



UNIVERSITÀ DEGLI STUDI DI MILANO

DIPARTIMENTO DI SCIENZE DELLA TERRA

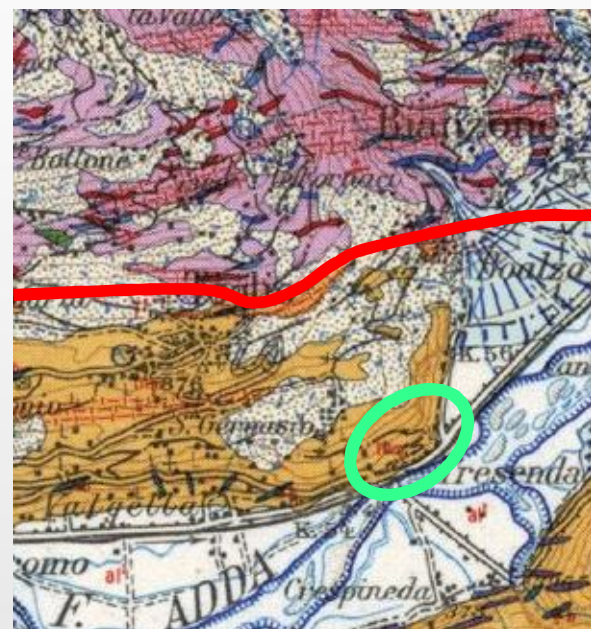
A. DESIO

Parametrization of a dry retaining wall on a terraced slope in Valtellina (Northern Italy) and stability analysis

(Corrado Camera, Tiziana Apuani, Marco Masetti)

