Workshop on Recent Development in Natural Terrain Landslide Risk Management
(Hong Kong, December, 13, 2007)

Italian Landslides and Mitigation Works

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Tessina mudslide (Pasuto & Silvano)

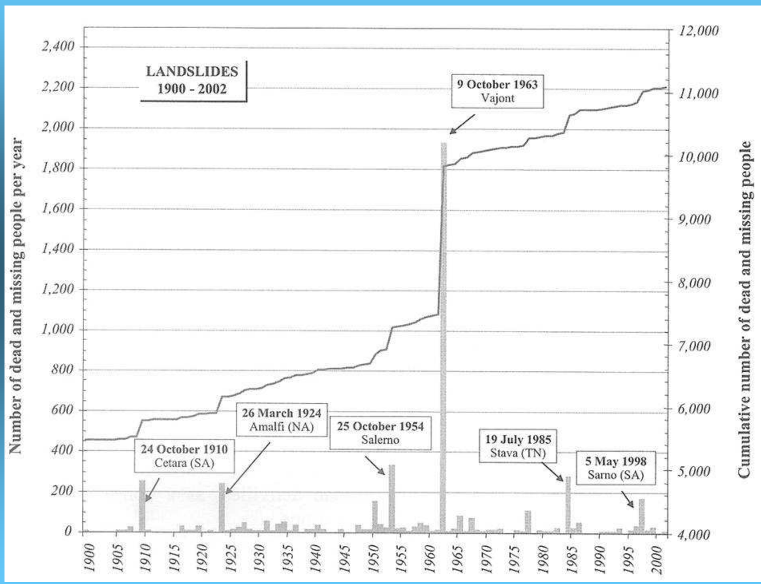
Italy is one of the most industrialized regions in the world with the highest concentration of natural risks because of:

- volcanic events (the last catastrophic eruption in Stromboli in 2002);
- earthquakes (the last killer earthquakes in 1976, in Friuli, and in 1980, in Campania);
- floods (the last killer flood in 1998; a well known recent catastrophic overflow, the one of Arno river in Florence, in 1966);
- landslides (the last killer landslide in 2006; almost 11,000 fatalities in the last century);
- snow avalanches;
- natural forest fires.

However, an excellent rating can also be assigned to anthropic risk (fired forests, rupture of tailing dams, as in Val di Stava in 1987, pollution)

Finally, and personally, the "mother in law risk", whose magnitude is higher than that of any other natural risk, cannot be disregarded

Fatalities due to landslides in the last century in Italy

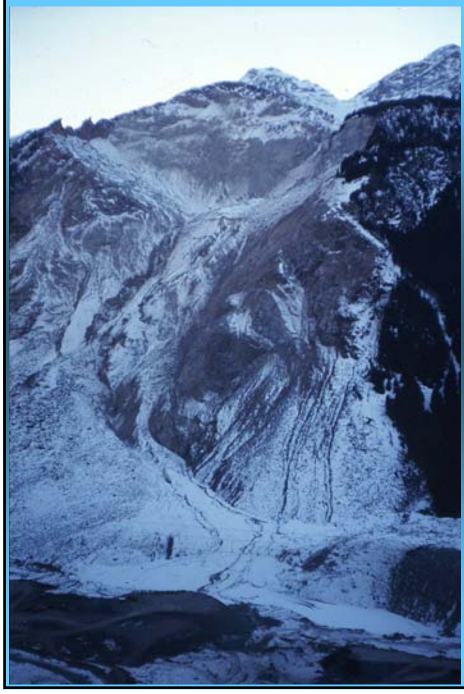


(Guzzetti, 2003)

Almost all types of landslides can be found in the Italian showroom:

- **extremely rapid rockslides (reaching even tens of millions of cubic metres) and debris flows in the Alps chain;**
- **from extremely slow to rapid slides and mudslides reaching tens of millions of cubic metres in stiff clay or flysch, mostly along the easternmost part of the Appennines chain;**
- **from rapid to extremely rapid debris avalanches, flowslides and debris flows in pyroclastic soils in Campania (Southern Appenines): the size of these landslides can attain hundreds of thousand of cubic metres;**
- **extremely slow huge lateral spreads in clay (mostly along the Appennines chain).**

The Vajont slide, 1963



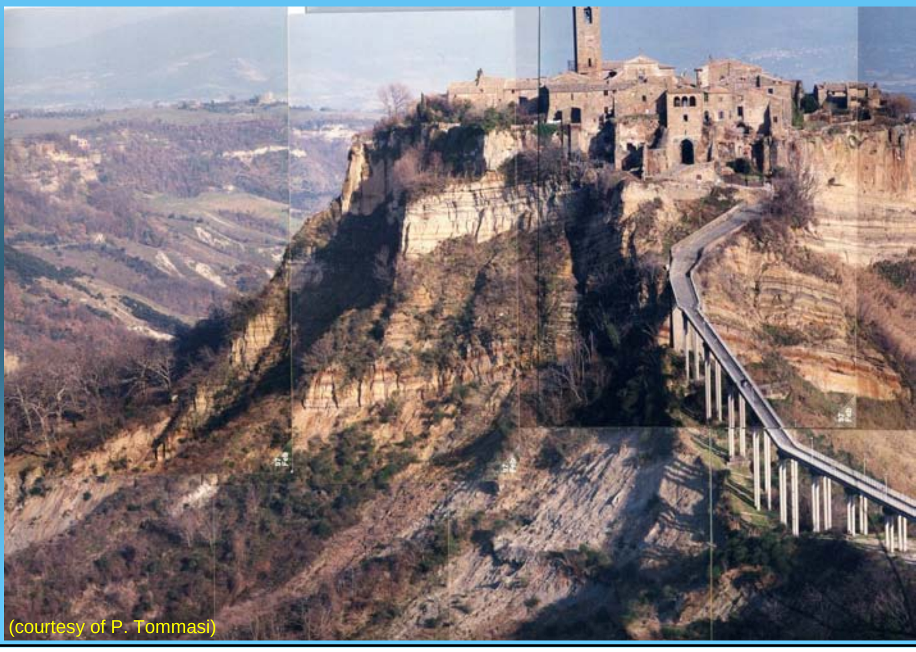
The Val Pola
rock avalanche, 1987

The Val di Stava debris flow, 1985

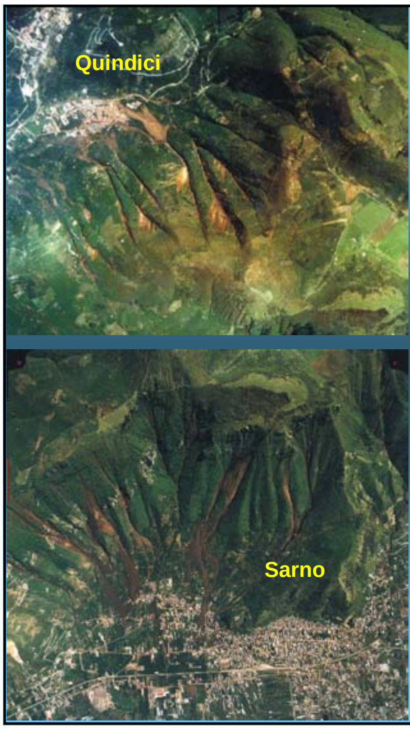
A rock fall occurred one century ago along the cliffs of the wonderful Orvieto town

