The Observational Method
Overview of French Practice

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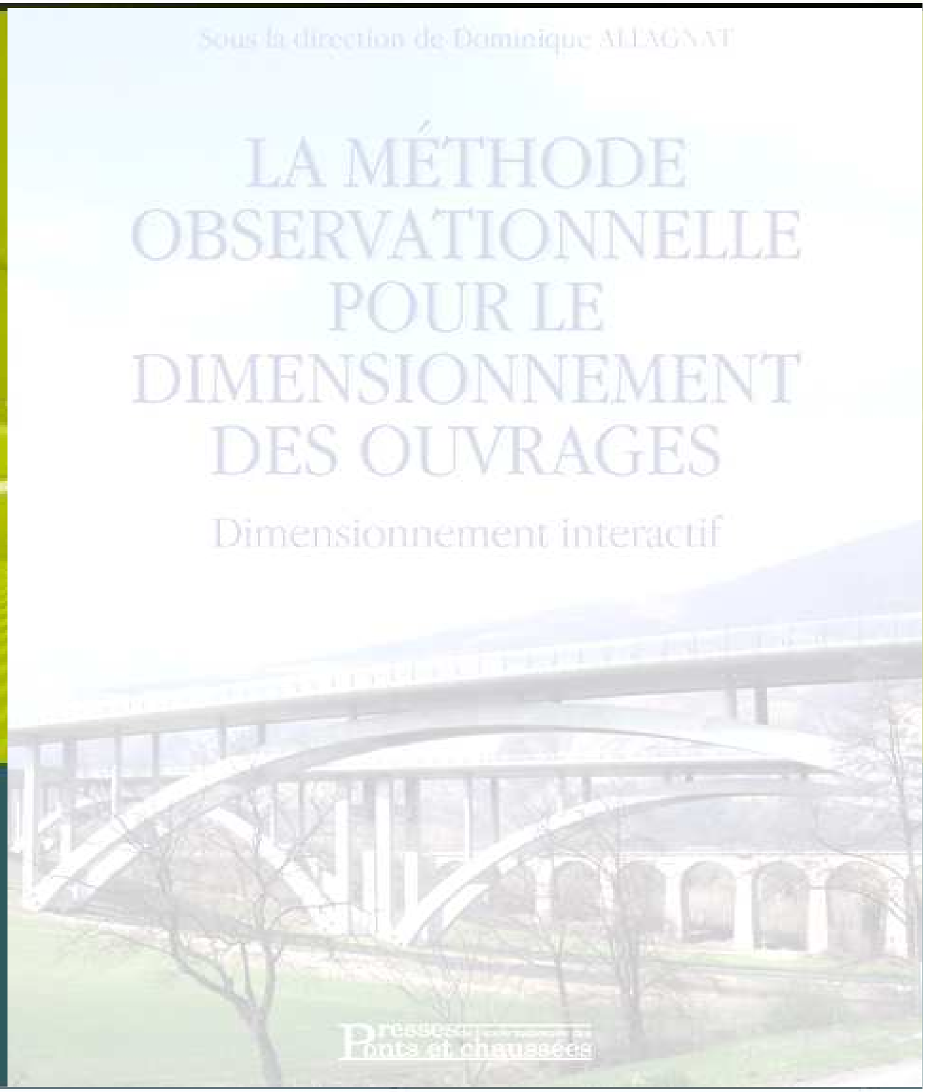


CONTENTS

1. INTRODUCTION (1/3)

PUBLICATION OF A GUIDE IN 2005

Observation :

The Observational Method requires a rigorous process and it is often used "after the event".

⇒ **EXPECTED DIFFICULTIES :**

- Contractual and legal aspects
- Definition of technical criteria

1. INTRODUCTION (2/3)

PRINCIPLES OF THE MOB

(considerations based on the definition of Eurocode 7)

The design is re-examined during the works (interactive design)
with a number of requirements :

1) Define the acceptable limits of behaviour

2) Estimate the range of variations to the behaviour

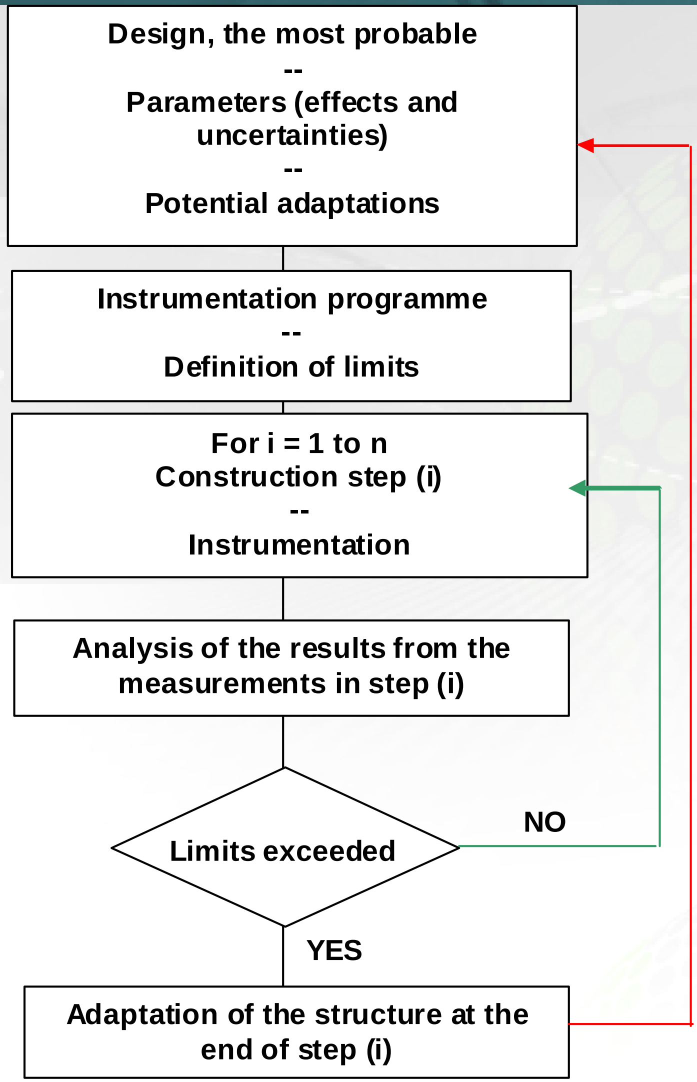
3) Establish a monitoring programme (responsiveness of the observation system)

4) Define a programme for «adaptation » of the works

+

«Contractual» anticipation

1. INTRODUCTION (3/3)



1. THE FOUNDATIONS OF STRUCTURES (1/12)

1) DURING THE CONSTRUCTION PHASE

Adaptation of the foundation according to the observations :

- for the geotechnical context,
- for the behaviour of the foundation itself (settlements, interaction with embankments on compressible soil, ...).