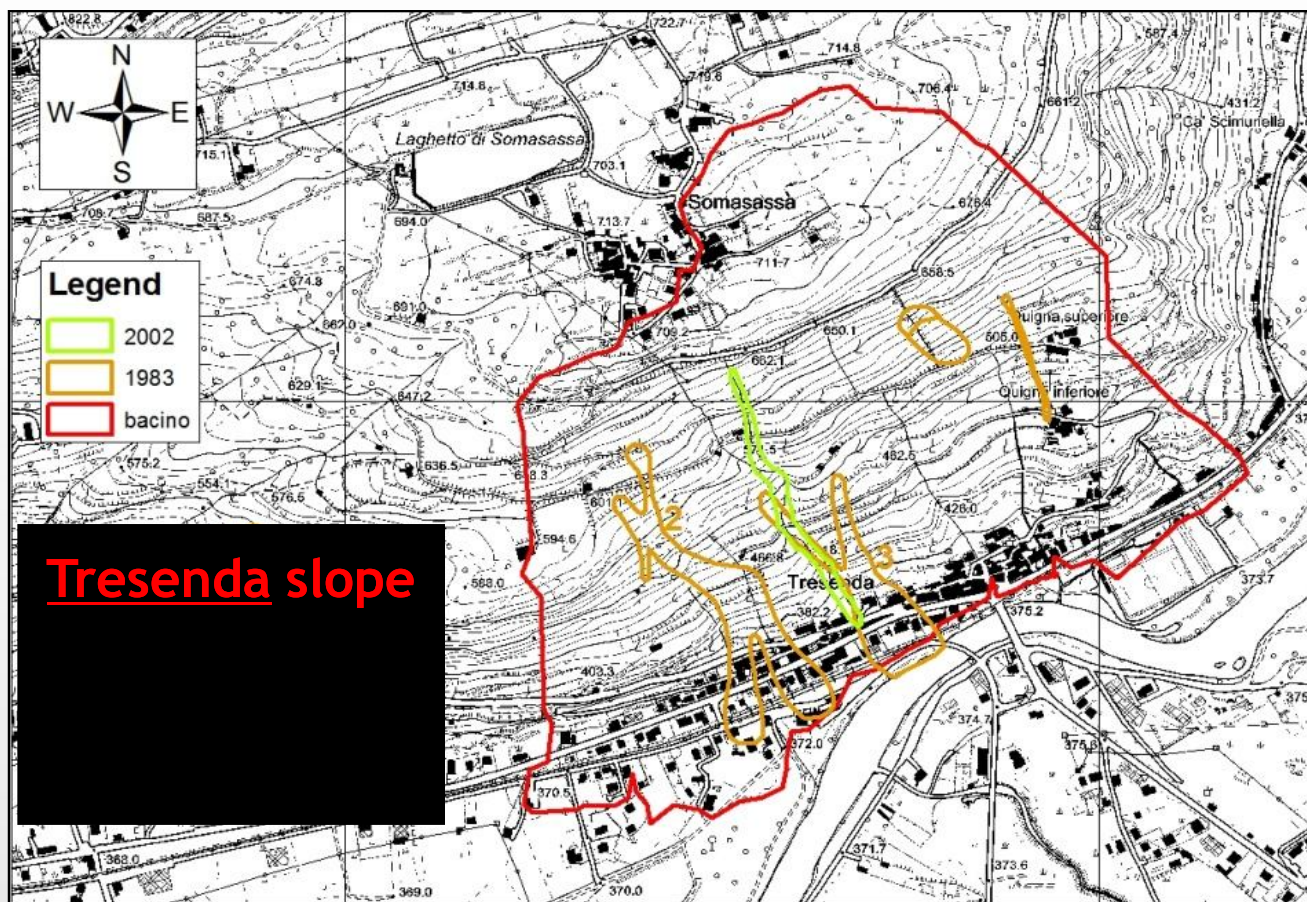
Study Area

Geographical and Historical Setting



1983: 3 soil slips/debris flows. Casualties and damages.

2002: 1 soil slip/debris flow. Damages.



Study Area

Geographical and Historical Setting



Study Area

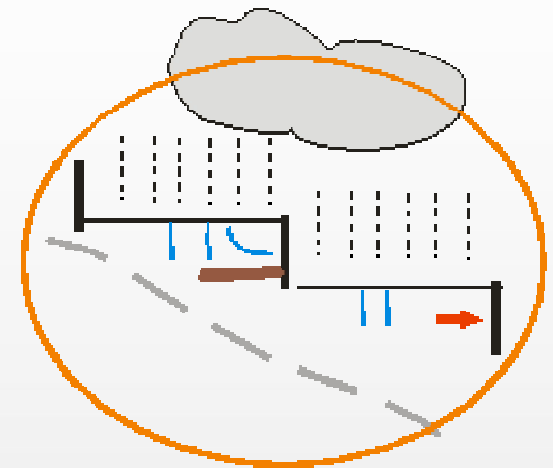
Geographical and Historical Setting



Targets

Triggering of superficial landslides:

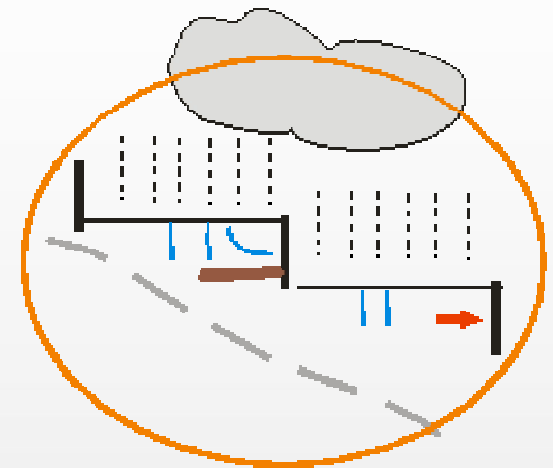
- ✓ **Why?** → rainfalls, antecedent water content, soil and walls properties, etc.
Single terrace scale. Single rainfall event.
- ✓ **Where and When?** → spatial and temporal variability.
Slope scale. Rainfall temporal series.
- ✓ **How do they evolve?** → reology, topography.
Slope scale. Post triggering.



