KLIMA 2050

13 April 2016

Lunsj presentasjon – WP3

Protection measures against debris flow

Photo: NGI (2015)

OUTLINE

- Definition and characteristics of debris flow
- Protection methods against debris flows
- Deflection walls
- Model test
  - Purpose
  - Test design
  - Results
  - Conclusions

Debris flow: Definition

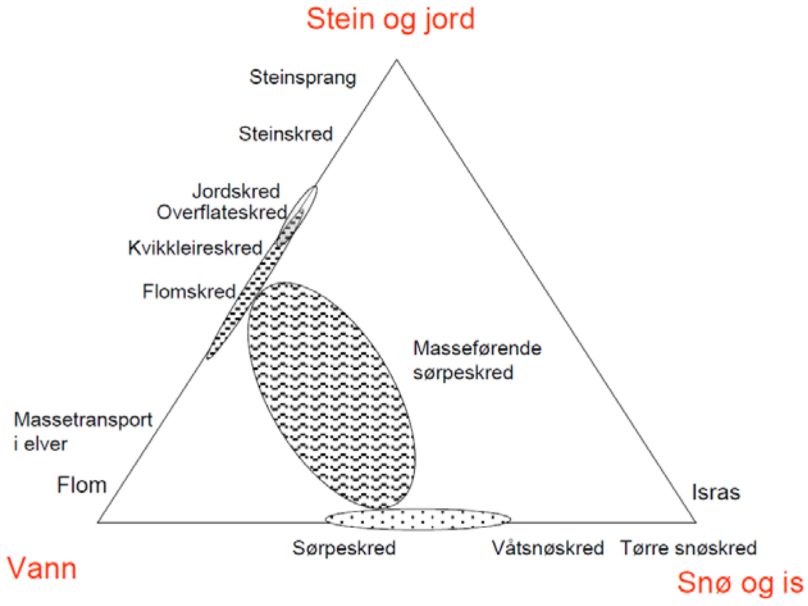
- Water-laden masses of soil, fragmented rock rush down hill/mountainside as a stream, entraining objects in their paths.

Debris flow occurred in 2007 In Flå (Photo: NGI)

Debris flow occurred in 2007 in Gol (Photo: NGI)

Debris flows: Characteristics

- saturated, poorly sorted mixture of granular materials
- Particle content: 40 – 80%

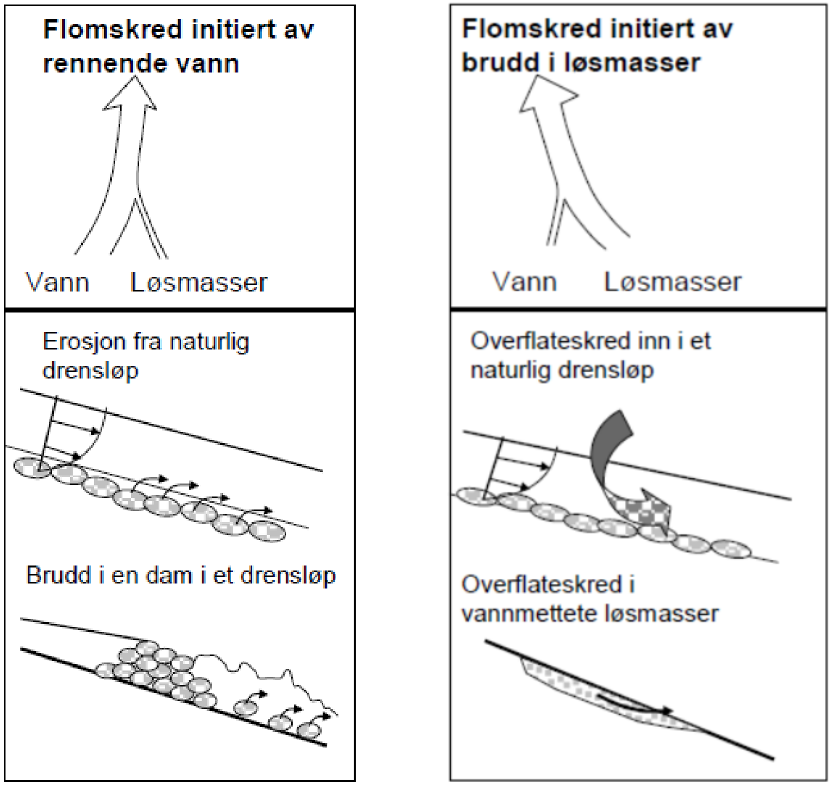


Classification of sliding types based on the proportion of water, rock, soil, snow and ice (Norem and Sandersen 2012)