2. THE FOUNDATIONS OF STRUCTURES (2/12)

Road of the Tamarins

2x 2 lanes – 33 km

700 M€

Bridges : 15% of road profile

Bridges : 50% of the cost

St Gilles – Etang Salé

18 VIADUCTS

3 LARGE VIADUCTS

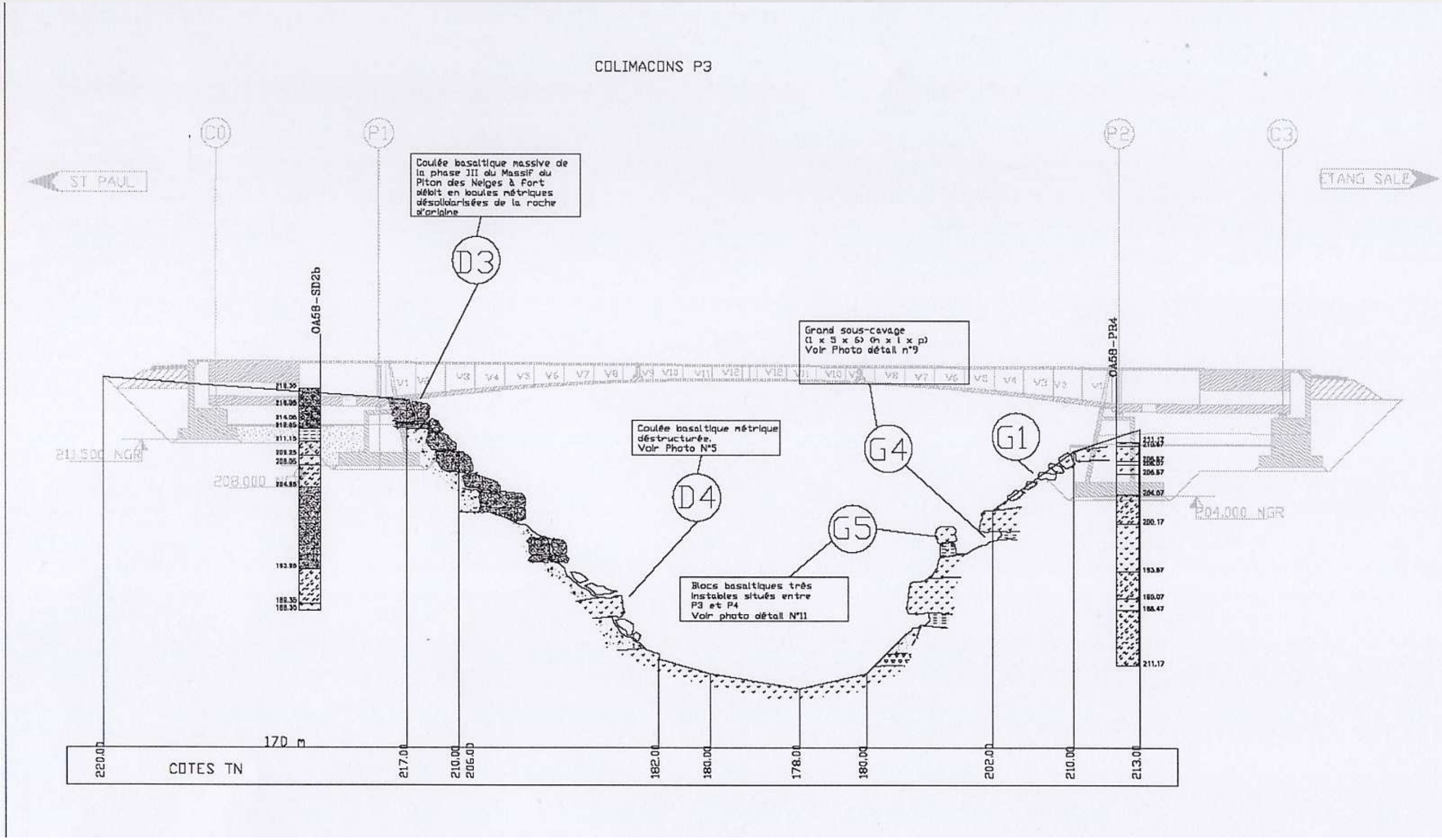
2. THE FOUNDATIONS OF STRUCTURES (3/12)

Volcanic geology :

- Superficial screes
- Breccias
- Lava flows : alternating basalt - scoriae – palaeosoils
- Lava tunnels

Figure 2-11 - Alternances basalte-scories

2. THE FOUNDATIONS OF STRUCTURES (4/12)



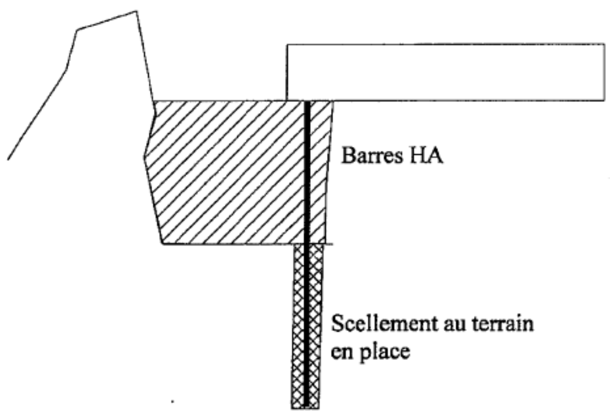
2. THE FOUNDATIONS OF STRUCTURES (5/12)

<u>**Solution to adapt to heterogeneous soils**</u> **:**

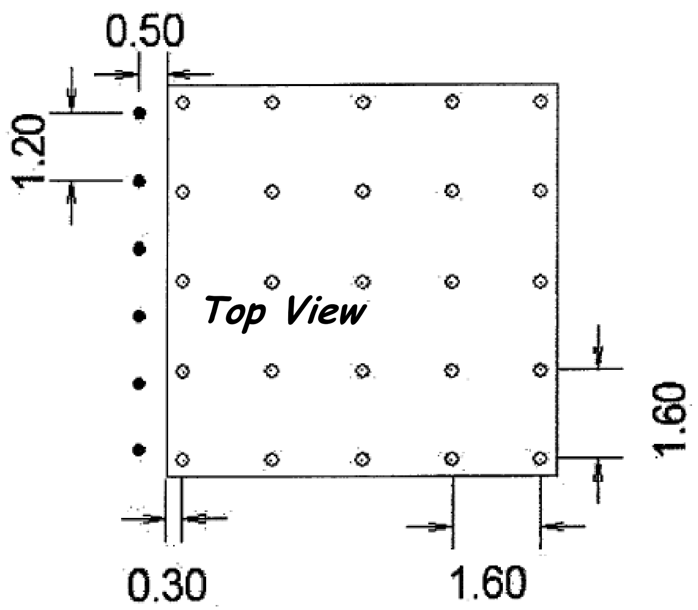
- Foundations on enlarged footings
- Weak stresses beneath the footing
- Controls at the bottom of the excavations
- Adaptations if needed : purges – injections – rigid inclusions

2. THE FOUNDATIONS OF STRUCTURES (6/12)

Reinforcement of the bedding stratum by rigid inclusions



Section



2. THE FOUNDATIONS OF STRUCTURES (7/12)

2) AFTER CONSTRUCTION OF THE STRUCTURE

Observation of the foundation's behaviour and its effect on the structure :

Monitoring of deformations and their evolution (settlements)