(courtesy of P. Tommasi)

The abandoned Civita di Bagnoregio ancient village



The "Sarno debris flows", in 1998



Spots

Northern side of the mountain

Southern side of the mountain

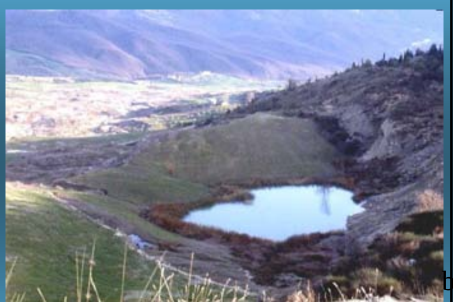
The 1997 Nocera Inferiore flowslide

The Cavallerizza mudslide, in 2005

Earthquake-induced mudslides (1980)

a)

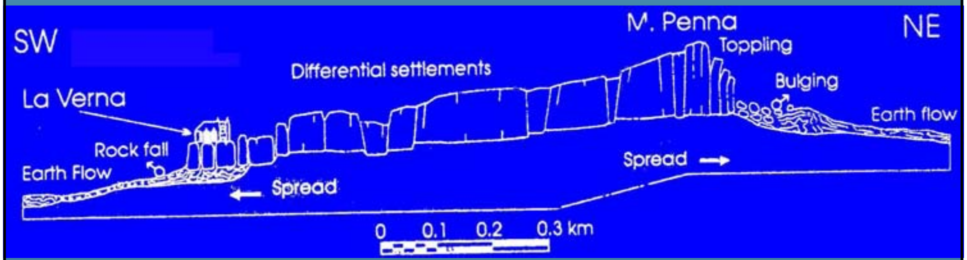
Serra dell’Acquara mudslide



b

Buoninventre mudslide

The historic Verna Mt. lateral spread



(Canuti et al., 1990)

The holy La Verna monastery has not troubles due to movement, with the help of St. Francis!

Features of catastrophic landslides

LARGE SIZE, which depends on stratigraphy, structure (discontinuities), soil properties, triggering mechanism

HIGH VELOCITY, which depends on acceleration at rupture and slope length and profile: as high is the acceleration and long the slope as high is the velocity attained by the soil mass

Acceleration is triggered by a unbalanced force acting on the landslide body, which can be caused by an increase of the driving force (loading conditions) or by a decrease of the resisting force (soil brittleness).

Brittleness is very in OC plastic fine-grained soils, in some saturated granular NC soils subject to fast loading (undrained conditions), along rough joints. It is low in slightly OC clays of low plasticity and in NC granular soils; it is nil along slip surfaces.

As a consequence …

Active or reactivated slides and first-time slides in NC granular soils are generally slow

First-time slides, debris flows in cemented or unsaturated non lithified soils, mudslides (undrained conditions), flowslides and debris flows in loose saturated pyroclastic soils (undrained conditions) are all fast movements

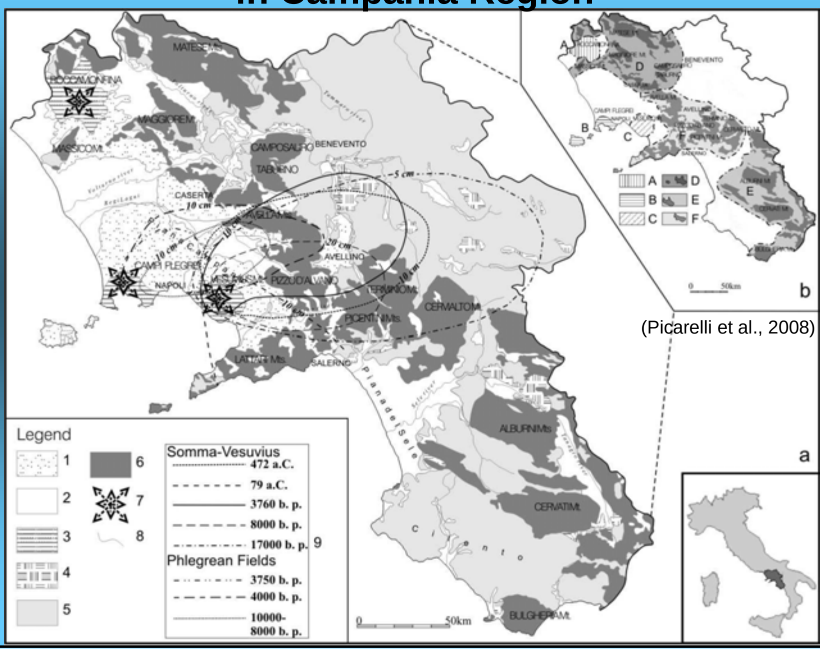
Three situations will be discussed here:

- **Flowslides, debris flows and debris avalanches in Campania**
- **Mudslides in turbiditic formations along the Appennines chain**
- **Lateral spreads of competent rock over stiff fine-grained deposits**

Definitions

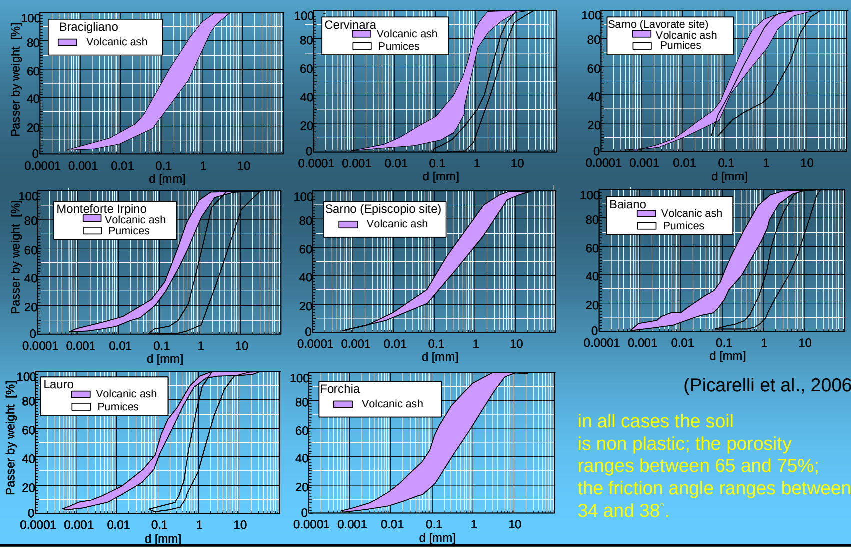
Debris avalanche: a non channellized flow-like landslide of dry or partially saturated soil, moving along a flat slope
Flowslide: a non channellized flow-like landslide provoked by liquefaction (or even by complete soil fluidization), moving along a flat slope
Debris flow: a channellized flow-like landslide running within a gully or a channel which indents the slope
Liquefied debris flow: a channellized flow-like landslide of liquefied soil running within a gully or a channel which indents the slope
Mudslide: a flow-like landslide of prevailingly fine-grained material
Lateral spread: a slow movement of material which essentially expands in a quasi-horizontal direction