Debris flow destroyed a road and a railway line in Ånn, Åre, Sweden on 30 July 2006 (Photo: Harald Norem)

Debris flow: Initiation

- by water:
  - water flow erodes and carries away soil particles
  - dominant in Norway
  - contributed climate factors (short duration intense rainfall; long duration low intensity rainfall (or combination); rapid snow melt
- by soil:
  - surface slides take up or release water



Two main initiating mechanisms of debris flow (Norem and Sandersen, 2012)

Debris flow: Motivation for study

- One of the deadliest and most destructive of all landslides due to high speed, shear destructive force and unpredictable behaviour!

Debris flow destroyed houses in Farmington, Utah in 1983 (Source: S. Ellen, USGS)

Debris flow in Brienz, Switzerland in 2005 (Source: S.Loew, ETH Zurich)

Protection methods against debris flow

- Purpose: Protect infrastructures from being damaged or affected by debris flows. Reduce danger, accidents and delay in operation or performance

- Principles: Active or Passive
  - Stop debris flow
  - Divert flows to low impact areas
  - Reduce extent of flows impact
  - Restricted use, warning system

Check dams stabilizing a channel near Toblach, South Tirol, Italy (Source: the Earth Physics Institute, the University Paris Diderot)

A lined channel designed for passage of debris flows on Alberta Creek, Lions' Bay, British Columbia (Source: the Earth Physics Institute, the University Paris Diderot)

A shooting channel conducting a debris flow channel through the village of Matrei, Austria (Source: the Earth Physics Institute, the University Paris Diderot)

Flexible debris flow barrier (Source: WSL, Switzerland)

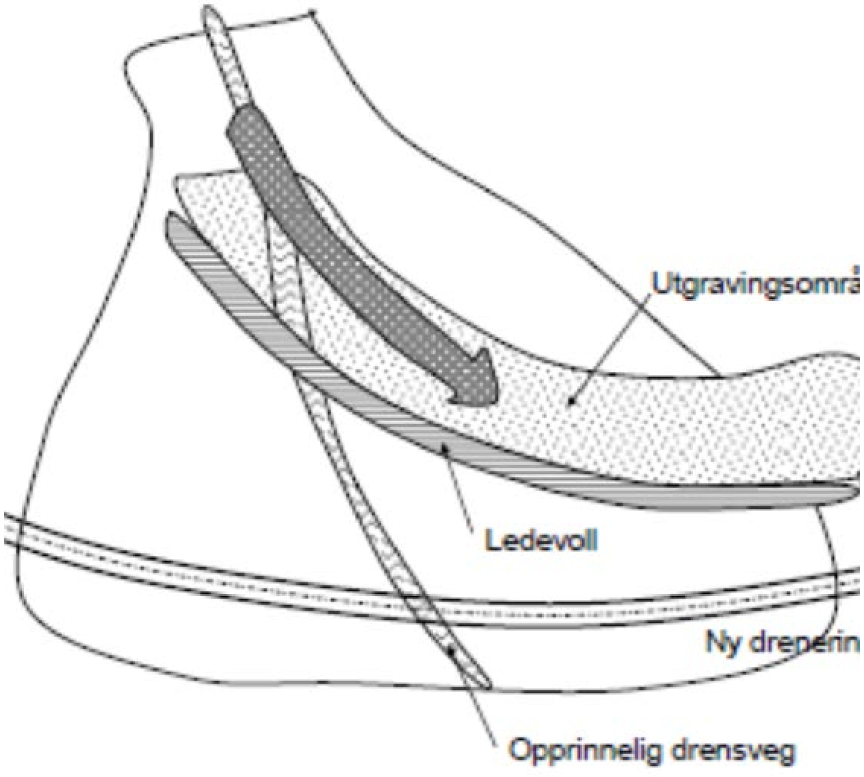
Debris flow passing check dam in Steinibach, Switzeland (Source: National Platform for Natural Hazard, Swiss Confederation)