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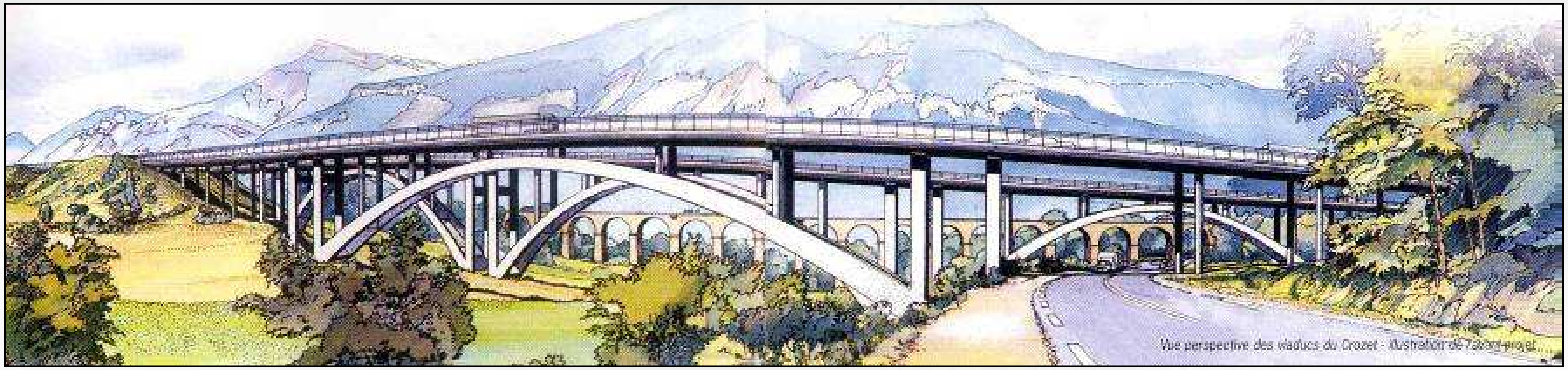
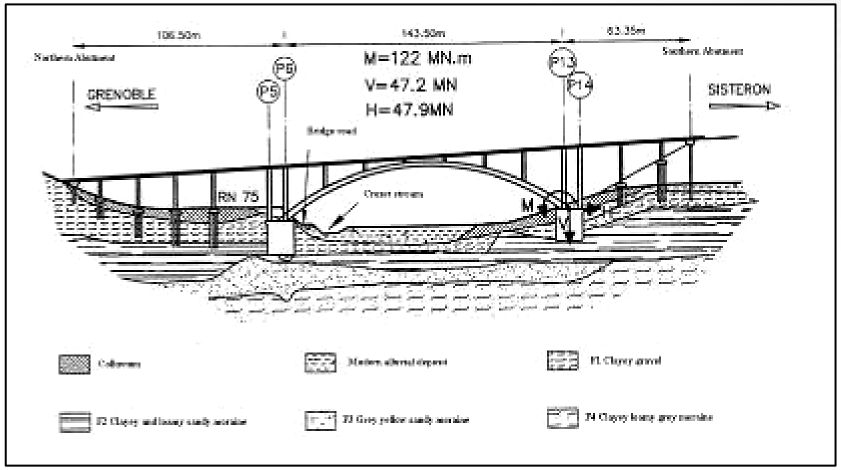
Adaptations or works to the structure, the design for which was foreseen at the conception stage

2. THE FOUNDATIONS OF STRUCTURES (8/12)

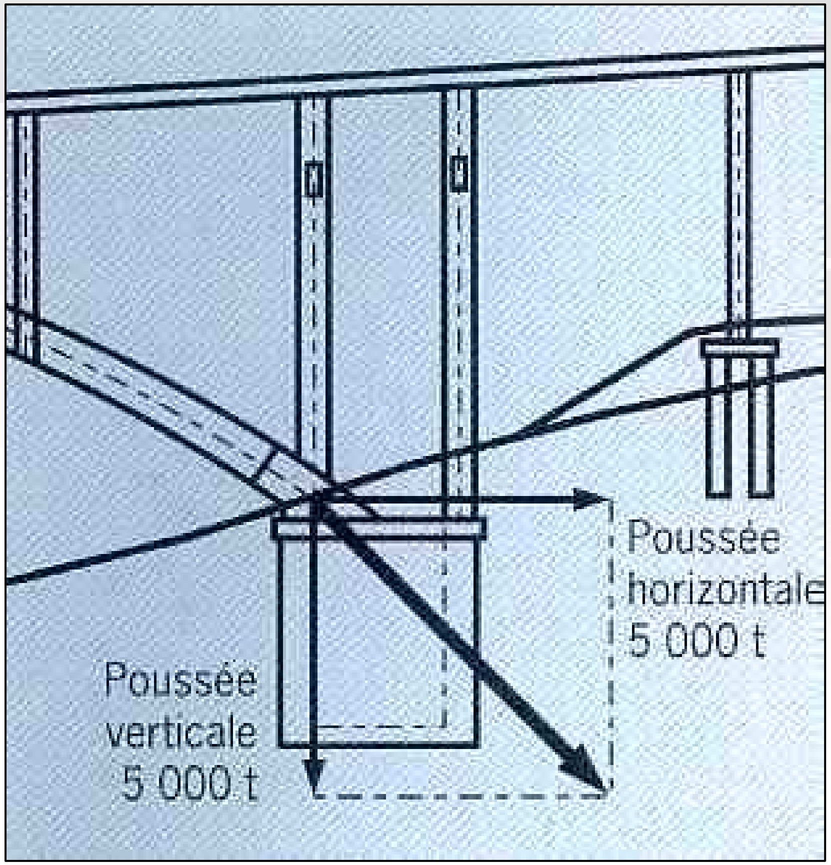




Geological context :

- Fluvioglacial deposits
- Dense moraines clayey-sandy (Riss)
- Substratum marly limestone at D> 45 m
- Seismic zone

2. THE FOUNDATIONS OF STRUCTURES (9/12)



Objectives :

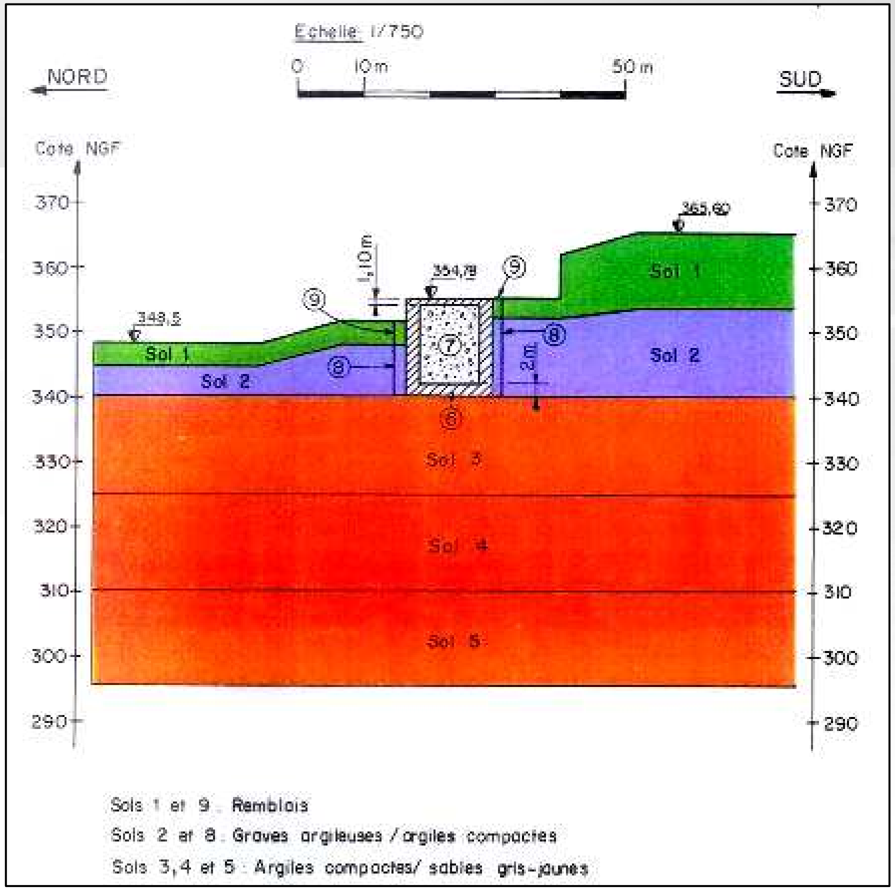
- Embedding within the dense moraines.
- Stability for horizontal loads static and dynamic (Δh order of centimetres, for loads V=H).
- Construction conditions allowing the stiffness of the soil to be retained.

