}{\partial {\xi'}^2} + a_3 \frac{\partial^3 \eta'}{\partial {\xi'}^3} = 0 \tag{1}$$

where, $a_1 = (3/2){c_0'}^2$, $a_2 = (1/2)\left(1/{c_0'}^2 - 1/2\right)\tan\theta\,(c_0'/u_0')$,
$a_3 = (1/2)\left\{(2 + {c_0'}^4)/(2{c_0'}^2) - 3/2\right\}$,
and η : fluctuation of mean flow depth, h_0 : mean depth, $h = h_0 + \eta$: flow depth, $\eta' = \eta/h_0$, x : coordinate axis of flow direction, $x' = x/h_0$, $\xi = \epsilon^{1/2}(x - v_{p0})$, $\xi' = \xi/h_0$, v_{p0} : phase velocity, the velocity parameter of Gardner - Morikawa transformation, y : coordinate axis of depth direction, $y' = y/h_0$, t : time, $t' = t\,v_{p0}/h_0$, $\tau = \epsilon^{3/2}t$, $\tau' = (v_{p0}/h_0)\,\tau$, g : acceleration due to gravity, θ : slope angle of the channel, $c_0 = \sqrt{g h_0 \cos\theta}$: wave velocity of a long wave, ${c_0}' = c_0/v_{p0}\ u_0$: mean velocity, ${u_0}' = u_0/c_0$.

Using for $v_{p0} = c_0$ under a long wave condition by observations and experiments, above equation is expressed as

$$\frac{\partial \eta'}{\partial \tau'} + \frac{3}{2}\,\eta'\,\frac{\partial \eta'}{\partial \xi'} - \frac{1}{4}\frac{\tan\theta}{{u_0}'}\,\frac{\partial^2 \eta'}{\partial {\xi'}^2} = 0. \tag{2}$$

This equation is a kind of Burgers equation. Analytical solutions for different wave number $k = 1/2,\ 3/2,\ 5/2$ and $k = 1, 2, 3$ on initial conditions were obtained, and calculated by numerical analysis. These results show that the wave shape are deformed to a wave of wave number $k = 1$ for not multiple wave number. This indicates that a surge is formed with a wave length from the wave of a lot of wave numbers in initial state on actual surges or experimental surge flows.