Bridges in eastern Turkey to allow debris flows from steep tributary valleys crossing a national road (Source: the Earth Physics Institute, the University Paris Diderot)

Debris flow bridge in the Savoy Alps, France (Source: the Earth Physics Institute, the University Paris Diderot)

Deflection walls

Deflection wall in Sandvika, Sogn og Fjordane (Photo: Harald Norem)



Principal of deflection wall: active protection method to divert debris flow to a low impact area (Source: Norem and Sandersen, 2012)

Model test study

- Purpose: understand mechanism of debris flow and contribute to design basis of deflection walls
- Master Thesis by Lise Føsund Christiansen in 2013
- Supervisor: Staten Vegvesen (Harald Norem), NTNU (Arnfinn Emdal) and SINTEF (Arnstein Watn)
- Model test conducted in Vassdragslaboratoriet (NTNU)

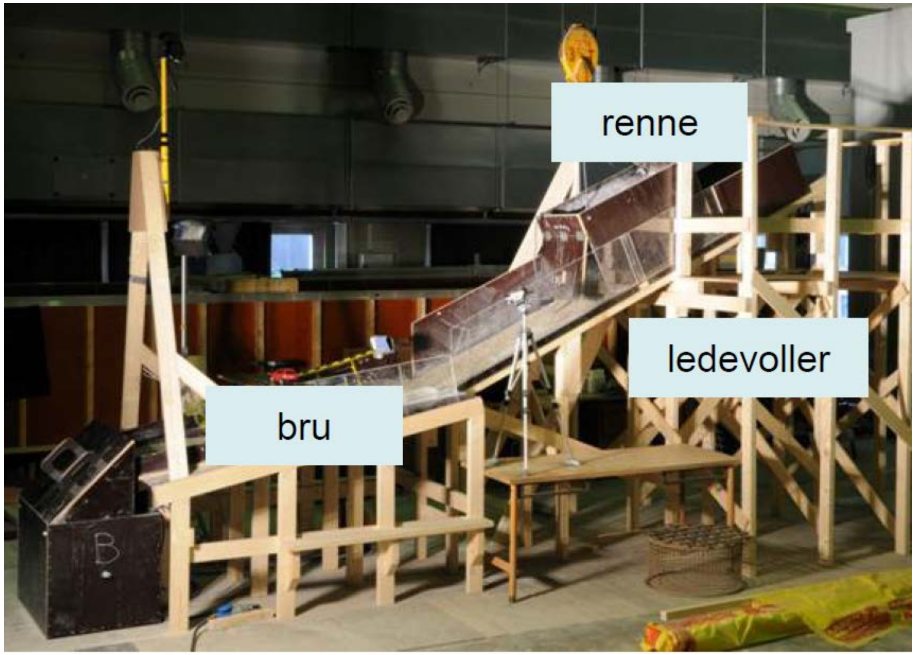
Terminal wall along Rv7 Indre Rotagjelet, Hordaland, Norway (Source: Harald Norem)

Model setup

- Principal model (1:20 scale)
- Debris flow path includes:
  - Upper sloping channel (23°)
  - Lower sloping channel (13.8°)
  - Rerouting table (1.6°)
- Operating equipment:
  - Model deflection wall
  - Two crates (for releasing at the start and collecting the test materials at the end)
  - High-speed cameras
  - Scanner

Model setup in the lab (Source: Christiansen, 2013)