Main volcanic centres and pyroclastic deposits in Campania Region



(Picarelli et al., 2008)

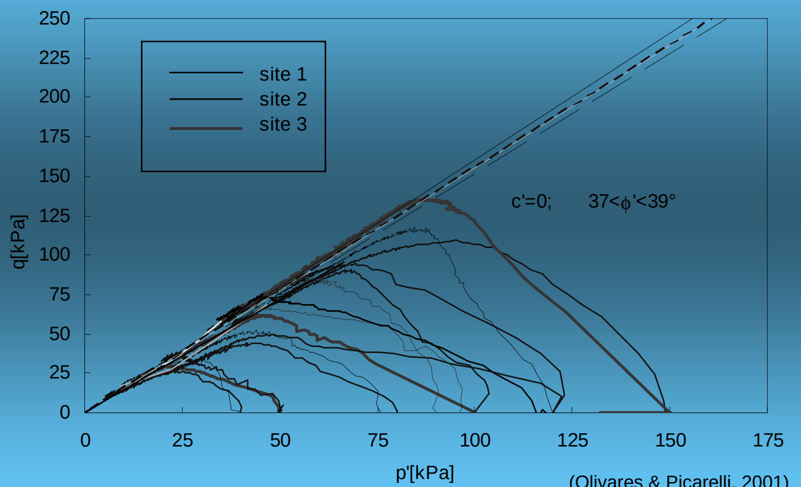
Grain size of air-fall pyroclastic soils involved in catastrophic debris flows



(Picarelli et al., 2006)

in all cases the soil is non plastic; the porosity ranges between 65 and 75%; the friction angle ranges between 34 and 38°.

Undrained shear strength of saturated natural specimens of air-fall ash from different sites



(Olivares & Picarelli, 2001)

Mechanisms of rainfall-induced landslides in unsaturated pyroclastic soils

1. On slope pyroclastic soils are always unsaturated: slope failure is hence provoked by rain water infiltration, increase of the degree of saturation and decrease of suction and associated apparent cohesion

2. If the soil is susceptible to liquefaction and failure occurs after full or quasi-full saturation has ben reached, a flowslide can be triggered

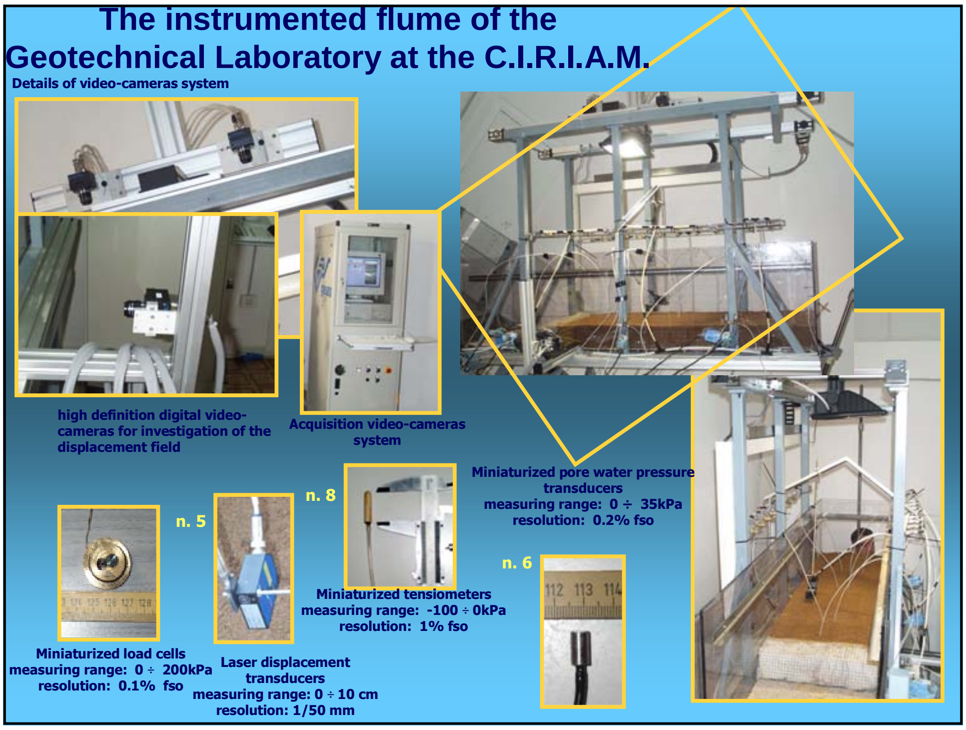
3. The flowslide can turn into a liquefied debris flow if the induced movement is channellized into a gully, otherwise it remains a flowslide

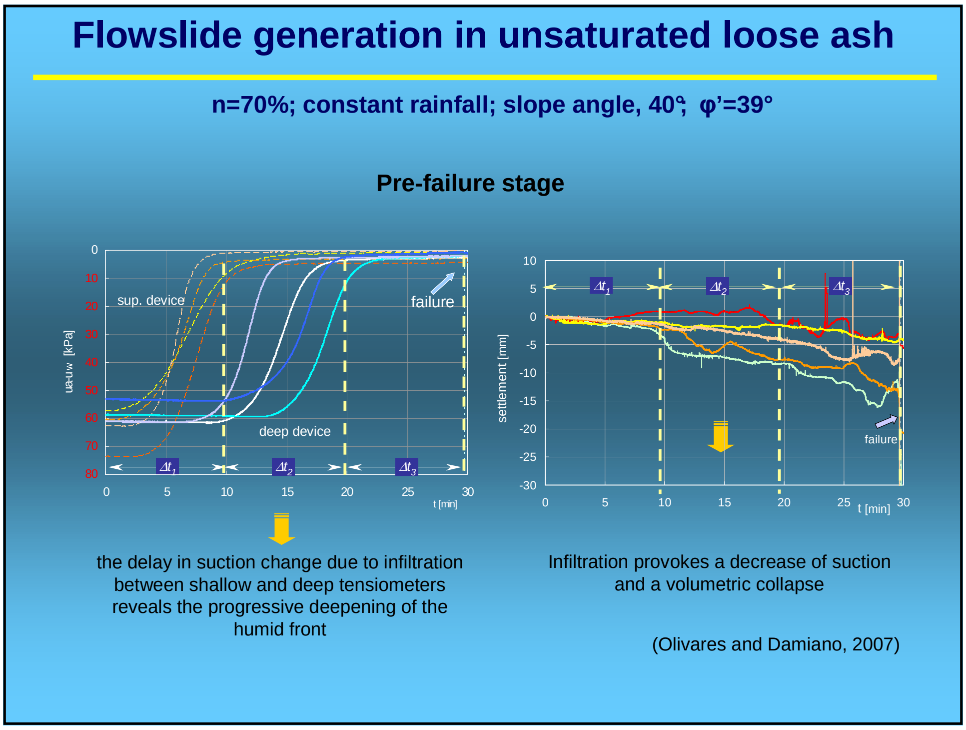
4. If the soil is not saturated or is not susceptible to liquefaction, a debris flow or avalanche is generated depending on slope features