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Methods: Hydrogeological and Stability Model

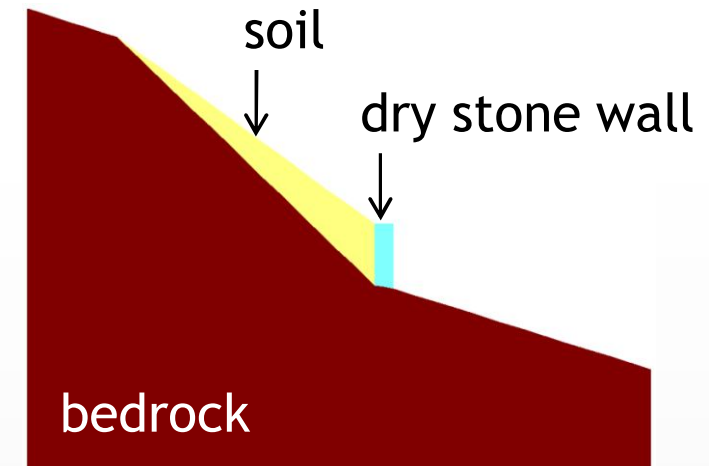
Parameterization

Hydrogeological parameters:

k_s → saturated hydraulic conductivity

SWRC → water content vs. water potential

k function → k vs. water content



for:

SOIL

k_s : field and laboratory data.

SWRC and **k function**: empirical methods from grain curve.



WALL

Derived by soil characteristics and depending on the wall's state of maintenance.

BEDROCK

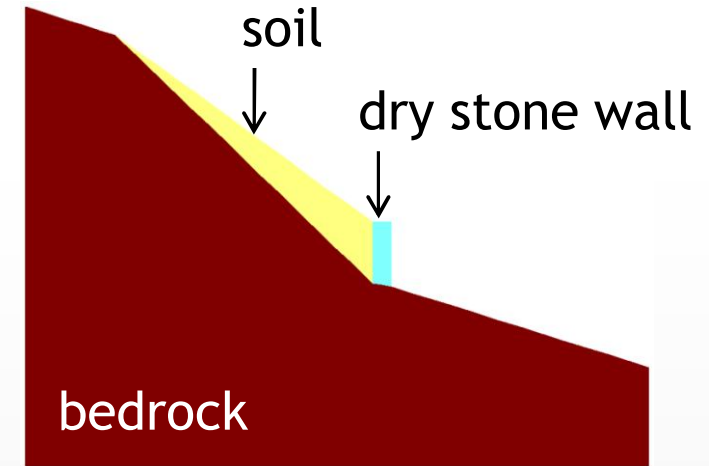
Impermeable respect to wall and soil.

Methods: Hydrogeological and Stability Model

Parameterization

Geotechnical parameters:

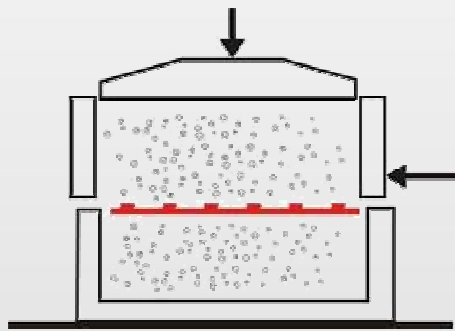
Cohesion, friction angle, bulk density, deformation modulus.



for:

SOIL

Laboratory and field measurements.



WALL

Geomechanical survey.



BEDROCK

Geomechanical survey.



Methods: Hydrogeological and Stability Model

Parameterization



The dry stone wall is assimilated to a **rock mass**.