Possible actions :

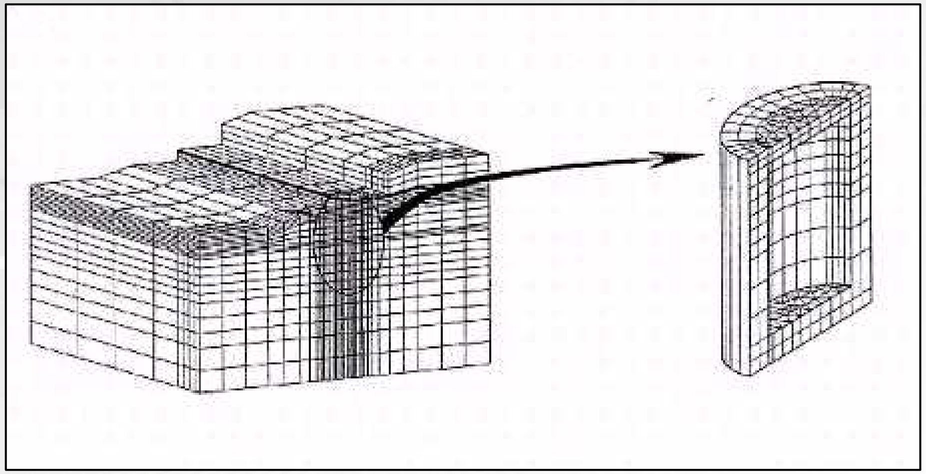
- Compensatory hydraulic-jacks

Conception of the arch foundations

2. THE FOUNDATIONS OF STRUCTURES (10/12)



Geotechnical model



3D Modelling

2. THE FOUNDATIONS OF STRUCTURES (11/12)

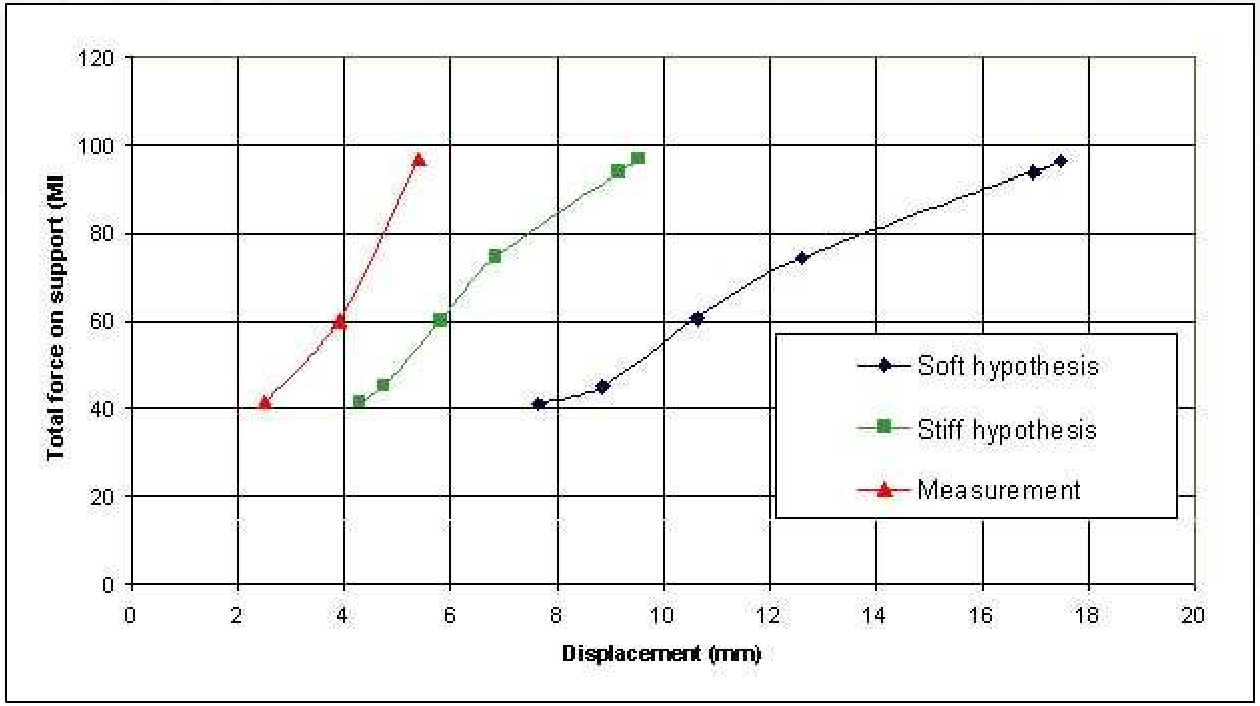
Excavation with BA concrete supports

Concreting of a borehole

2. THE FOUNDATIONS OF STRUCTURES (12/12)

Monitoring of the loading of the foundations + creep

- 2 inclinometers to measure the rotation of the foundations.
- 8 displacement sensors to monitor the gap of the hydraulic jacking sections.
- Topographic measurements (X, Y, Z) automatic + prisms.

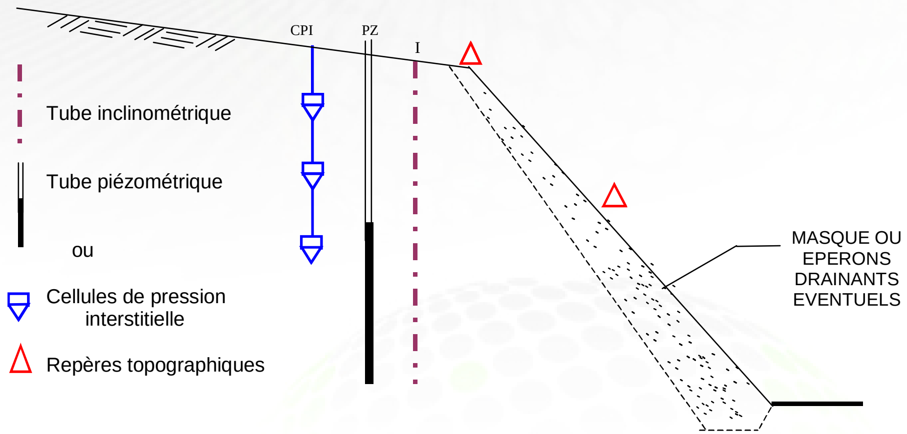


3. SLOPE STABILISATION (1/3)
(EXCAVATED CUTS OR NATURAL SLOPES)

Optimisation, gradient of the slopes and retaining solutions arrangements.

