Approaches to describe debris flow loading for the dimensioning of check dams

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Reference: Dept. natural hazards Interlaken

Introduction:

Debris flows are highly concentrate mixtures of solid rocks, mud and water in steep areas. Debris flow volume up to some 100.000m³, peak discharge of 100 ÷ 800 m³/s, velocity up to 5 ÷ 20 m/s and a density from 1,6 to 2,2 t/m³ are essential characteristics of debris flows.

This poster shows an overview how to get the pressure values on structures step by step. Furthermore you can see the different pressure distributions on structures.

Impact of debris flows:

Calculation of effects

Debris flow volume M
⇩
Peak discharge Q_P
⇩
Flow velocity v / Flow depth h
⇩
Cross section A

without protection measurements: Deposit area ⇦ Cross section A ⇨ with protection measurements: Impact on structures

Example: „Torrent Illgraben“ (Wallis), Switzerland:

Characteristic properties:

Catchment area	A_c = 10,5 km²
Active length	L_c = 2,6 km
Slope angle	J_c = 13,0 %
Average slope	J_f = 10,2 %
Friction angle	φ = 34°
Specific density	ρ_s = 2,1 t/m³
Maximum water discharge	Q_w = 20,0 m³/s
Average width	b = 16,5 m

Measured data (years 2005 ÷ 2006):

Debris flow volume	M = 4.000 ÷ 55.000 m3
Specific density	ρ_s = 1,6 ÷ 2,2 t/m3
Maximum flow depth	h = 0,8 ÷ 2,7 m
Velocity	v = 0,7 ÷ 7,9 m/s

Debris flow volume M ⇩ Peak discharge Q_P ⇩ Flow velocity v / Flow depth h ⇩ Impact pressure on structures

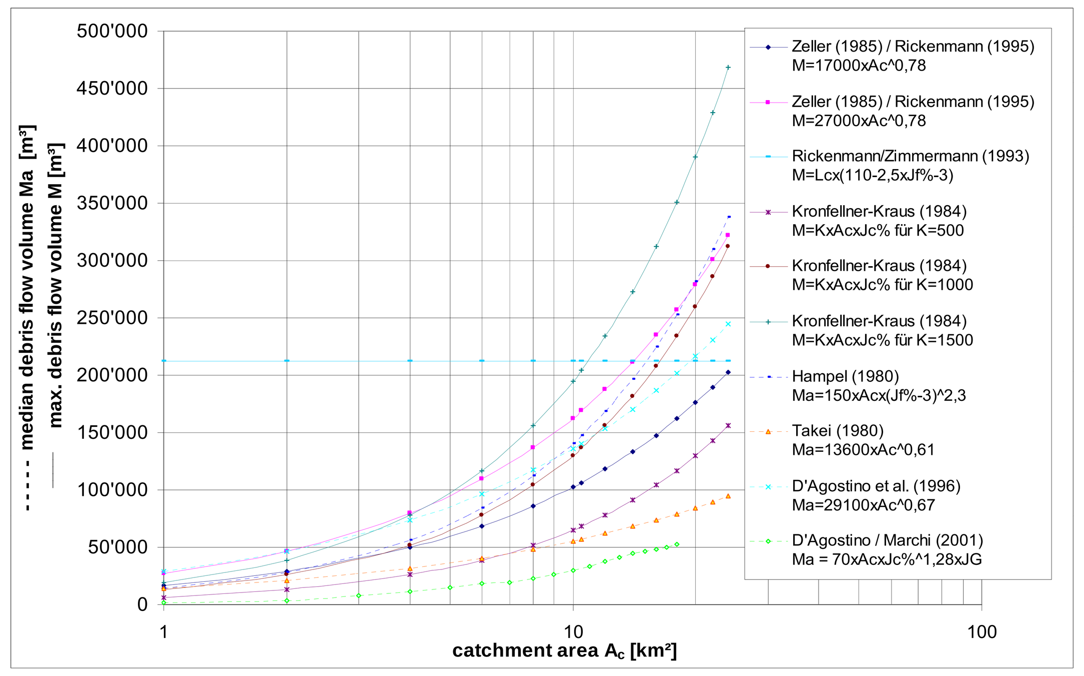

Fig. 1: Debris flow volume M (complete) depending on the catchment area A_c for L_c = 2.600m, J_f = 10,2%, J_c = 13,0% and J_G = 1 (Geological Index)