Methods: Hydrogeological and Stability Model

Parameterization



GSI

GEOLOGICAL STRENGTH INDEX FOR JOINTED ROCKS (Hoek and Marinos, 2000)

From the lithology, structure and surface conditions of the discontinuities, estimate the average value of GSI. Do not try to be too precise. Quoting a range from 33 to 37 is more realistic than stating that GSI = 35. *Note that the table does not apply to structurally controlled failures.* Where weak planar structural planes are present in an unfavourable orientation with respect to the excavation face, these will dominate the rock mass behaviour. The shear strength of surfaces in rocks that are prone to deterioration as a result of changes in moisture content will be reduced if water is present. When working with rocks in the fair to very poor categories, a shift to the right may be made for wet conditions. Water pressure is dealt with by effective stress analysis.

STRUCTURE	SURFACE CONDITIONS				
	VERY GOOD Very rough, fresh unweathered surfaces	GOOD Rough, slightly weathered, iron stained surfaces	FAIR Smooth, moderately weathered and altered surfaces	POOR Slackensided, highly weathered surfaces with compact coatings or fillings or angular fragments	VERY POOR Slackensided, highly weathered surfaces with soft clay coatings or fillings
INTACT OR MASSIVE - intact rock specimens or massive in situ rock with few widely spaced discontinuities	90			N/A	N/A
BLOCKY - well interlocked undisturbed rock mass consisting of cubical blocks formed by three intersecting discontinuity sets	80	70			
VERY BLOCKY - interlocked, partially disturbed mass with multi-faceted angular blocks formed by 4 or more joint sets		60	50		
BLOCKY/DISTURBED/SEAMY - folded with angular blocks formed by many intersecting discontinuity sets. Persistence of bedding planes or schistosity			40	30	
DISINTEGRATED - poorly interlocked, heavily broken rock mass with mixture of angular and rounded rock pieces					20
LAMINATED/SHEARED - Lack of blockiness due to close spacing of weak schistosity or shear planes	N/A	N/A			10

DECREASING INTERLOCKING OF ROCK PIECES (downward arrow)

DECREASING SURFACE QUALITY (rightward arrow)

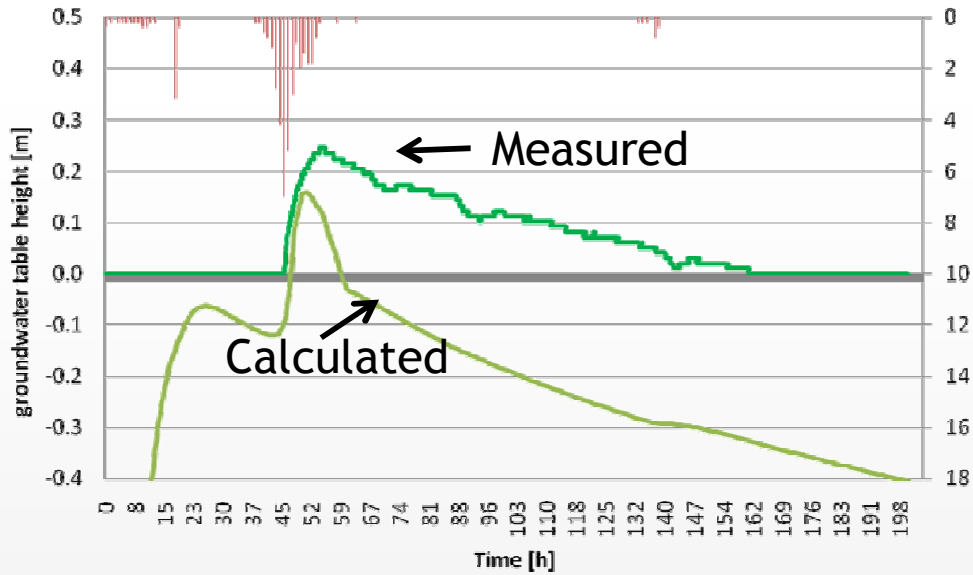
Hoek & Brown criterion → equivalent Mohr-Coulomb c and ϕ

GSI	σ_{ci} [MPa]	E_m [MPa]	c [kPa]	ϕ [deg]
10 - 20	20 - 50	450 - 1250	25 - 40	45 - 55

