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Seismic Stability Analysis and Stabilization of an Unstable Urbanized Slope

(Case of Tizi-N'Bechar slope, Province of Setif, Algeria)

Mohamed Khemissa & Ahmed Seddiki
Geomaterials Development Laboratory, University of M'sila, Algeria

Outline

- *Introduction*
- *Description of the site*
- *Problem data and slope stability calculations*
- *Research of a reinforcement solution of the slope*
- *Conclusion*

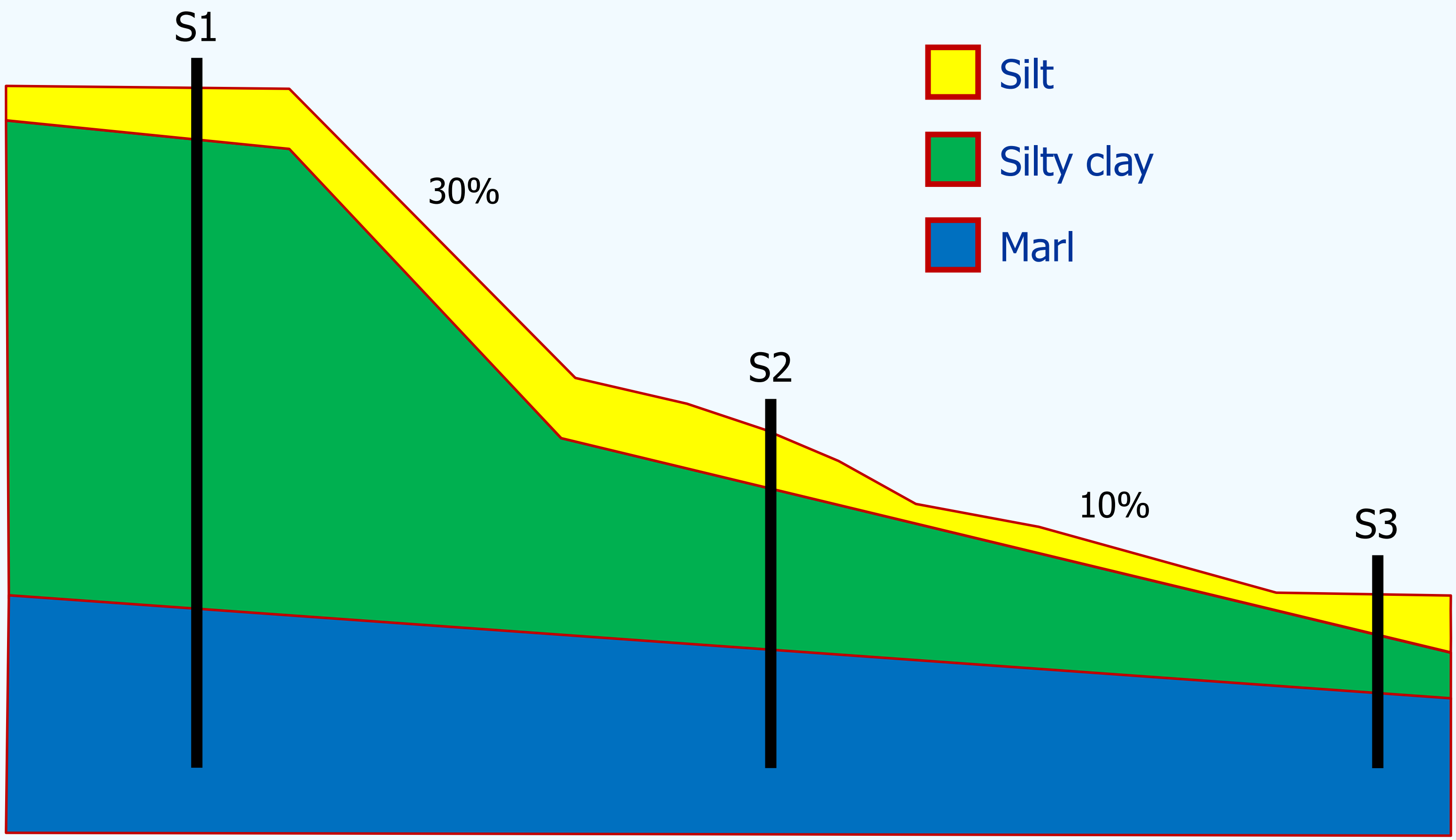
Introduction

❑ Map of Tizi-N'Bechar city (Province of Setif, Algeria)