⇨ M ≈ 20.000 m³ (...with 6 waves)

(middle from the max. debris flow volume, measured: M = 4.000 ÷ 55.000m³)

Debris flow volume M ⇩ **Peak discharge Q_P** ⇩ Flow velocity v / Flow depth h ⇩ Impact pressure on structures

- Mizuyama 1992: $Q_P = 0{,}135 \cdot M^{0,78}$ = 315 m³/s
- DIN 19663 "Wildbachverbauung": $Q_{wglF} = Q_w \cdot IF$ = 150 m³/s
- Takahashi 1978: $Q_{DF} = Q_o \cdot P$ = 23 m³/s

⇨ Q ≈ 180 m³/s

M: middle from the max. debris flow volume
IF: intensity factor (3,5 ÷ 100 for debris flow)
P: increase factor
$Q_0 = Q_w$: clear water discharge
$Q_p = Q_{wglG} = Q_{DF}$: Peak discharge

Debris flow volume M ⇩ Peak discharge Q_P ⇩ **Flow velocity v / Flow depth h** ⇩ Impact pressure on structures

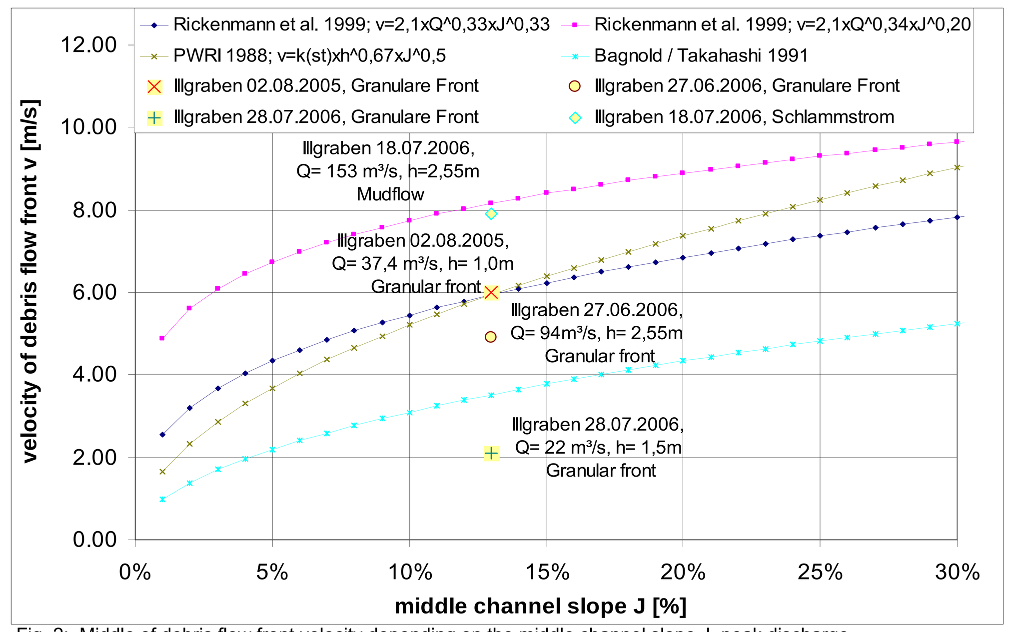

Fig. 2: Middle of debris flow front velocity depending on the middle channel slope J, peak discharge Q = 180 m³/s, middle flow depth h = 2,1m and Strickler factor k_{st}=10 m$^{1/3}$/s

The velocity v is linked with the flow depth h. The flow depth h is calculated with the equation from PWRI 1988 $v = k_{st} \cdot h^{0,67} \cdot J^{0,5}$.

⇨ v ≈ 6,0 m/s; h ≈ 2,1 m

(measured: v = 0,7 ÷ 7,9 m³/s; h = 0,8 ÷ 2,7 m)