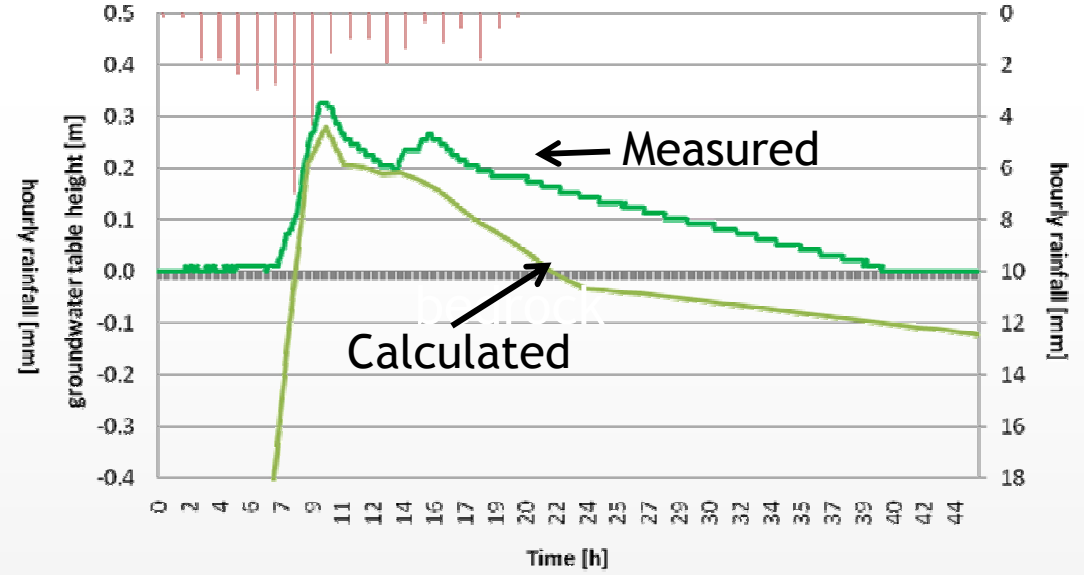
Methods: Hydrogeological and Stability Model

Calibration and Validation - Hydrogeological part

CALIBRATION



VALIDATION



Methods: Hydrogeological and Stability Model

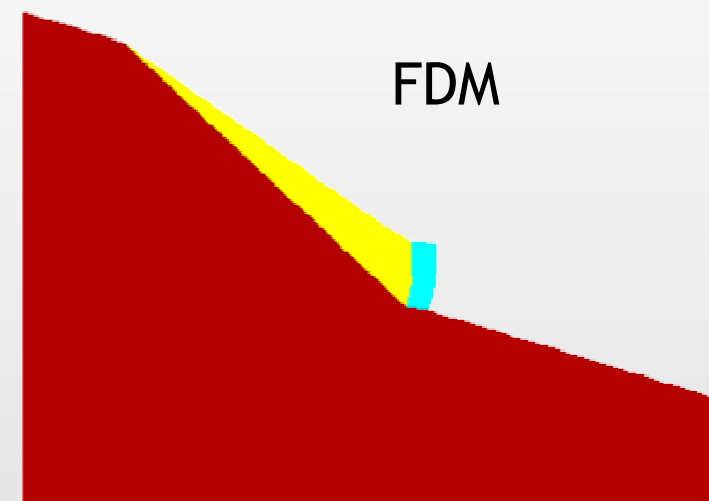
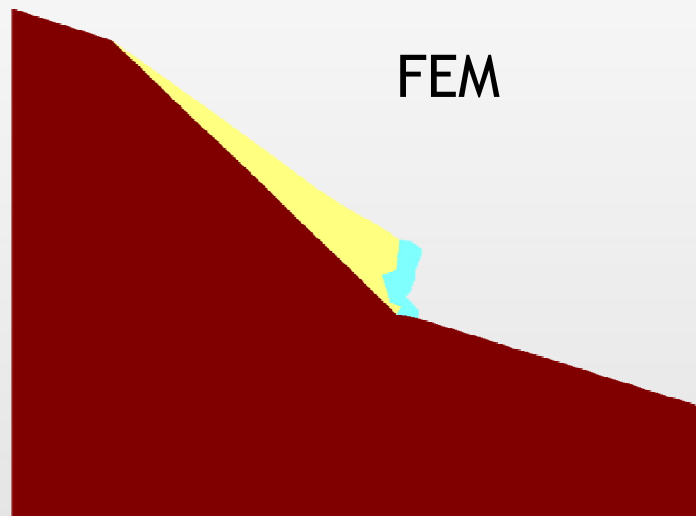
Calibration and Validation - Stability part