5. Since pyroclastic soils cover long slopes, they can attain very high velocities covering large distances: the highest magnitude is possessed by liquefied debris flows; a high magnitude also characterises flowslides, while debris avalanches are less "intense", but rapid enough to destroy houses and other structures when impacted

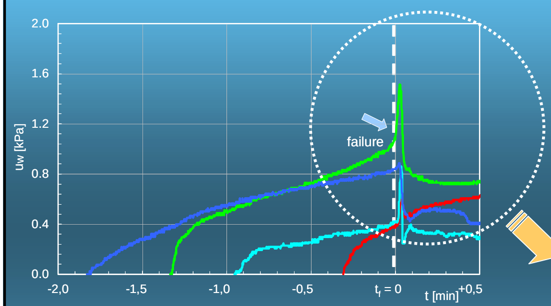
Liquefied debris flow

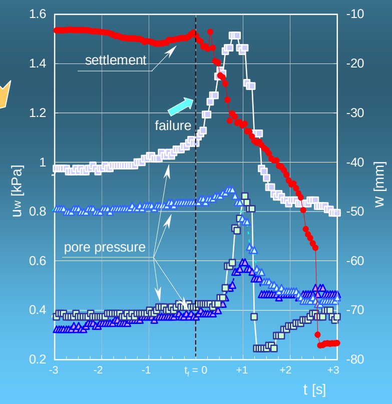
Debris avalanche


The instrumented flume of the
Geotechnical Laboratory at the C.I.R.I.A.M.
Details of video-cameras system
high definition digital video-cameras for investigation of the displacement field
Acquisition video-cameras system
Miniaturized pore water pressure transducers
measuring range: 0 ÷ 35kPa
resolution: 0.2% fso
n. 8
n. 5
n. 6
Miniaturized tensiometers
measuring range: -100 ÷ 0kPa
resolution: 1% fso
Miniaturized load cells
measuring range: 0 ÷ 200kPa
resolution: 0.1% fso
Laser displacement transducers
measuring range: 0 ÷ 10 cm
resolution: 1/50 mm


Flowslide generation in unsaturated loose ash
n=70%; constant rainfall; slope angle, 40°; φ'=39°
Pre-failure stage
sup. device
failure
deep device
ua-uw [kPa]
t [min]
settlement [mm]
failure
t [min]
the delay in suction change due to infiltration between shallow and deep tensiometers reveals the progressive deepening of the humid front
Infiltration provokes a decrease of suction and a volumetric collapse
(Olivares and Damiano, 2007)

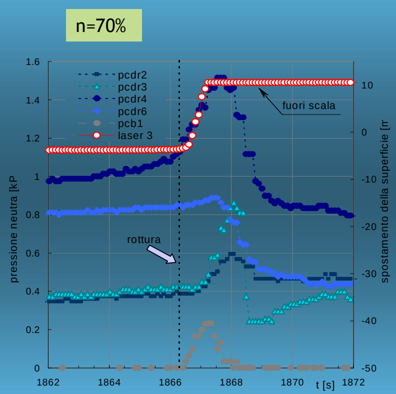
Pore pressure evolution until slope failure

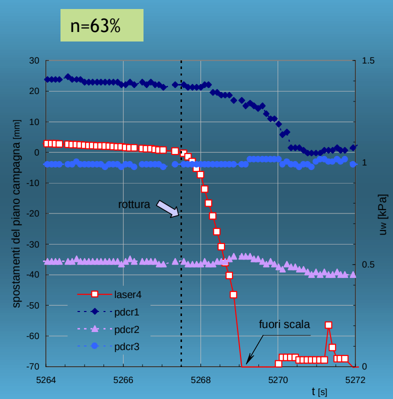




(Olivares and Damiano, 2007)

Comparison of pore pressures for a loose and a denser sand





(Picarelli et al., 2007)

A mapping of hazard areas with special reference to the potential sources of flowslides and liquefied debris flows is then possible.

Adopting the model of infinite slope, the main factors to be accounted for are:

- slope angle, which governs the degree of saturation at rupture;
- apparent cohesion and friction angle, which are extremely uniform in pyroclastic soils, and govern slope failure;
- grains size, plasticity and density, which govern the susceptibility of soil to liquefaction;
- slope morphology (existence of gullies), which governs turning of a flowslide into a debris flow

Areas susceptible to debris flows in the neighbours of Bracigliano, and comparison with 1998 events

no cover
susceptible to flowslide
susceptible to debris avalanche
boundaries of the 1998 flowslide

a)

crack
1998 debris flow

b)

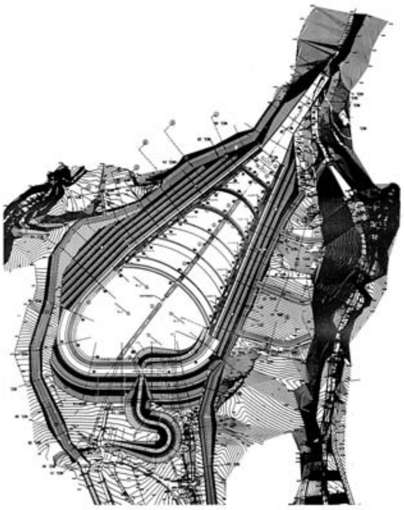
(Picarelli et al., 2007)

Such a mapping allows to have a complete spatial distribution of the landslide prone areas, but not of the hazard nor of the time when a landslide will eventually occur

This last can be obtained through procedures of landslide prediction

Risk mitigation can be obtained through structural or non-structural measures, such as:

- passive woks (retention basins, check dams, diversion channels etc.), which have been built in several areas of the Region;
- active works, which are not very popular because of the extension of hazard slopes to be stabilised;
- non structural works (restrictions in land use, emergency plans, early warning systems).