Observations of geological conditions (provisional model) and geotechnics
(characteristics, piezometry) ⇒ **visual controls**

For particular cases, evaluated as more susceptible during the detailed studies (high cuts, valley slopes, …) ⇒ **instrumentation**



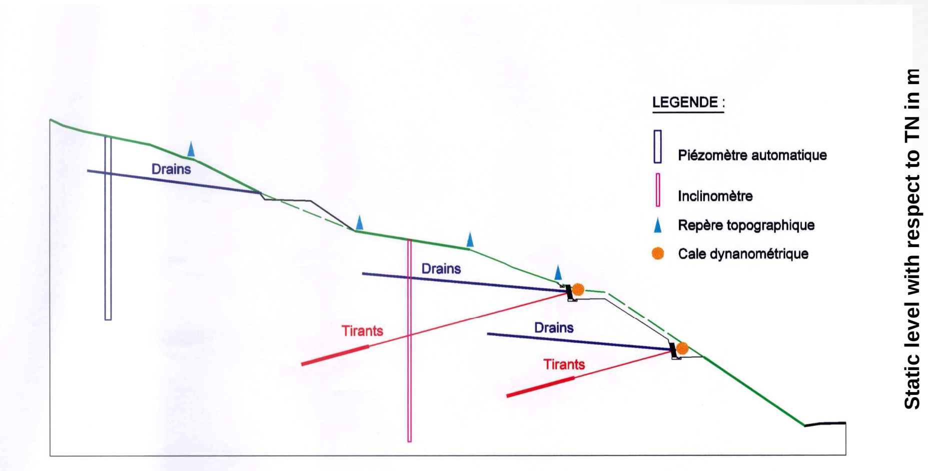
3. SLOPE STABILISATION (2/3)
(EXCAVATED CUTS OR NATURAL SLOPES)

EXAMPLE: REINFORCEMENT OF A LANDSLIDE

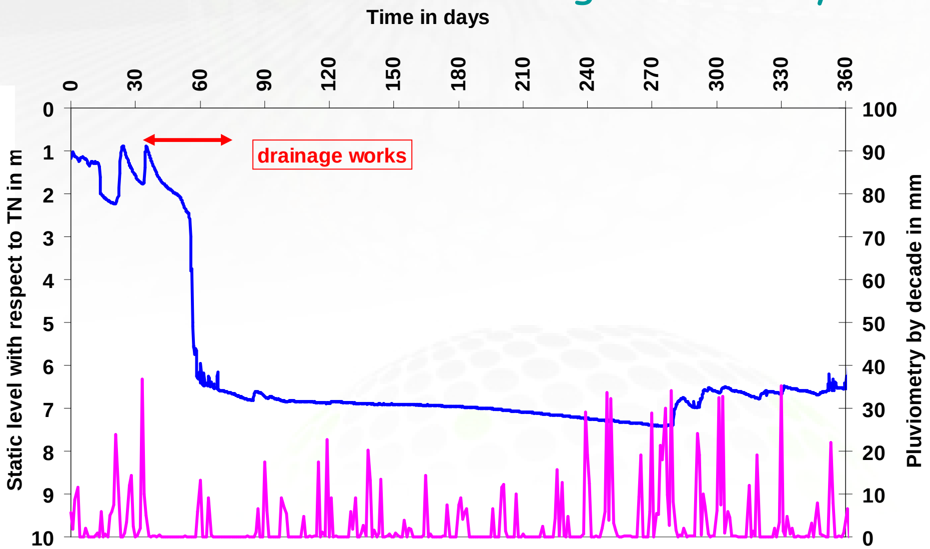
Reinforcement in several stages

- Drainage upstream
- 1st stage reinforcement + drainage
- 2nd stage reinforcement

Complete instrumentation

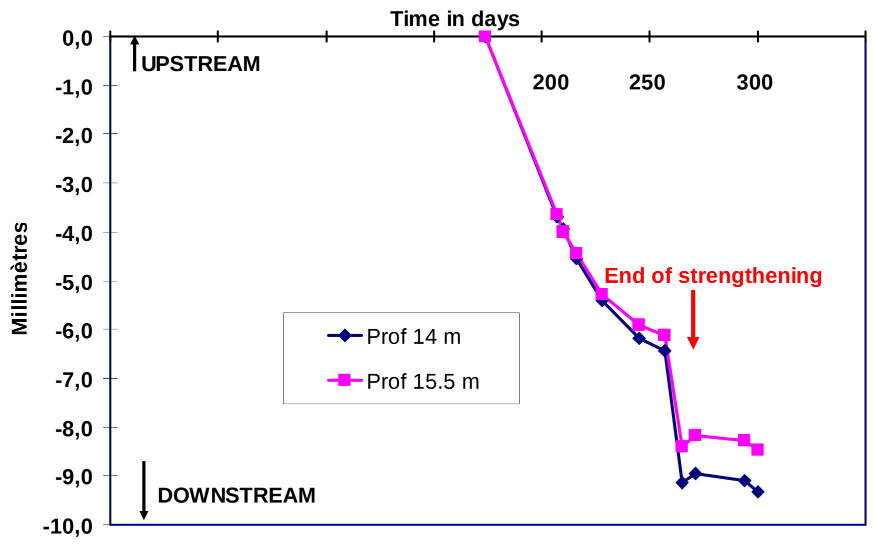


Verification of the drainage efficiency



3. SLOPE STABILISATION (3/3)
(EXCAVATED CUTS OR NATURAL SLOPES)

Effect of the strengthening on the displacement measures



General view of the works at the end of the 1st stage = 55 % of the prestressed anchored tie rods (that is 74 % of the total budget)

4. GRAVITATIONNAL PRE-LOADING (1/2)

The observations are generally made for two aspects.

- **<u>Consolidation</u> (settlements, consolidation time, creep)**

  - Monitoring of settlements and interstitial pressures

    ⇓

  - Reinforcement of soils, vertical drains, temporary over-loadings, …

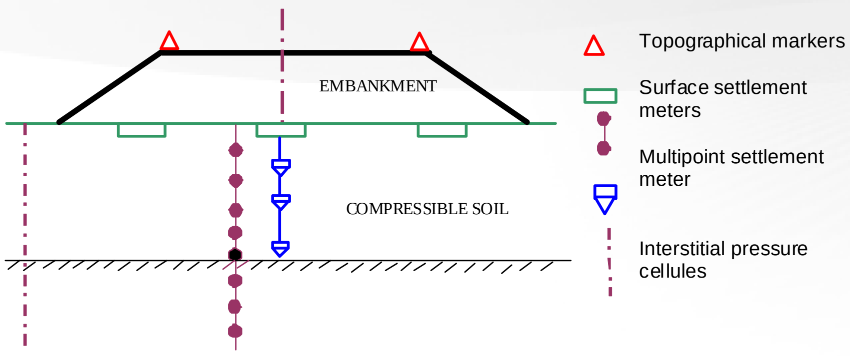
4. GRAVITATIONNAL PRE-LOADING (2/2)

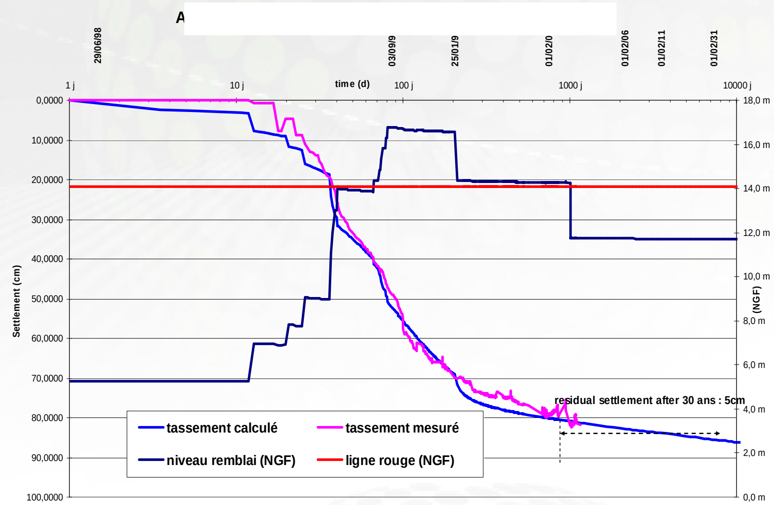
- **General stability**

  - Interstitial pressures

⇓

  - Banks, construction in stages, low embankments, reinforcement...