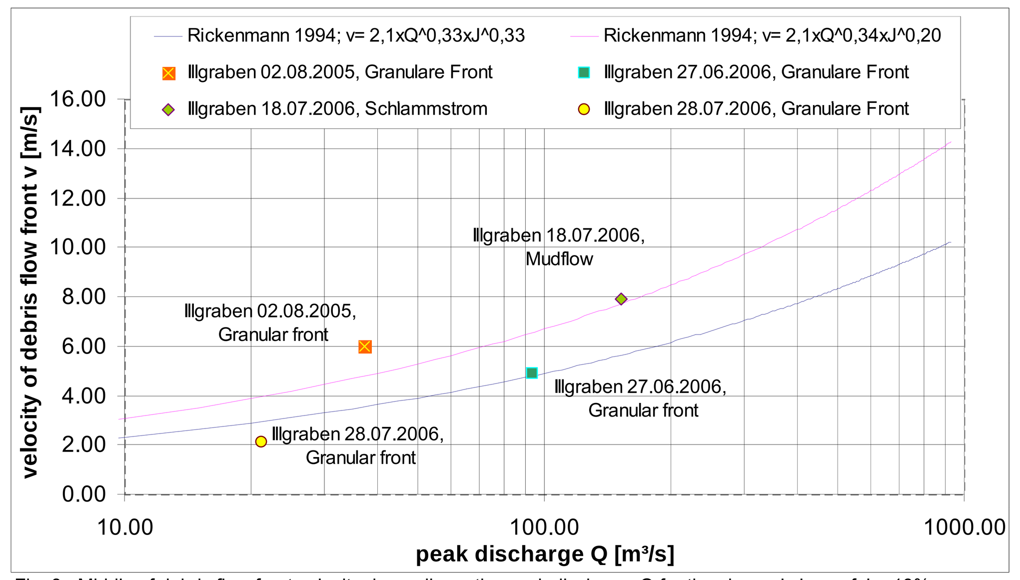

Fig. 3: Middle of debris flow front velocity depending on the peak discharge Q for the channel slope of J = 13%

Debris flow volume M ⇩ Peak discharge Q_P ⇩ Flow velocity v / Flow depth h ⇩ **Impact pressure on structures**

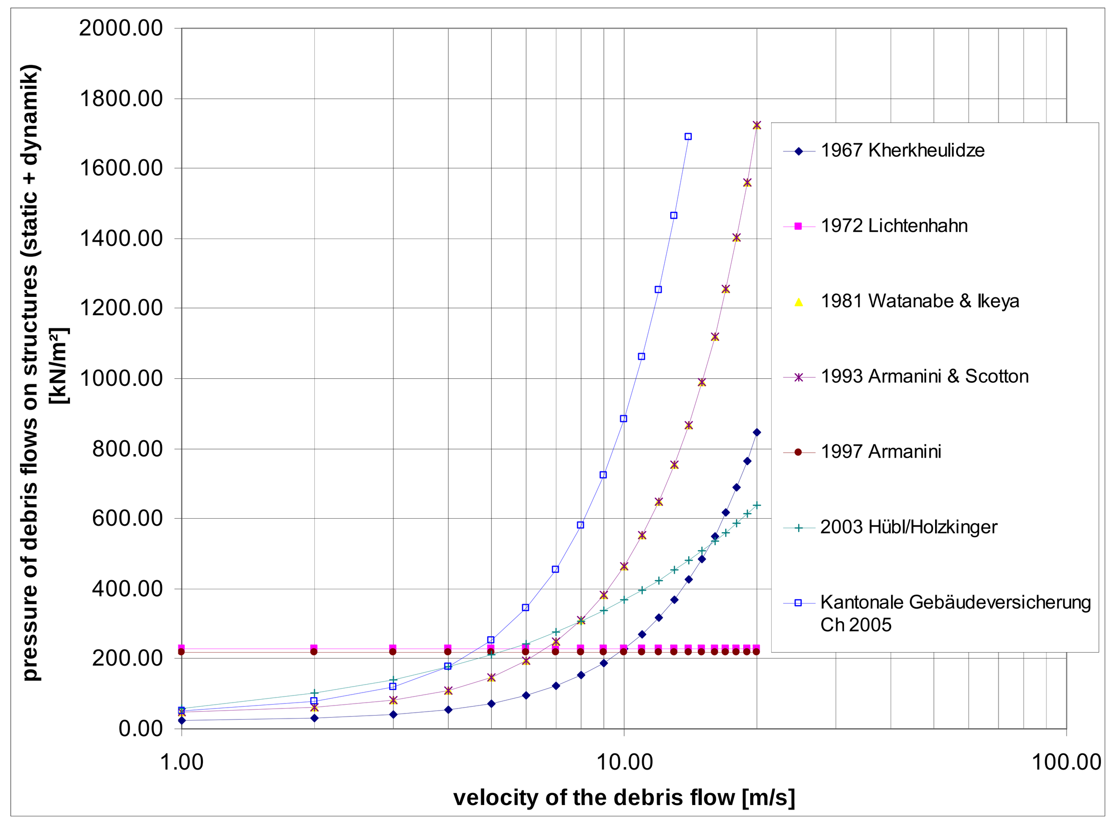

Fig. 4: Pressure of debris flow on structures depending on the velocity for the flow depth = 2,1m and a density of 2,1 t/m³