- ✓ *Growing urbanization dictated by galloping demography.*
- ✓ *Extension of the urban fabric towards virgin zones often less favorable than those already urbanized.*
- ✓ *Instability of inclined soil massifs to be feared in this area due to its geological and geomorphological context, in addition to the climatic and geophysical conditions characterizing the Tellien Atlas in northern Algeria.*

Description of the site

- ***Geological and geomorphological context***

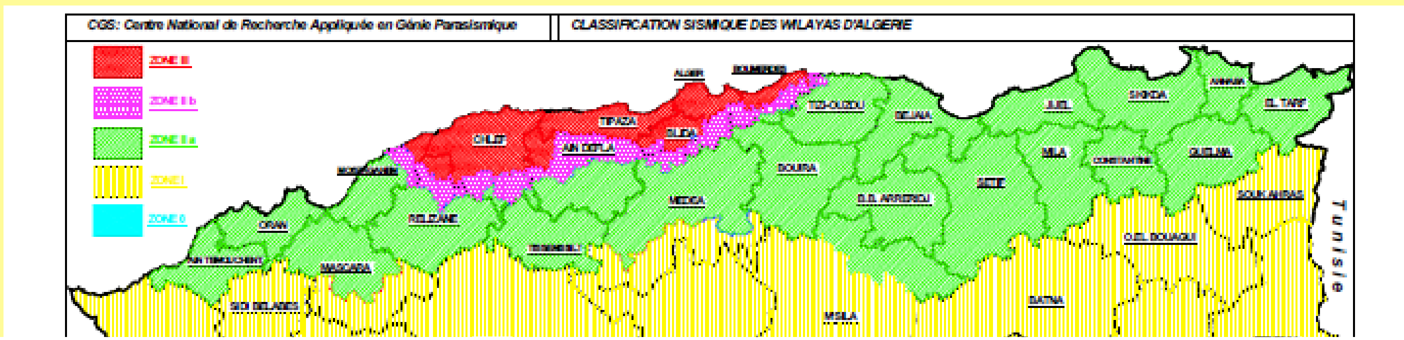


Note: The water table fluctuates from a low level in summer (completely dry slope) to a high level in winter (fully saturated slope).

Description of the site

- ***Seismic characteristics*** (Seismic zoning map of Algeria)

CARTE DE ZONAGE SISMIQUE DU TERRITOIRE NATIONAL – RPA99/ APRES ADDENDA



	Zone			
Group	**I**	**IIa**	**IIb**	**III**
1A	0.15	0.25	0.30	0.40
1B	0.12	0.20	0.25	0.30
2	0.10	0.15	0.20	0.25
3	0.07	0.10	0.14	0.18

Tizi-N'Bechar city is classified as a zone of average seismicity (RPA 99 2003)

Source : CGS

Zone 0 **Zone I** **Zone IIa** **Zone IIb** **Zone III**

Description of the site

- ***Seismic characteristics*** (Calculation parameters)

The horizontal and vertical pseudo-static coefficients taken into account in the calculation are (**RPA 99, version 2003**):

$$k_h = 0.5Ag$$

$$k_v = 0.3k_h$$

Tizi-N'Bechar city is classified as a zone of average seismicity (**zone IIa**), hence the following values:

Group	Classification of works	A	k_h (xg)	k_v (xg)
1A	Vital importance (safety, hospitals)	**0.25**	**0.1250**	**0.0375**
1B	Great importance (school buildings, mosques)	**0.20**	**0.1000**	**0.0300**
2	Currents (housing, offices)	**0.15**	**0.0750**	**0.0225**
3	Low importance (sheds)	**0.10**	**0.0500**	**0.0150**

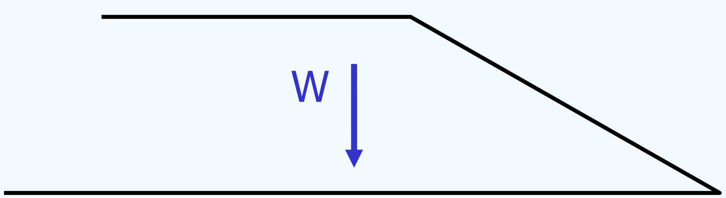
Problem data and slope stablility calculations