5. SUPPORT OF EXCAVATED CUTS (1/6)

Effects of the supporting wall on the environment (buildings, infrastructures, …) :

settlements, transversal deformations.

But also :

- Impact on the hydraulic conditions (transparency)
- Lowering of the ground water…

5. SUPPORT OF EXCAVATED CUTS (2/6)

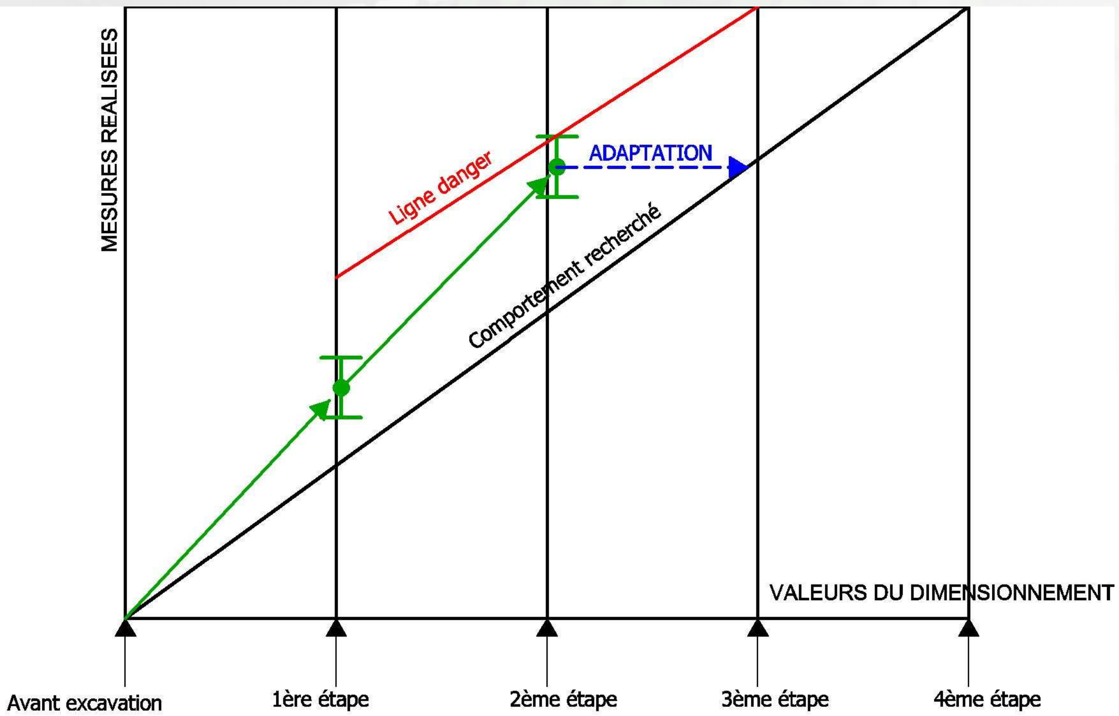
Observations made with respect to the deformation modelling results (parametric study, effect of the different stages …) :

- Identification markers - topographic/supporting wall + environment,

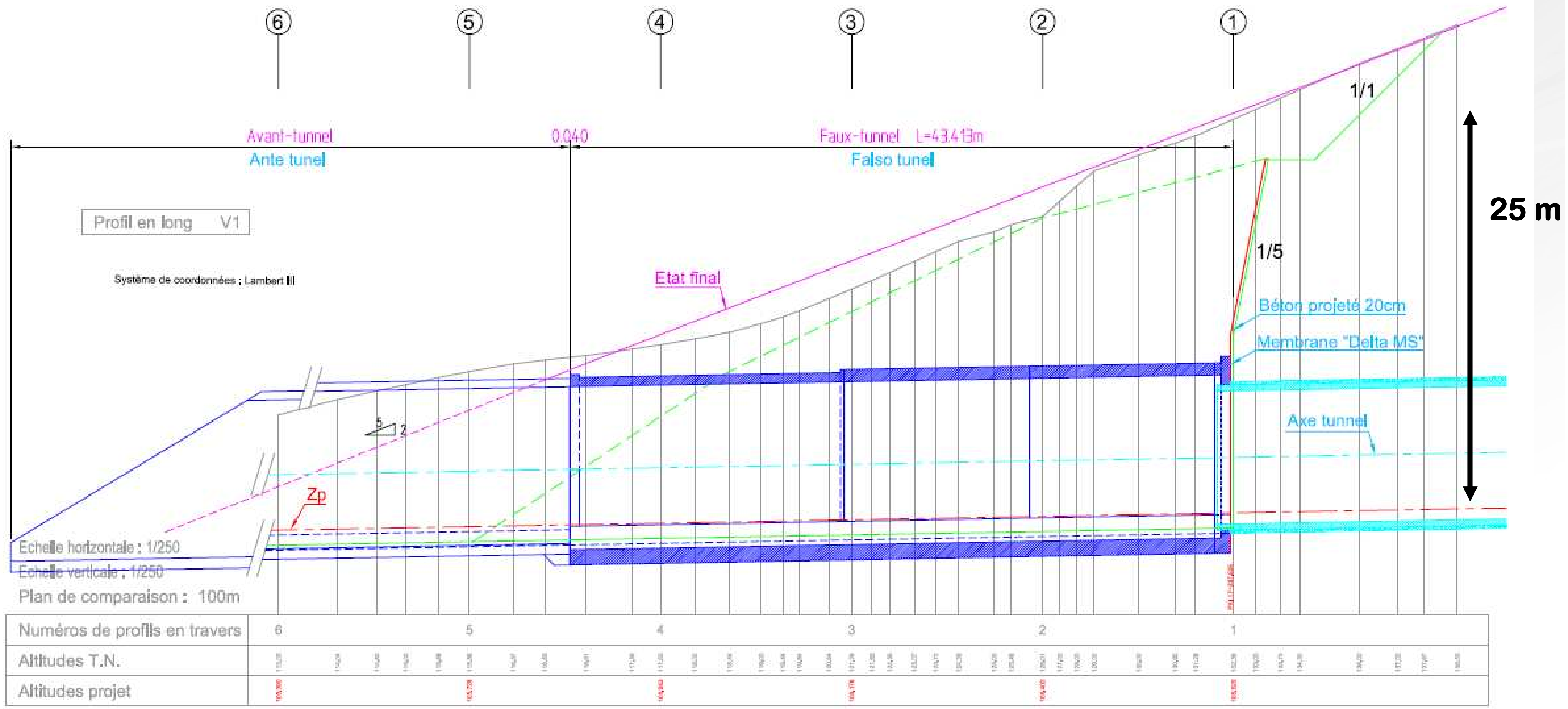
- Inclinometer tubes behind the supporting wall,

