Notes for Debris Flow Simulation with FLUMEN

Term	Formula	Values
Basic equation	$\tau_{total} = max(\tau_{turb}; \tau_B) + \tau_y + \tau_c$	
Turbulent	$\tau_{turb} = \rho \frac{u^2}{c_f^2}$ Strickler : $c_f = k_{st} h^{1/6} \sqrt{g}$ or log-law: $c_f = 2.5 \ln(\frac{h}{k_s}) + 6.0$	ρ – density of fluid h – flow depth u – flow velocity (depth averaged) c_f – friction factor g – gravitational acceleration k_{st} – Strickler value [$m^{1/3}$/s] k_s – Sand roughness [m]
Bingham	$\tau_B = 3 \mu_B \frac{u}{h}$	μ_B – Bingham viscosity [Pa s]
Yield	τ_y	τ_y – Yield stress [Pa]
Coulomb	$\tau_c = \rho g h \tan \delta$	δ – internal friction angle

Examples of Parameters used for Simulation

Dam break problem with plastic fluid (in /1/)

Turbulent & Yield	K_{st}=? $m^{1/3}$/s; τ_y=2'390 Pa; ρ=1'835 kg/m^3
Turbulent, Coulomb & Yield	K_{st}=15 $m^{1/3}$/s; τ_y=500 Pa; tan(δ)=0.18; ρ=1'835 kg/m^3
Simplified Bingham	μ_B=100 Pa s; τ_y=2'250 Pa; ρ=1'835 kg/m^3

1976 Kamikamihori debris flow with front with large boulders; rear part more fine material (/1/)

Turbulent & Yield	K_{st}=9 $m^{1/3}$/s; τ_y=300 Pa; ρ=2'000 kg/m^3
Turbulent, Coulomb & Yield	K_{st}=9 $m^{1/3}$/s; τ_y=300 Pa; tan(δ)=0.06; ρ=2'000 kg/m^3
Simplified Bingham	μ_B=3'200 Pa s; τ_y=300 Pa; ρ=2'000 kg/m^3

Maschänser Rüfe (/2/)

liquid debris	$\mu_{B,flo-2d}$=10 Pa s; τ_y=1'000 Pa; ρ=? kg/m^3
viscous debris	$\mu_{B,flo-2d}$=10 Pa s; τ_y=5'000 Pa; ρ=? kg/m^3

Landslide and debris flow Val Bondasca (/3/)

Landslide	K_{st}=23 $m^{1/3}/s$; τ_y=1'000 Pa; tan(δ)=0.28; ρ=2'000 kg/m^3
Debris stream	K_{st}=10 $m^{1/3}/s$; τ_y=8'750 Pa; tan(δ)=0.03; ρ=2'000 kg/m^3
Debris flow	K_{st}=10 $m^{1/3}/s$; τ_y=500-4'000 Pa; tan(δ)=0.03; ρ=2'000 kg/m^3

References

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/2/ Schatzmann M. 2004. Die Bedeutung der rheologischen Parameter bei der Murgangsimulation mit dem Programm Flo-2d. In: VAW Mitteilung Nr. 184, ETH Zürich.

/3/ Tognacca Ch., Gabbi J., Cattaneo G., Beffa C. 2019. Gravitative Prozesse in der Bondasca. “Wasser Energie Luft”, 111. Jahrgang, Heft 3.