Design of a retention basin

Volume of mud to be collected up to a couple of hundred thousand Cubic metres

Retention basin built upslope Quindici town

Early warning

In areas which are not covered by monitoring of indicators, the procedure for landslide prediction to be used within early warning systems can include:

- hydrological models, such as the one used in Sarno (FLAiR), which requires only a continuous monitoring of rainfall;
- criteria of analysis of infiltration on large areas and consequent effects on slope stability, supported by GISs, such as SHALSTAB and TRIGRS

In areas covered by monitoring of indicators, the prediction can be based only on the crude elaboration of data from monitoring or using these ones as input parameters for slope analysis

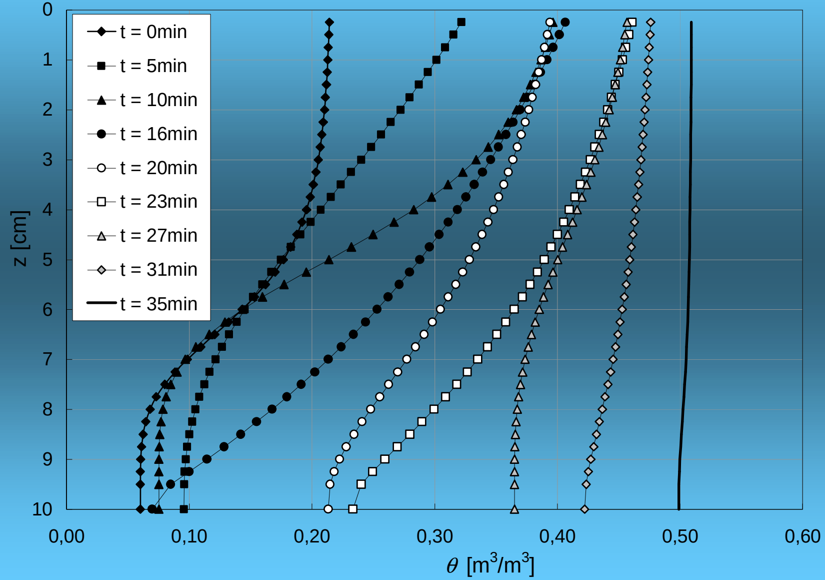
A combination of more criteria can be useful

Recently the use of TDR devices for the assessment of water content profiles, and optical fibers for capturing pre-failure soil deformation are being tested in flume experiments in order to adopt new instruments for prediction of failure

TDR can be used for water content measurement and consequent suction assessment along instrumented verticals: real-time readings and elaborations and data transmission can be used to rapidly assess the safety factor

Optical fibers could be used for capturing the indicators of incoming failure

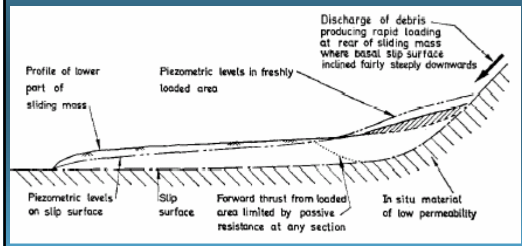
Evolution of the water content profile during a flume test measured with TDR



(Damiano et al., 2008)

Lama del Gallo mudslide

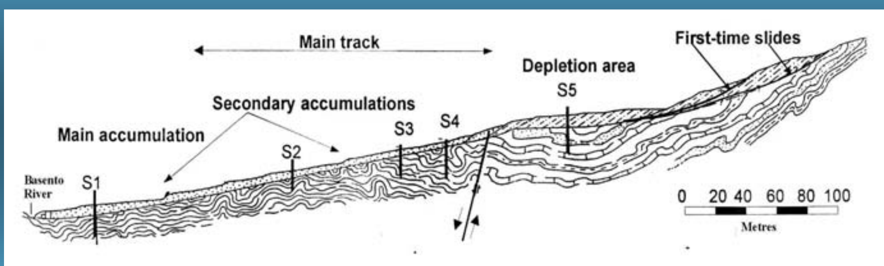
Undrained loading as a mechanism of mudslide generation



(Hutchinson and Bandhari, 1971)

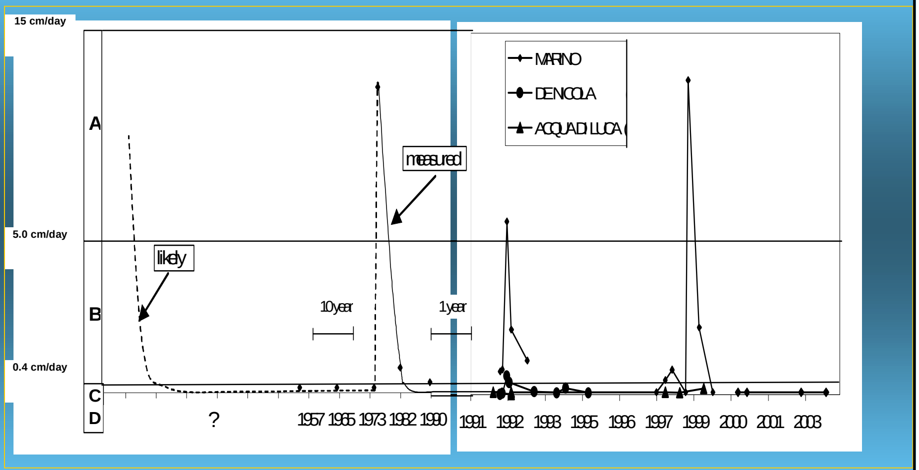
Biferno Valley

Brindisi di Montagna mudslide



(Cotecchia et al, 1984)

Displacement history of three mudslides in the Basento valley



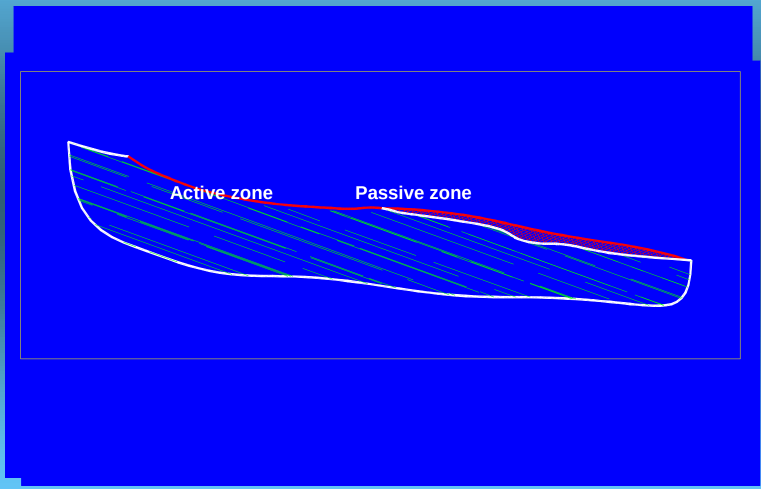
(Picarelli et al., 2005)