Three real rainfall events:

- similar duration
- similar total cumulated rainfall
- different antecedent water content

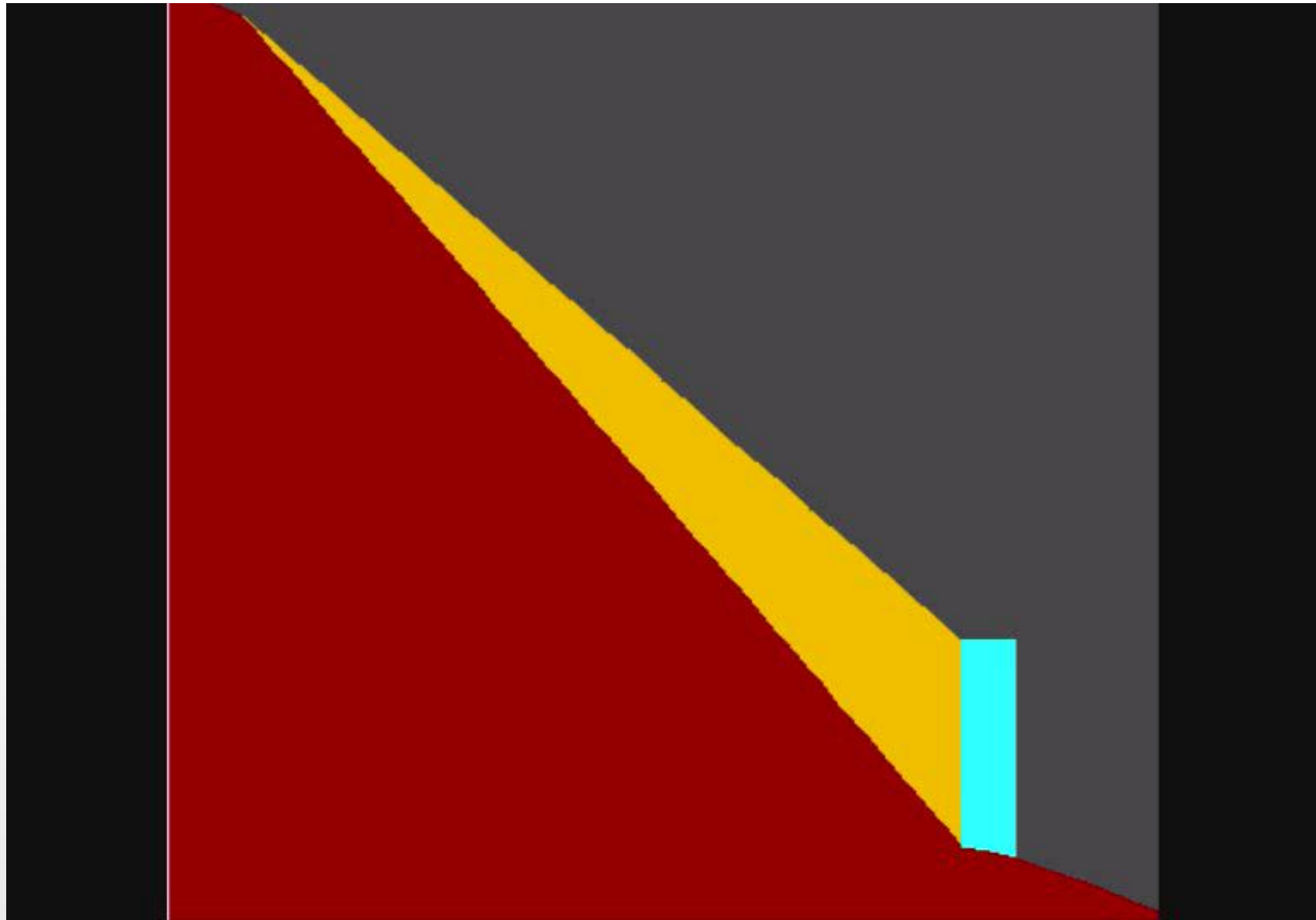
Two stable
One failure

Finite Elements Method			Finite Differences Method		
E [Mpa]	c [kPa]	ϕ [deg]	E [Mpa]	c [kPa]	ϕ [deg]
250	120	55	250	15	55



Methods, Hydrogeological-Stability Model

Calibration and Validation - Stability part



Methods: Hydrogeological and Stability Model

Use of the model and results

ID	Return period	Wall maintenance	Initial water content	Results FEM	Results FDM
1	10 years	Good	dry	stable	stable
2	10 years	Good	almost saturated	stable	stable
3	10 years	Bad	dry	stable	stable
4	10 years	Bad	almost saturated	stable	stable
5	50 years	Good	dry	stable	stable
6	50 years	Good	almost saturated	stable	stable
7	50 years	Bad	dry	stable	stable
8	50 years	Bad	almost saturated	stable	unstable