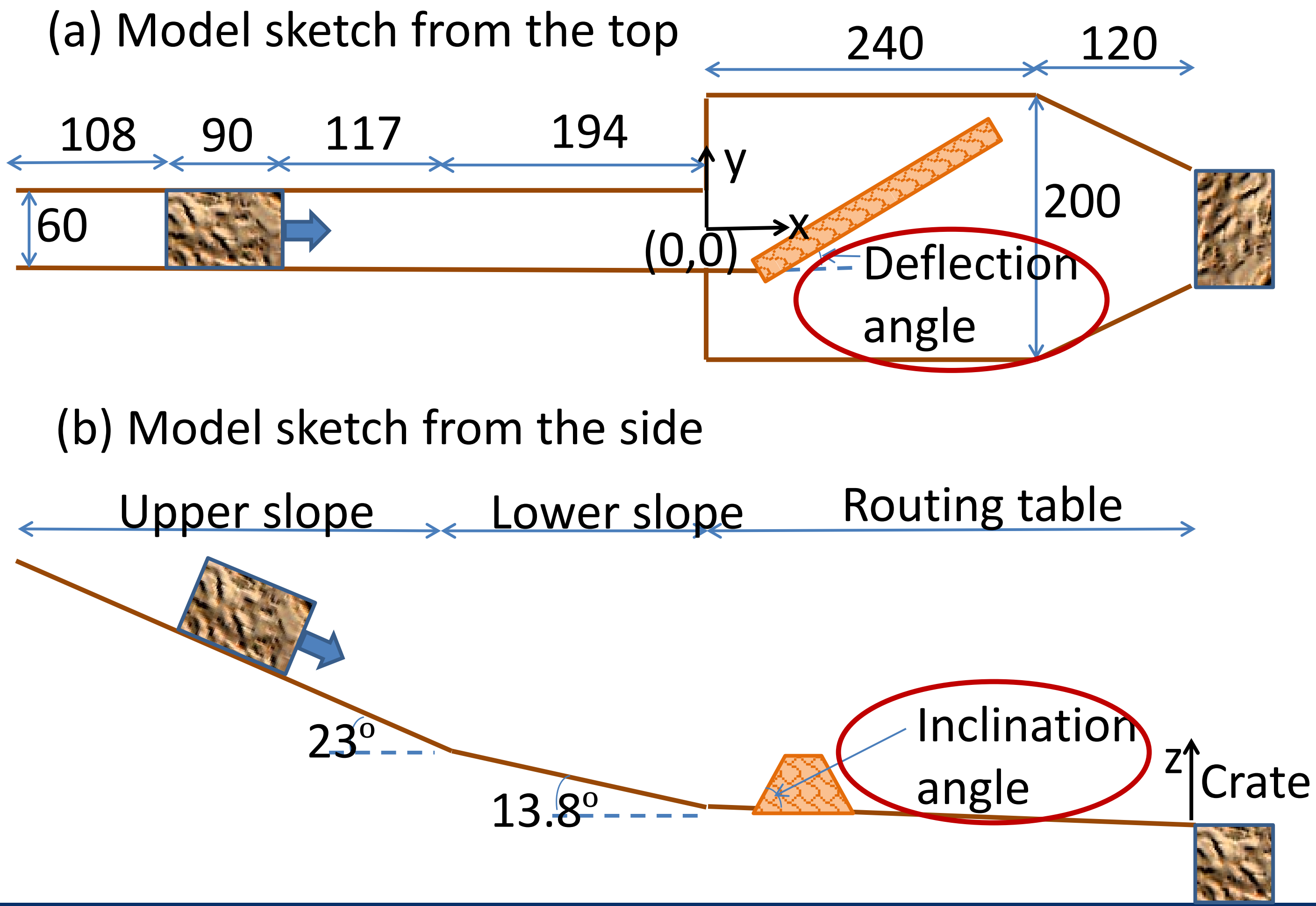
Model setup



Original model construction (Source: Harald Norem, 2010)

Example of test operations (Source: Harald Norem, 2010)

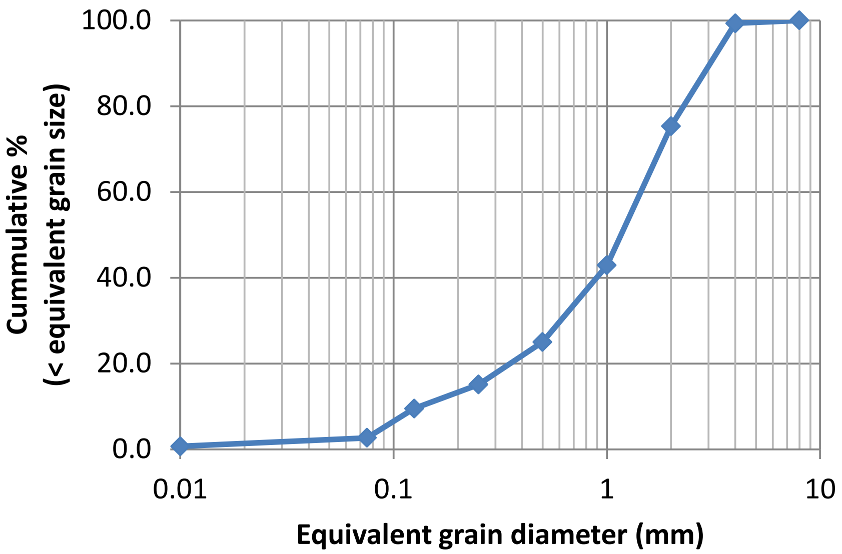
Model setup


(a) Model sketch from the top
240
120
108
90
117
194
y
60
200
x
(0,0)
Deflection
angle
(b) Model sketch from the side
Upper slope
Lower slope
Routing table
Inclination
angle
23º
13.8º
z
Crate