movement is a result of a history of undrained-drained phases

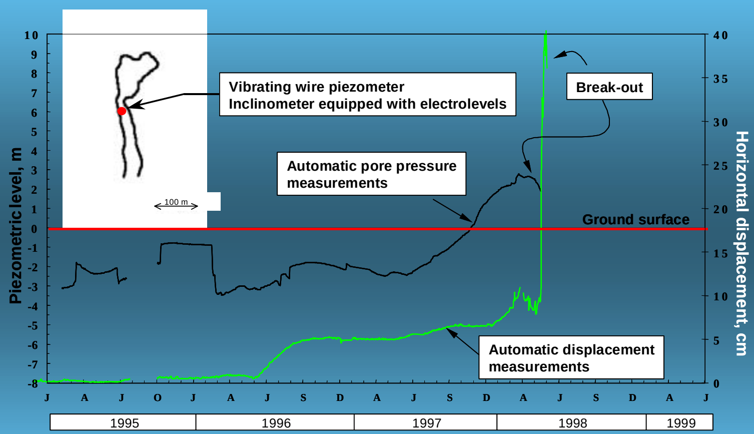
Mechanism of internal compression

(courtesy of G. Bertolini)

Mechanism of internal compression

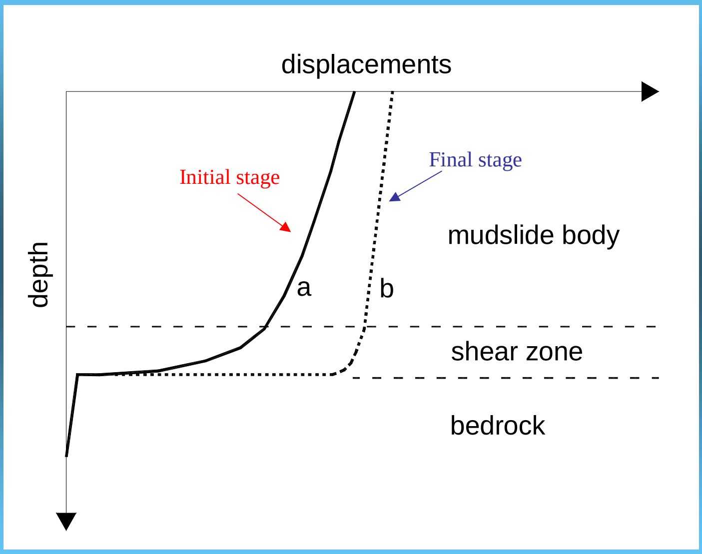


Excess pore pressure measured in the Masseria Marino mudslide (transducer located at a depth of 3m)



(Pellegrino et al., 2004)

Displacement profiles of a mudslide at different stages



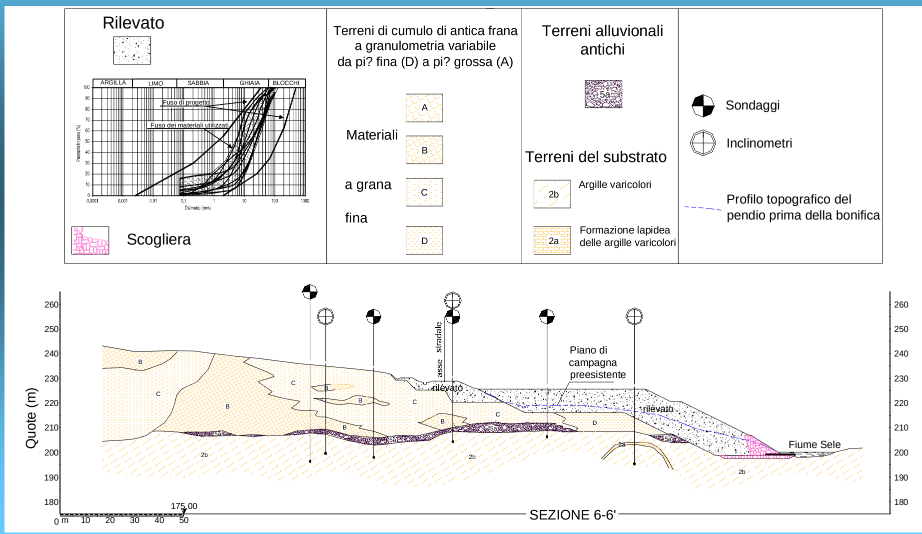
(Comegna & Picarelli, 2005)

The historic Morsiana mudslide

i.e. living with landslides is sometimes possible, but with caution!

(courtesy Bertolini)

Stabilization of a mudslide with earthworks



(Di Placido et al., 2004)

Road construction over a mudslide

Covatta mudslide, 1996

The alimentation zone

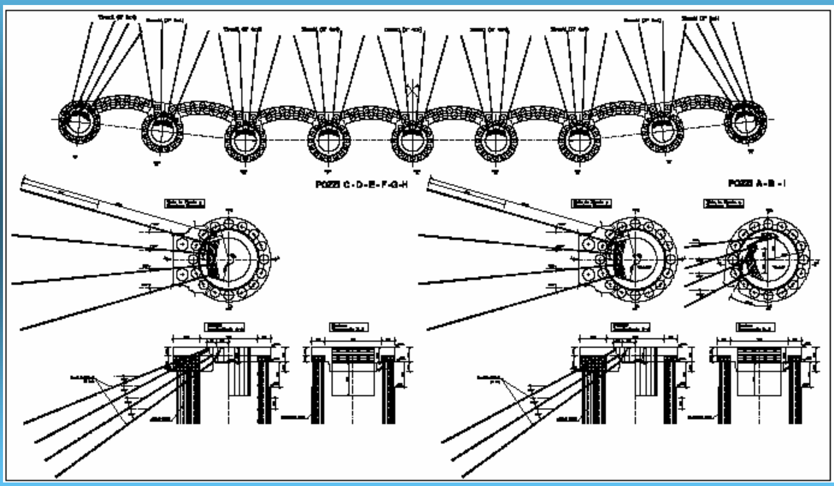
Consequences of the movement

Consequences of the movement

First emergency works

One year after

Retaining structure at the foot of the mudslide to contrast river damming



(Picarelli and Napoli, 2003)

Construction of the structural wells

Safety channel assuring a continuous river discharge

Run-off control

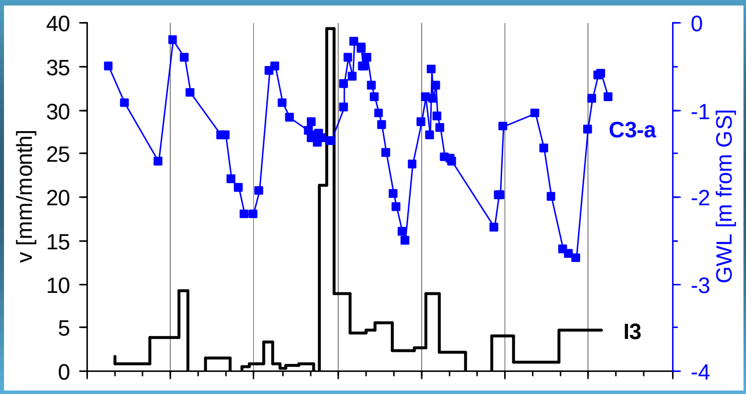
In addition, two smaller mudslides discharging material in the main track have been stabilized, one with shallow drainage works and a series of check dams, along tyhe track, the other with a couple of structural deep wells located at the toe