9	100 years	Good	dry	stable	stable
10	100 years	Good	almost saturated	unstable	stable
11	100 years	Bad	dry	stable	stable
12	100 years	Bad	almost saturated	unstable	unstable

Methods: Hydrogeological and Stability Model

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1) For **dry** initial conditions the system is always **stable**.

Methods: Hydrogeological and Stability Model

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- 1) For **dry** initial conditions the system is always **stable**.
- 2) FEM-FDM models are **coherent** for **the worst scenario**.

Methods: Hydrogeological and Stability Model

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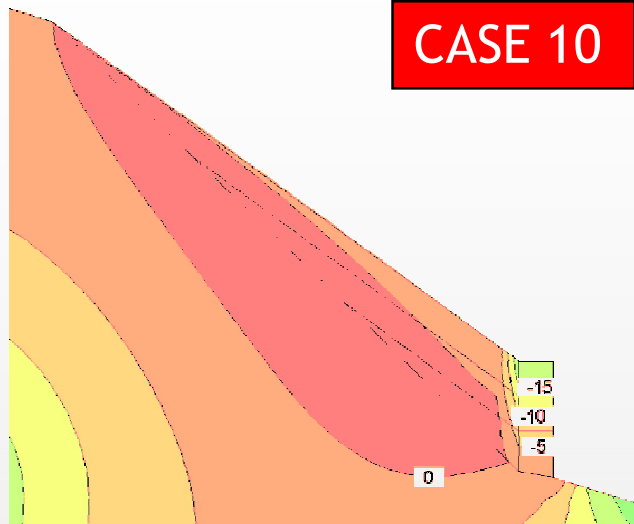
- 1) For **dry** initial conditions the system is always **stable**.
- 2) FEM-FDM models are **coherent** for **the worst scenario**.
- 3) Two cases are **not** in agreement.