-Air bubble/ spirit levels…

- Dynamometers



5. SUPPORT OF EXCAVATED CUTS (3/6)

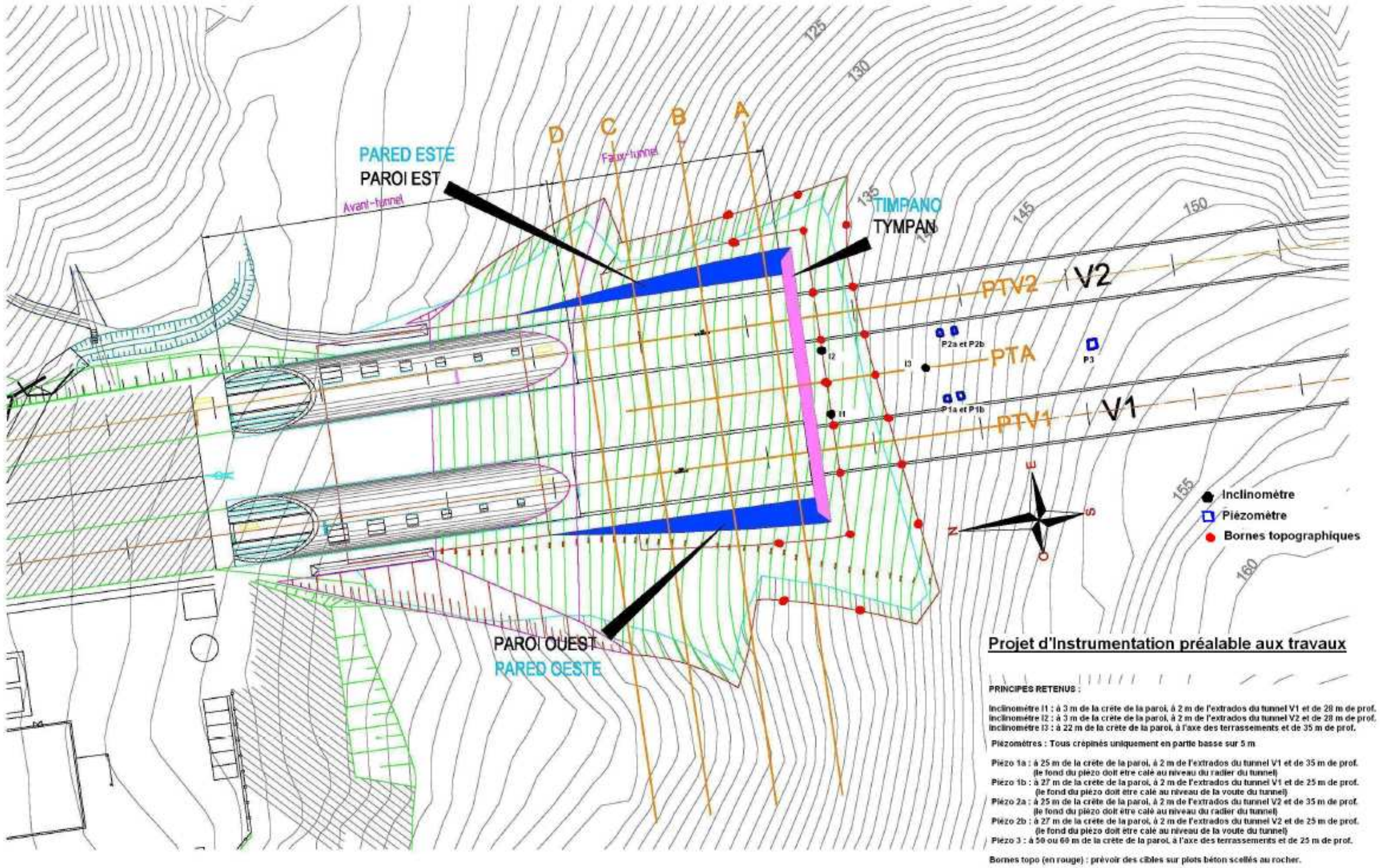


Longitudinal profile of the tunnel's head

5. SUPPORT OF EXCAVATED CUTS (4/6)

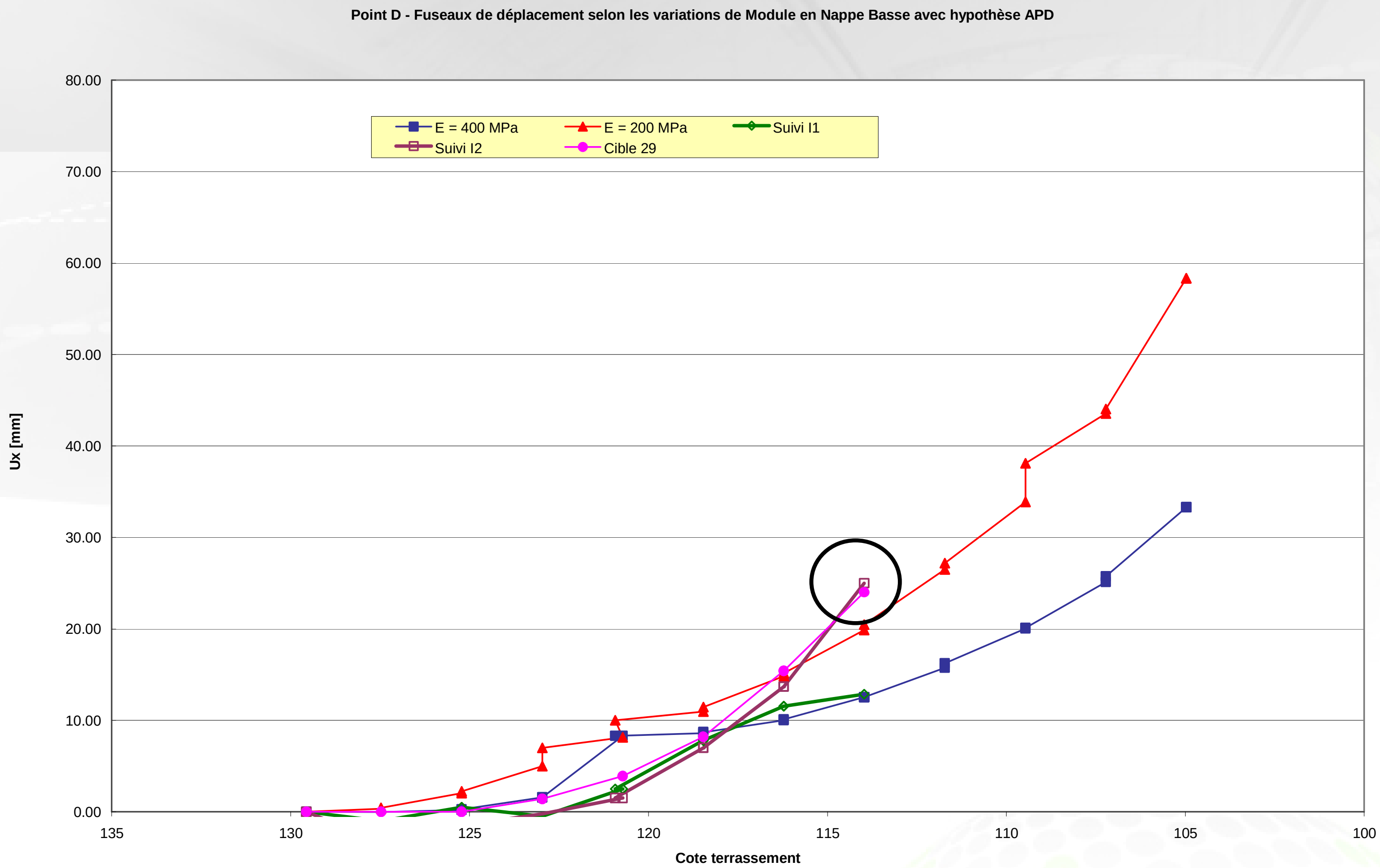
General view at the Northern head of the tunnel (excavation = 40 %)