Construction of structural wells at the neck of the alimentation zone

Reshaping of the crown; material substitution, deep and shallow drainage in the depletion zone, stabilization of the neck

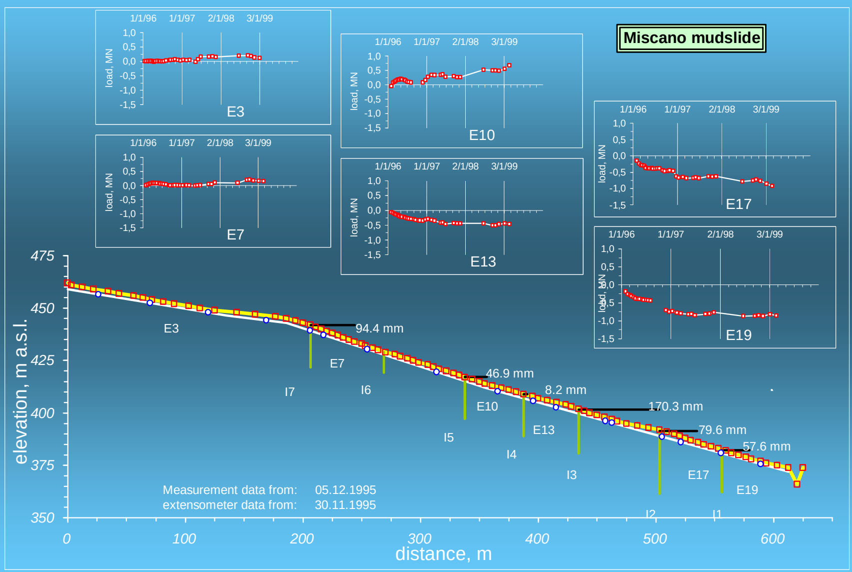
Effects of a slow mudslide on a buried pipeline

Miscano mudslide: relationship between pore pressures and displacement rate



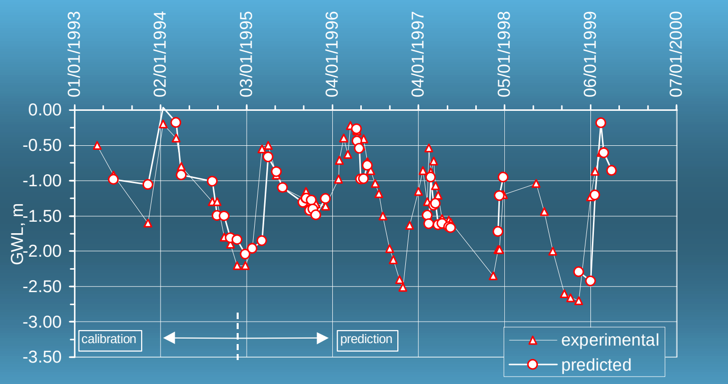
(Giusti et al.1996)

Slope displacements and stresses in the pipe



(Picarelli et al., 1996)

Prediction of piezometer levels

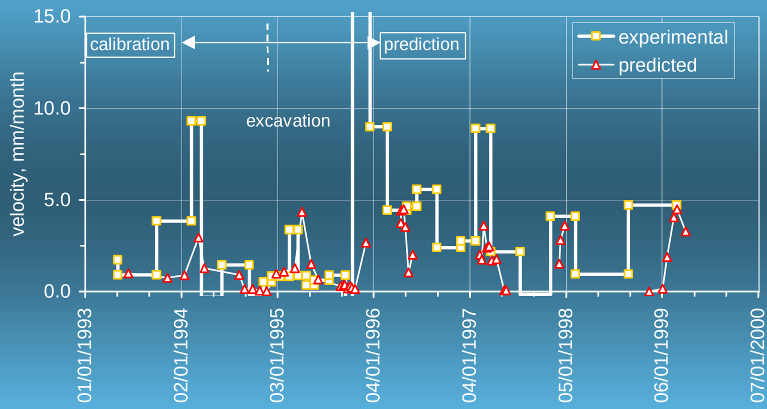


spring, summer GWLi = 0.65 x GWLi-1 + 0.0045 x P21 + 0.002 x P28 - 0.66

fall, winter GWLi = 0.76 x GWLi-1 + 0.02 x P14 + 0.015 x P21 + 0.01 x P28 - 0.84

(Mandolini and Urciuoli, 1999)

Prediction of the displacement rate



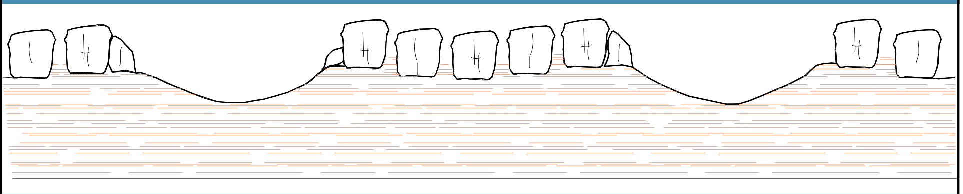
(Mandolini and Urciuoli, 1999)