Debris materials

Dry debris material used in testing on milimeter paper

- Coarse sand
- D_{90} = 2.7 mm
- D_{50} = 1.2 mm

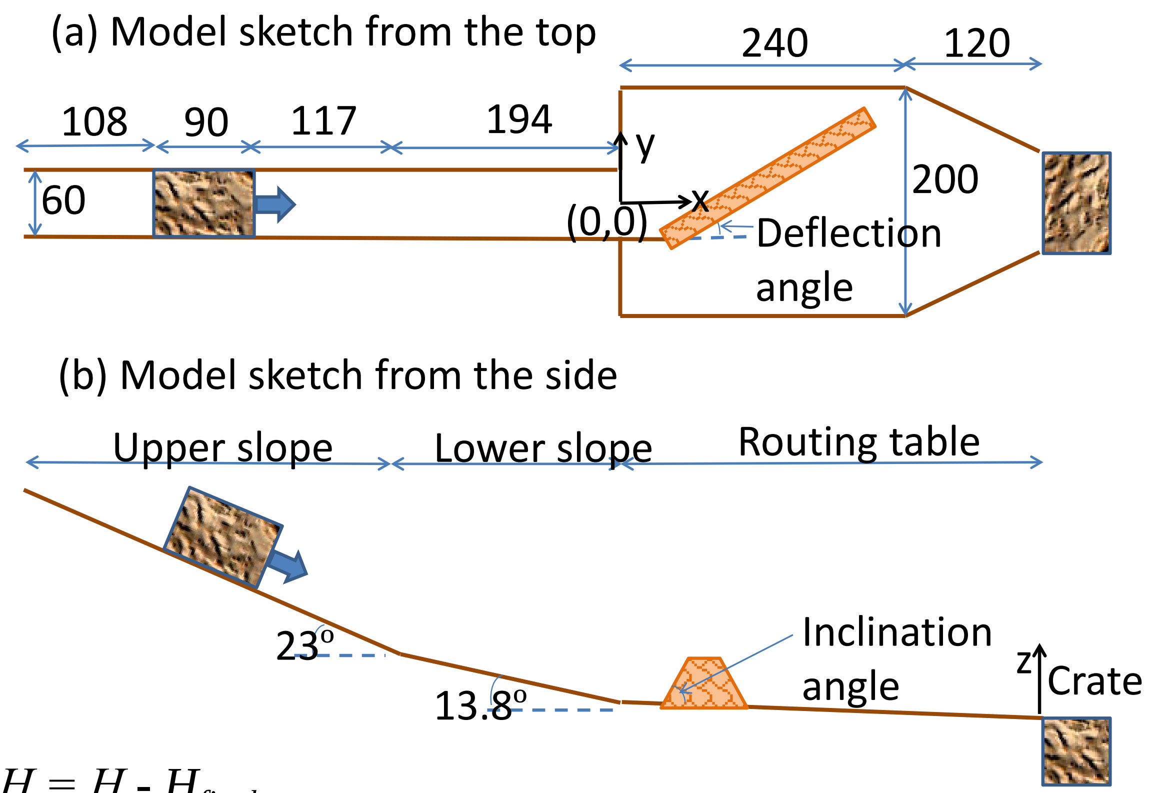


Grain size distribution for tested debris materials

- well-graded
- visible grains of sands and pebbles

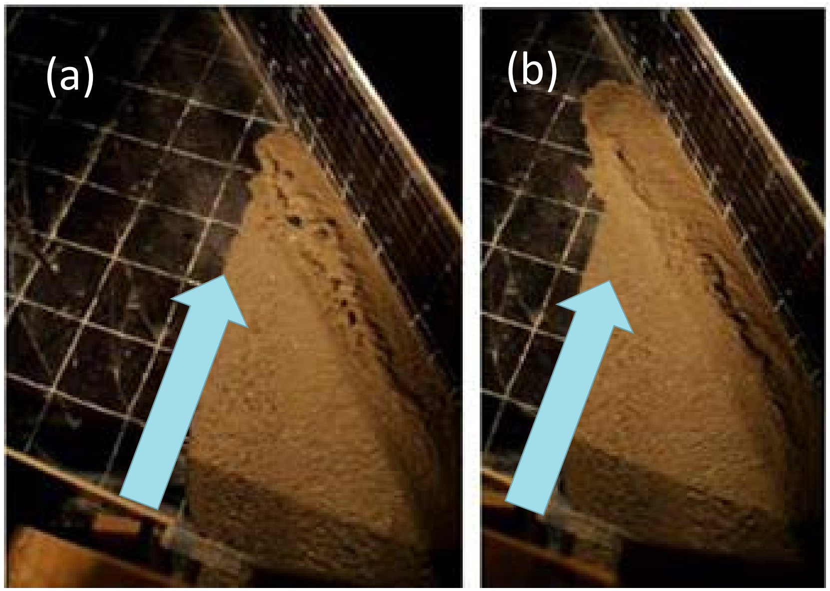
Testing procedure

- Deflection angles:
  - 90º - terminal wall
  - 40º
  - 20º
- Inclination angles:
  - 90º - vertical wall
  - 72º (3:1 sloping wall)
  - 34º (1:1.5 sloping wall)
- Measured parameters:
  - maximum shooting height (*H*)
  - flow height (H_{flow})
  - final height (H_{final})
  - front velocity (*v*)



$$\Delta H = H - H_{final}$$

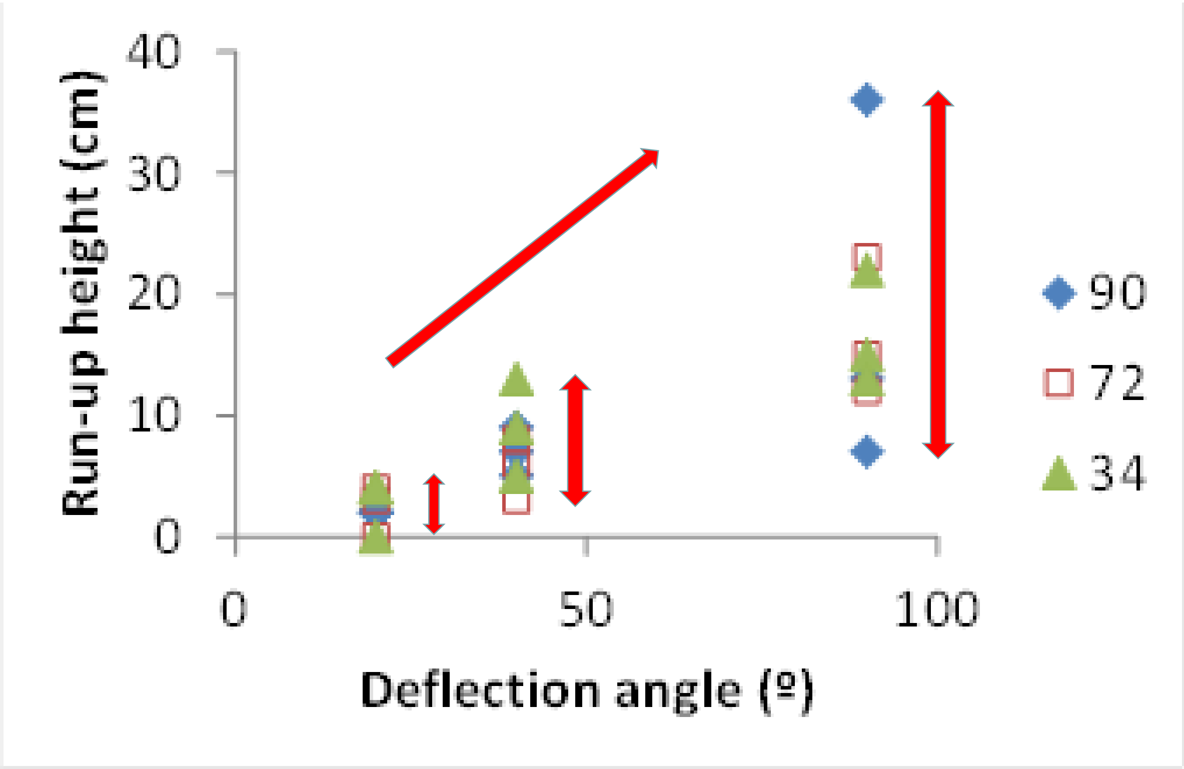
Test results: Qualitative description



The debris flow at
(a) hitting the deflection wall
(b) right after hitting the deflection wall