- ***Values retained for geotechnical parameters***

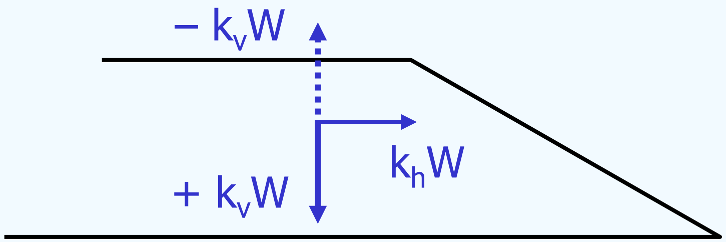
N°	Layer	γ_h (kN/m^3)	c′ (kPa)	φ′ (°)
1	Silt	16	10	15
2	Silty clay	17	13	20
3	Marl	18	30	7

- ***Softwares used***
  - TALREN 4 (version 2.0.3)
  - PLAXIS-2D (version 8.2)

- ***Calculation approach considered*** : Pseudo-static approach



Static force



Pseudo-static force

Problem data and slope stablility calculations

- ***Calculation method used in TALREN 4 (version 2.0.3)***

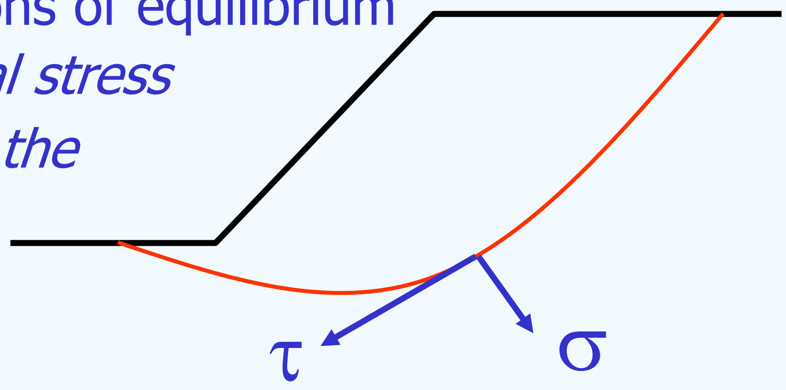
  Limit equilibrium calculation by slice method for circular and non-circular failure surfaces (Fellenius, Bishop, RRT).

Principle of calculation by the method of disturbances (RRT-method):

- Developed at LCPC (France) by Raulin, Rouquès and Toubol (1974).

- Applicable to any form failure (circular and multi-linear slip surface).

- Based on the simple resolution of equations of equilibrium *(with automatic adjustment of the normal stress distribution obtained by a disturbance of the Fellenius stress along the failure line).*



Problem data and slope stablility calculations

Calculation method used in PLAXIS-2D (version 8.2)

- Finite element calculation by the shear parameter reduction method "φ-c reduction method"

$$\frac{\tan\varphi_{data}}{\tan\varphi_{reduced}} = \frac{c_{data}}{c_{reduced}} = \sum Msf$$

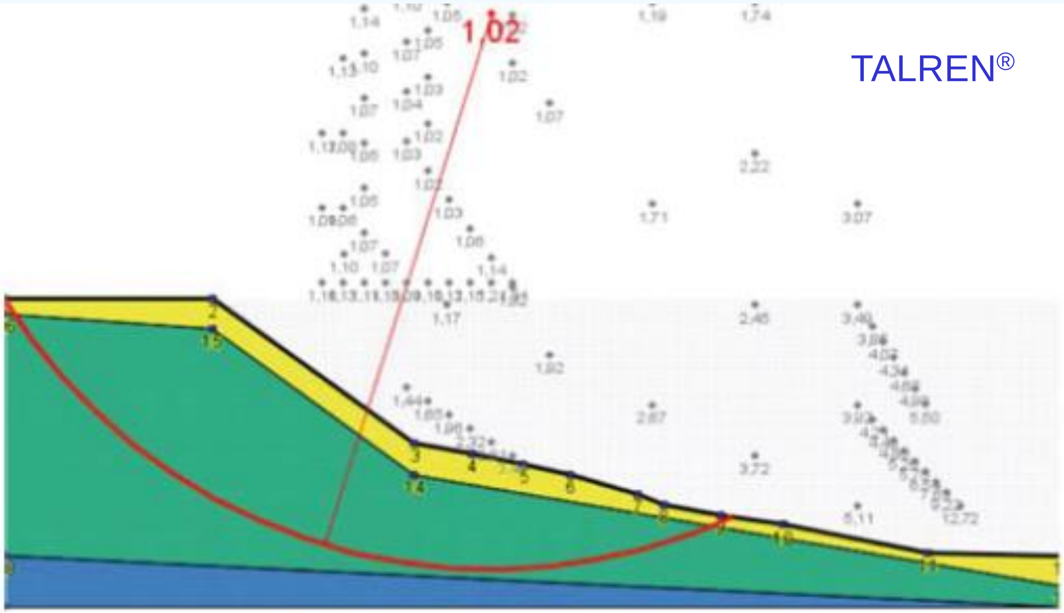
- Hence, we define the factor of safety:

$$F = \frac{\text{available strength}}{\text{strength at failure}} = \text{value of } (\sum Msf) \text{ at failure}$$

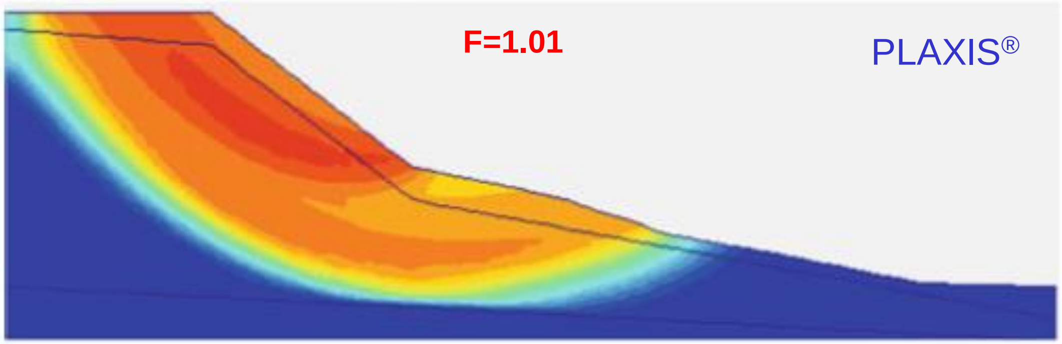
Phasing calculations:

- Initial calculation (Geostatic stresses state)
- Plasticity calculation (Mohr-Coulomb model)
- Safety calculation (φ-c reduction method)