Kherkheulidze 1967:
$p_{max} = 0{,}1 \cdot \rho_{wg} \cdot g \cdot (5 \cdot h + v^2)$ = 94,5 kN/m²

Lichtenhahn 1972:
$p_{max} = k \cdot \rho_{water} \cdot g \cdot h_{fl}$ = 227,6 kN/m²

Armanini 1997:
$p_{max} = 5 \cdot \rho_{DF} \cdot g \cdot h_{fl}$ = 217,2 kN/m²

Hübl/Holzinger 2003:
$p_{max} = 5 \cdot \rho_{DF} \cdot v^{0,8} \cdot (g \cdot h_{fl})^{0,6}$ = 242,2 kN/m²

Swiss Assurance for buildings:
$p_{max} = a \cdot \rho_f \cdot v_f^2$ = 340,2 kN/m²

⇨ p_{max} ≈ 203 kN/m² (distribute on flow depth)

Calculation example in diploma thesis:

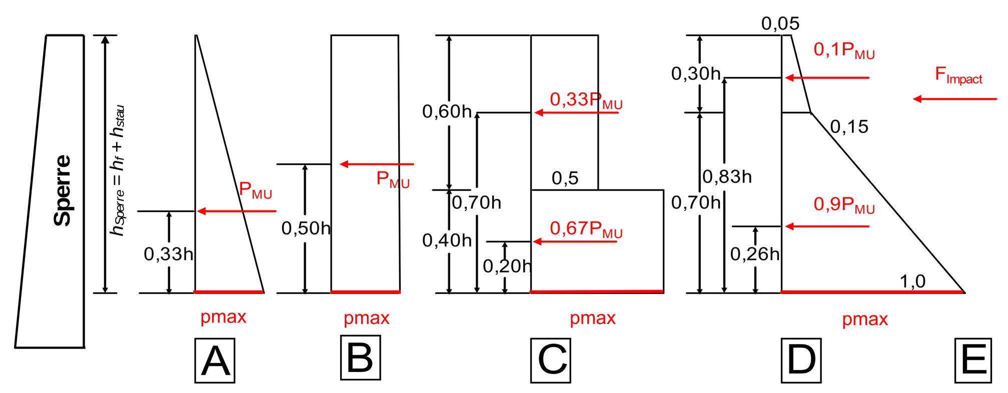

Fig. 5: Pressure distribution taken out of the Betonkalender 2008

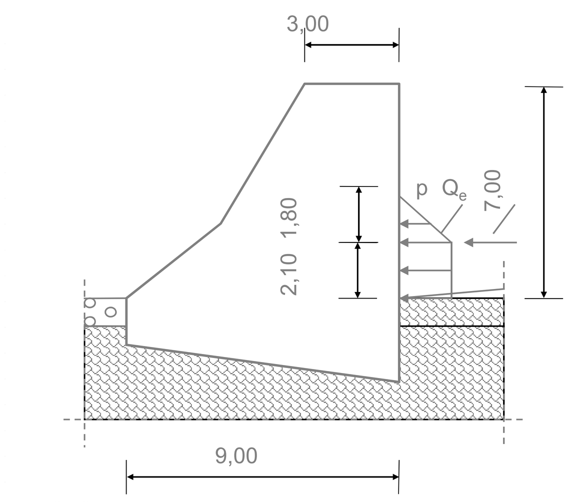

Fig. 6: Selected pressure distribution in diploma thesis

p: dynamic debris flow pressure
Q_e: dynamic single load (single bolder)

Conclusion:

The lack of knowledge is still very obvious for efficient debris flow loading approaches. More information about this topic are shown in the diploma thesis from Magdalena Schlickenrieder: „Approaches to describe debris flow loading for the dimensioning of check dams“. Furthermore there can be found a calculation example for a concrete barrier in the Illgraben (Fig. 6).