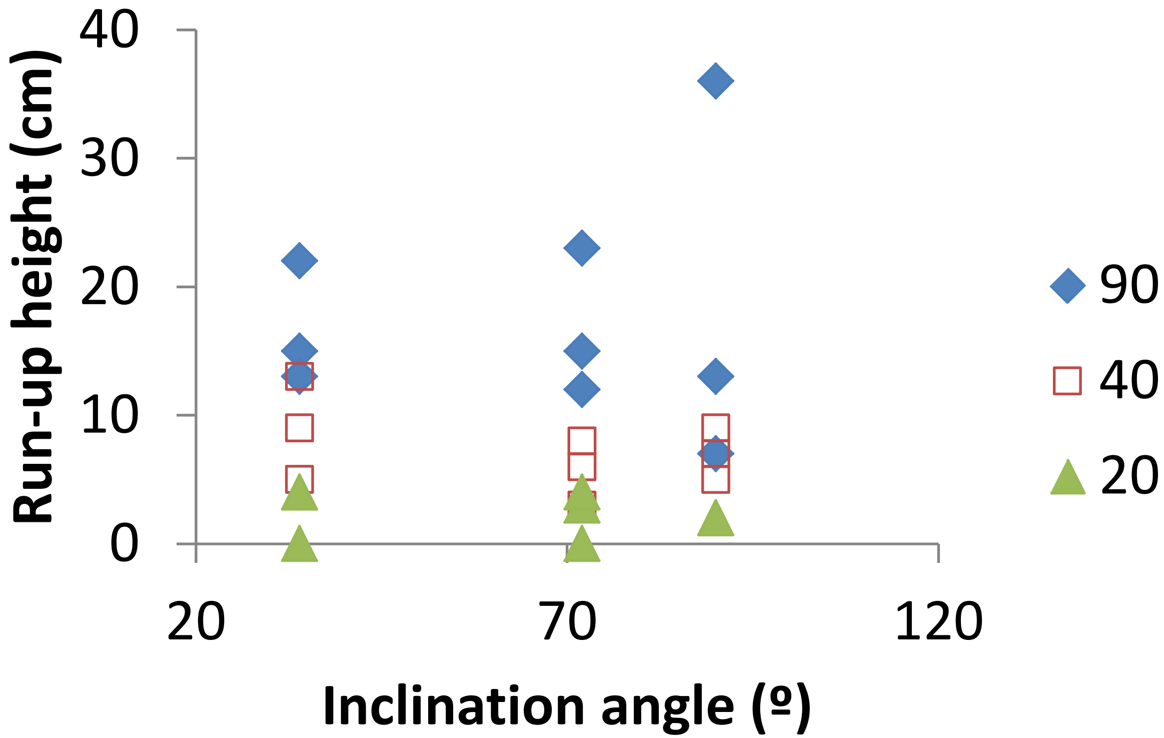
An example front of the debris flow showing the separation between large particles and the debris mass