The Bisaccia hill

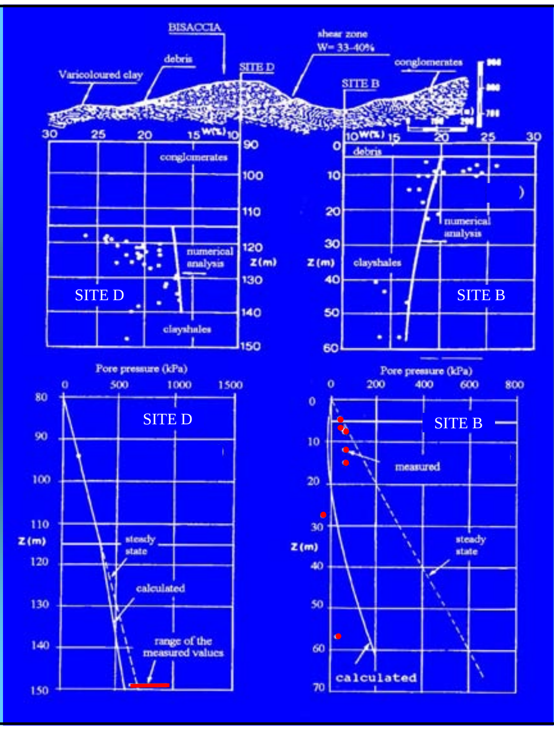
Eastern side of the hill

The hill is sinking in the basal formation while it spreads laterally

Mechanism of spread

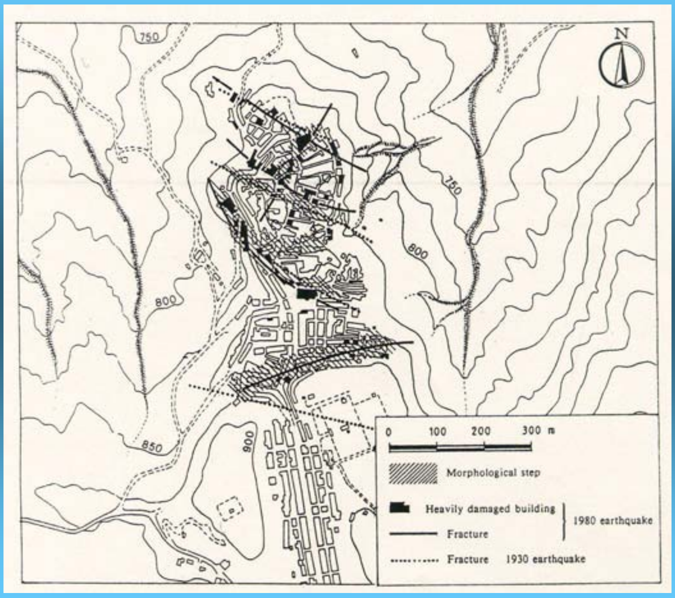


Water content and pore pressures



(Picarelli and Urciuoli, 1993)

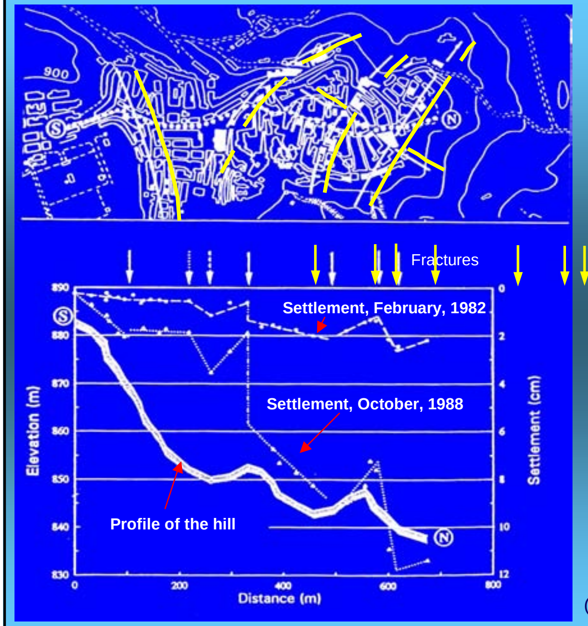
Damages provoked by earthquakes



(Fenelli and Picarelli, 1990)

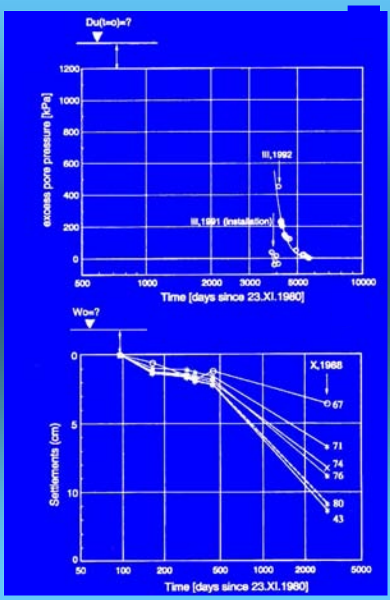
Post 1980 earthquake damages

Settlements in the town after the 1980 Earthquake



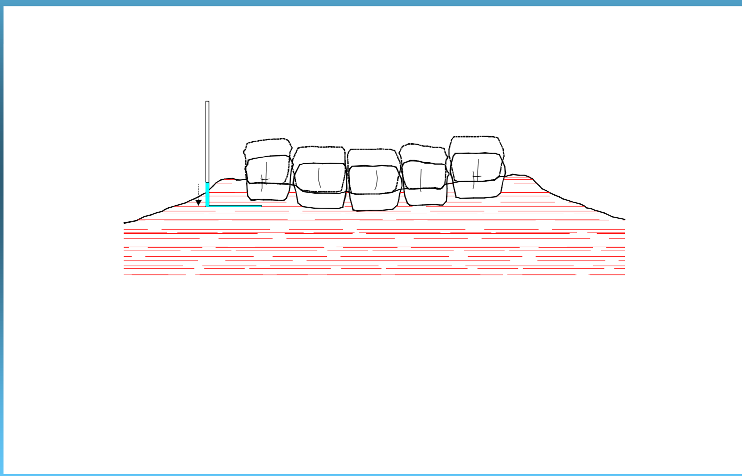
(Fenelli et al., 1992)

Pore pressure and settlement evolution after the 1980 earthquake

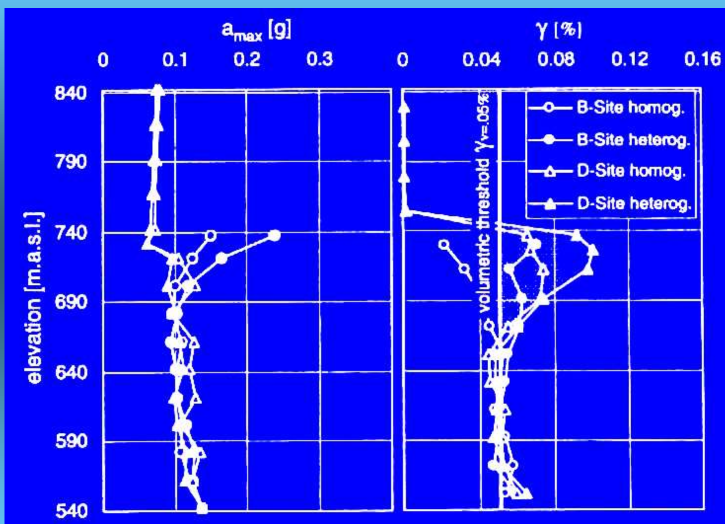


(Olivares and Silvestri, 2001)

Mechanism of post-seismic subsidence



Computed peak accelerations and shear strains



(Olivares & Silvestri, 2001)

According to a law promulgated in 1908, after the 1930 earthquake the population should have been transferred into another village which was actually built just in front of the first one.

The most of population did not move and is still living in the old village 77 years after the quake.

As a consequence of erosion, the width of the slab is maybe 7 mm higher and the elevation of the town 2 mm less.

As a consequence of the 1980 quake the elevation of the village is probably 10 cm more less, but the life goes on as many years before.

Now a phylosophical question rises: do we have the right to disturbe such a quit and natural style of life imposing to people our conception of safety?

What is freedom?