Methods: Hydrogeological and Stability Model

Use of the model and results

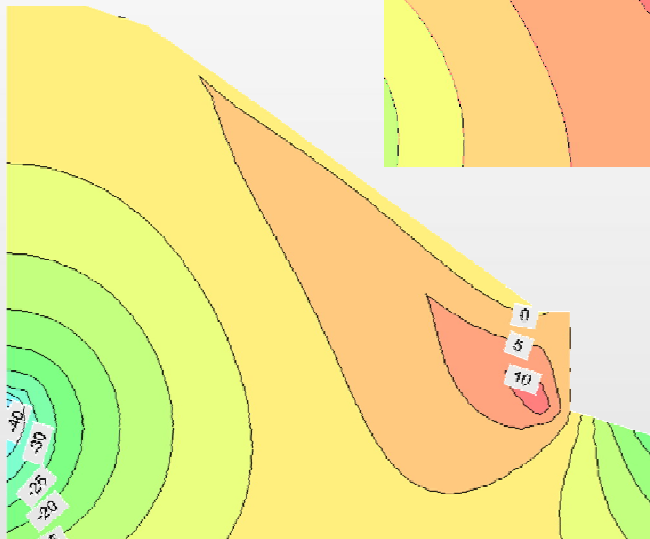
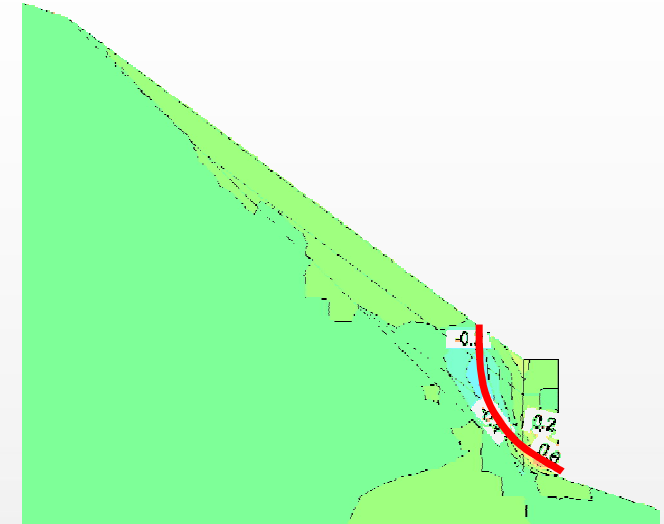
ID	Return period	Wall maintenance	Initial water content	Results FEM
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Pore water pressure

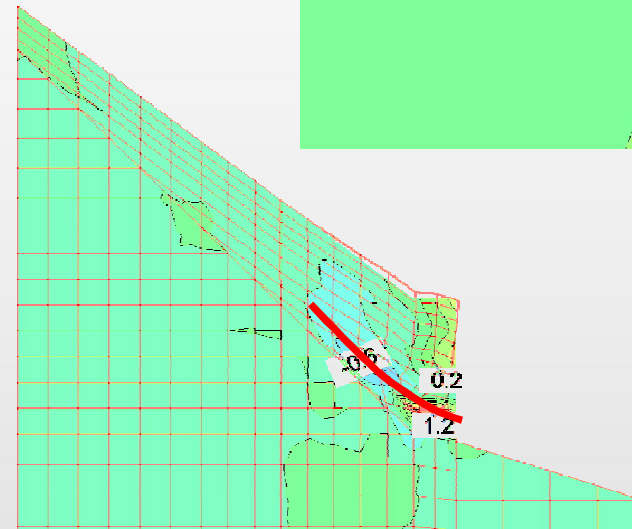


CASE 10

XY shear strain



CASE 12



Conclusions

- ✓ Importance of **field and laboratory characterization**.

HYDROGEOLOGICAL MODEL

Differences in the behaviour of differently maintained walls.

STABILITY MODEL

Validation of the GSI procedure.

Definition of scenarios.

- ✓ **Extreme rainfalls events** combined with **antecedent rainfalls** are crucial factors for stability.
- ✓ Walls conditions and water table geometry complicate the reaction of the system.

A high-angle, panoramic view of a lush mountain valley. The foreground shows a vineyard on the left and a small town with a church spire on the right. A river flows through the center, surrounded by green fields and trees. In the background, steep, forested mountains rise, with snow-capped peaks visible in the distance under a clear blue sky.

Thanks for you attention