Test results: Runup height vs Deflection angle



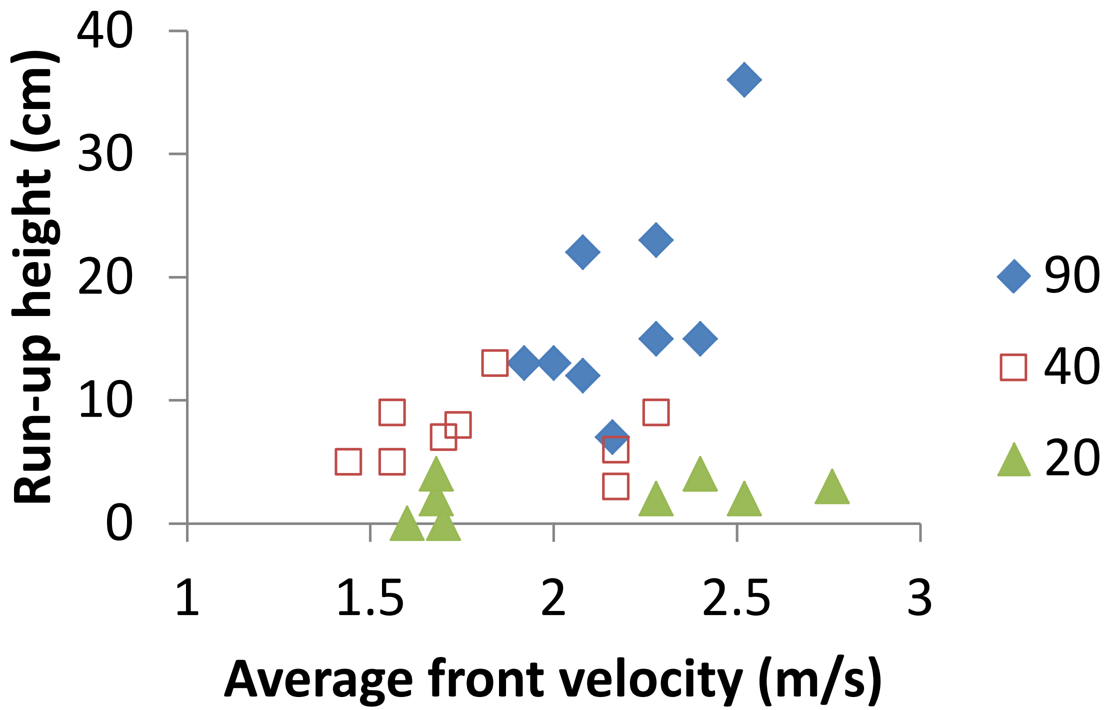
- Runup height increases with increasing deflection angle
- Variation range increases with increasing deflection angle
- Reason: Increasing deflection angle causes increases in collision impact

Test results: Run-up height vs Inclination angle



- No visible correlation between the runup height and inclination angle
- Trends might be hidden due to large variation of the test results
- Reason: energy loss during collision and friction against the wall

Test results: Run-up height vs Front velocity



- No visible correlation between the runup height and average front velocity
- Large variation in test results overpower expected trend

Test No	Deflection angle	Inclination angle	Maximum shooting height (H)	Final height (H_{final})	Run-up height (ΔH)	Average front velocity (v)
	º	º	cm	cm	cm	m/s
1	90	90	46	10	36	2.52
2	90	90	23	10	13	2.00
3	90	90	18	11	7	2.16
4	90	72	27	12	15	2.28
5	90	72	33	10	23	2.28
6	90	72	22	10	12	2.08
7	90	34	25	10	15	2.40
8	90	34	24	11	13	1.92
9	90	34	30	8	22	2.08
10	40	90	12	7	5	1.44
11	40	90	16	7	9	2.28
12	40	90	14	7	7	
13	40	72	15	7	8	1.74
14	40	72	14	8	6	2.17
15	40	72	11	8	3	2.17
16	40	34	16	7	9	1.56
17	40	34	20	7	13	1.84
18	40	34	12	7	5	1.56
19	20	90	6	4	2	1.68
20	20	90	7	5	2	2.52
21	20	90	8	6	2	2.28
22	20	72	9	6	3	2.76
23	20	72	10	10	0	
24	20	72	9	5	4	1.68
25	20	34	8	4	4	2.40
26	20	34	8	4	4	2.40
27	20	34	7	7	0	1.70

Test results: Variability

- Wide variation of the test results caused by:
  - Inhomogeneity of tested material
  - Variation in testing techniques

- Reflect the large variability of natural debris flow occurring in uncontrolled condition

- Improve testing technique can improve repeatability of the test

Conclusions

- Shooting height and runup height tend to increase with increasing deflection angle
- No visible correlation between run-up height and inclination angle
- Large variability in the test results might overpower some expected trends
- Improve consistency in testing technique should reduce the man-made variability in the test results

Future studies

- Testing different types of protection measures
- Varying test parameters: sloping angles, degree of materials homogeneity
- Develop other testing technique for debris flow protection measures

SINTEF

Technology for a better society