Problem data and slope stablility calculations



(a) Localization of the potential rupture curve

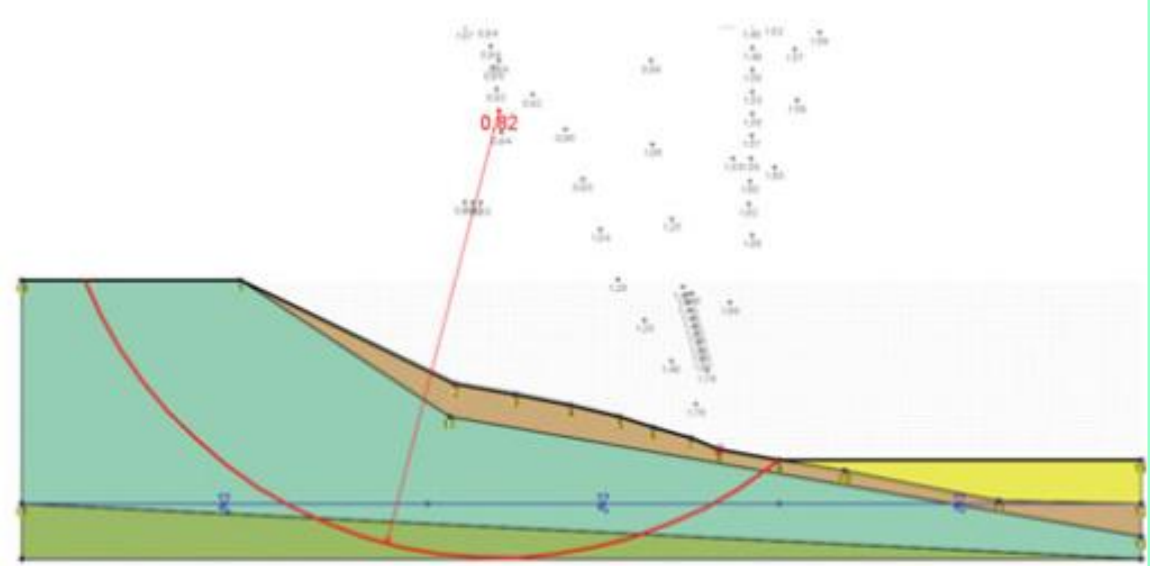


(b) Localization of the plasticized area

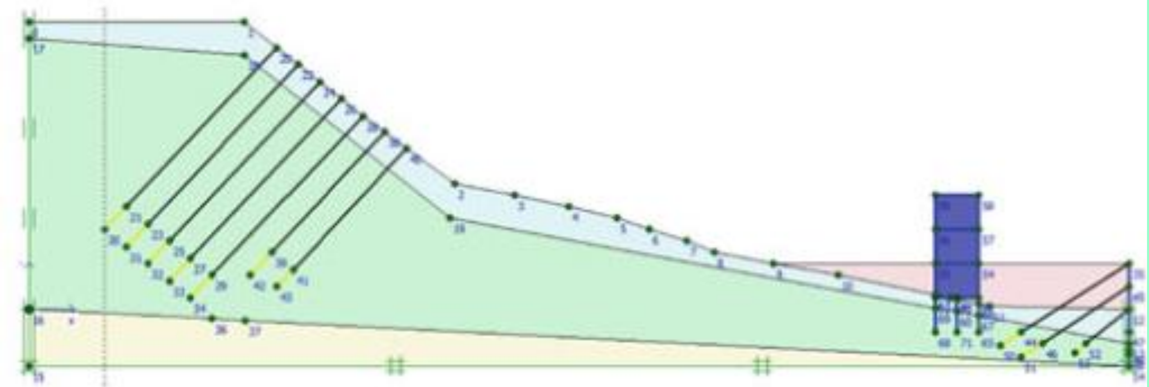
Results

- *Stability calculations of the slope carried out by the limit equilibrium method only under its own weight show that it is potentially unstable (F=1.02).*
- *Calculations results obtained in plasticity are agree with the assumption of a circular failure surface and confirm the calculation results obtained by the previous approach (F=1.01). We can conclude that:*
  - *The stability of the slope is not guaranteed under the action of the overloads brought by the constructions, in particular during probable climatic and/or seismic events.*
  - *Also, should we look for an adequate solution for its reinforcement.*

Research of a reinforcement solution of the slope



(c) Reinforcement by upstream pickling and downstream filling



(d) Reinforcement by nailing, piling and anchored wall

Results

- *Stability calculations of the slope reinforced by an upstream pickling and downstream filing show that it is unstable under the combined effect of its own weight and a water table located at its half-height (F=0.82).*
- *Alternative slope reinforcement solution by means of upstream nailing and downstream piling combined with an anchored wall at toe seems to be convenient:*
  - *Calculations results show that the slope is stable under its own weight (F=1.24).*
  - *It will probably be unstable under the combined effect of its own weight, water table located at half-height and a seism corresponding to the current structures (F=1.03).*

Conclusion

- The geological and geomorphological context of slopes located in Tizi-N'Bechar city (Province of Setif, Algeria) raises fears of possible instabilities, especially during probable climatic and/or seismic events.
- Indeed, the stability calculations of the slope intended to construction of supermarkets carried out under its own weight justify this fear since they show that this slope is in critical equilibrium, therefore potentially unstable.
- However, the stability calculations of the slope reinforced by means of an upstream pickling or downstream filling indicated that it would be stable. The combination of these two solutions is the most advantageous, but inadequate when the slope is eventually subjected to a slight seism combined with a water table located at its half-height.
- Also, a reinforcement solution of this unstable urbanized slope by means of an upstream nailing and downstream piling combined with an anchored wall at toe is thus necessary (this is the most effective alternative solution).

However, the criteria for a good modeling are much more dependent on the good sense of the engineer, his intuition and his experience.

The End

Thank you for your attention