5. SUPPORT OF EXCAVATED CUTS (5/6)



Instrumentation plan

5. SUPPORT OF EXCAVATED CUTS (6/6)



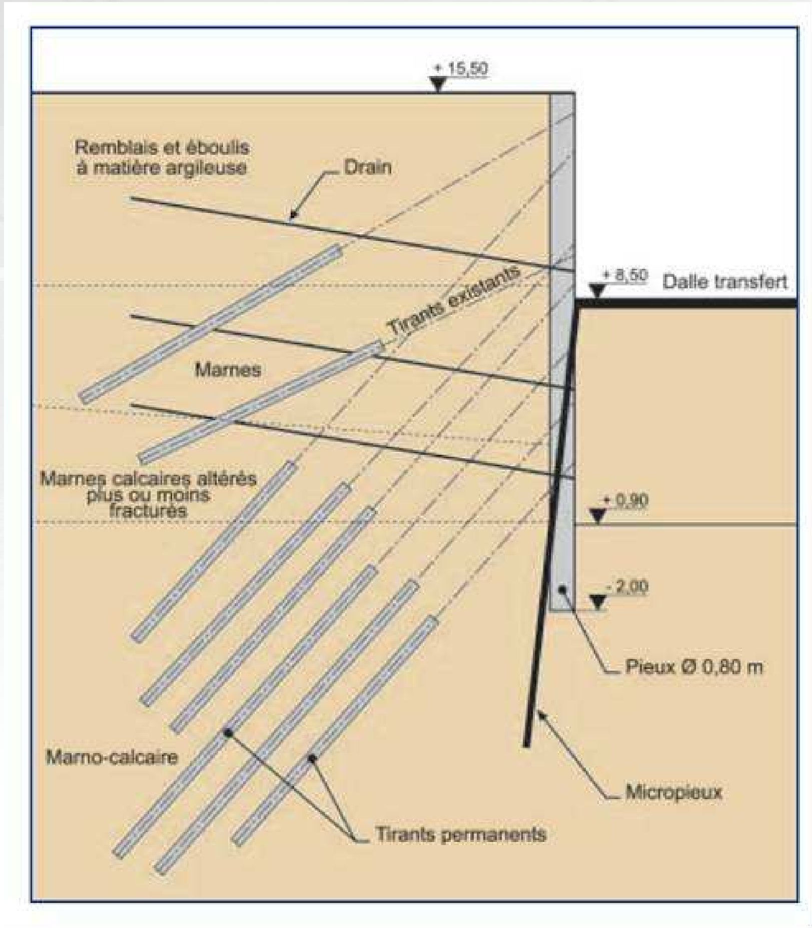
Comparison of measurements for predefined limits – Modification of the strengthening following an over threshold

5. SUPPORT OF DEEP EXCAVATIONS (URBAN)

There are numerous examples for urban projects in large towns (parkings, high towers / Paris, Marseille, Lyon, Monaco…)

* Global application of the Method in only a few cases.

* Difficulty to set the limits for buildings situated in the proximity.



6. TUNNELS (1/2)

- **Shallow urban tunnels**

- Main problem : surface settlements and deformations

- Observations of the neighbourhood, within the ground and within the structure

- Definition of limits

- Works actions : ground improvements, modification of supports, tunnel boring machine parameters,...

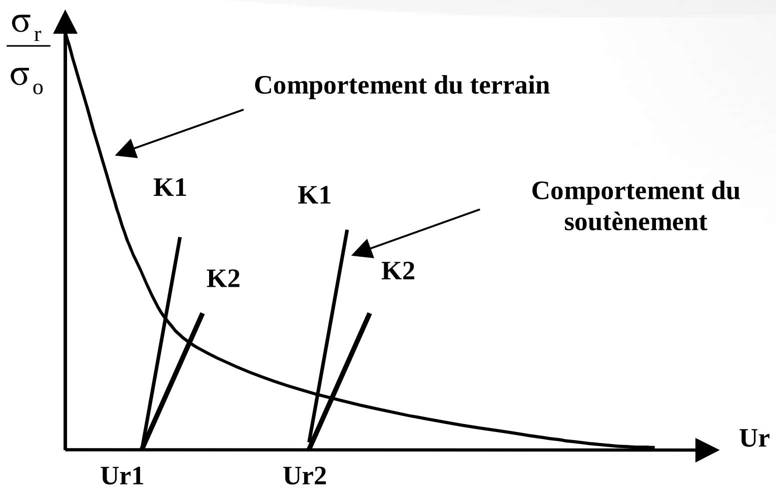
6. TUNNELS (2/2)

- **Deep tunnels**

- Uncertainties : precise behaviour of the ground, natural constraints, three-dimensional character

- Observations : radial and axial deformations, stresses upon or within the supports

- Works : actions to the supports (convergence-confinement method)



7. SUMMARY (1/3)

GENERAL CONTEXT

In the case of « delicate » geotechnical situations

Involvement of a geotechnician (AVP and PRO studies)

Intervention of a geotechnician (studies + works in the EXE stage)

CONCEPTION | **INTERACTIVE**

→ **Optimised Engineering structure**

→ **Without concession/security**

7. SUMMARY (2/3)

	① Foundations	② Slopes	③ Compressible Soils	④ Reinforcements	⑥ Tunnels
⓪ Contractual aspects (Anticipation)	..	..	...	.	...
① Acceptable limits Cpt	..	..	..	..	...
② Range of variation Cpt	..	..	...	..	..
③ Monitoring programme (instrumentation)	...	...	....	..	...
④ Technical solutions (alternatives)	...	..	...	..	...

.... Current practice, easy ... Frequent, quite easy .. Not very often, delicate . Rare, difficult

7. SUMMARY (3/3)

The main points :

• Definition of the limits « 13,45 mm » !

⚠ confusion concerning the predicted/acceptable behaviour (ELS/ELU)

•Deformation measurements
Complimentary stress measurements for the reinforcements

• Precision and reliability of real time measurements.

• Deformation measurements are not easy for all geotechnical engineering structures (rigid structures) and sometimes limits are set with very high requirements.

8. CONCLUSIONS (1/2)

Interactive design (Observational Method) :

- Very often evoked
- The total Method is still seldomly used or without anticipation

Requirements :

- Rigorous technical framework and contract

Must allow :

Better control of risks
Work economies (cost, completion date)
for susceptible geotechnical structures.

Final objective : to build the « **best engineering structure** » for which **anticipation** and **« consistent» geotechnical studies** are required.

Reduction Method for risks

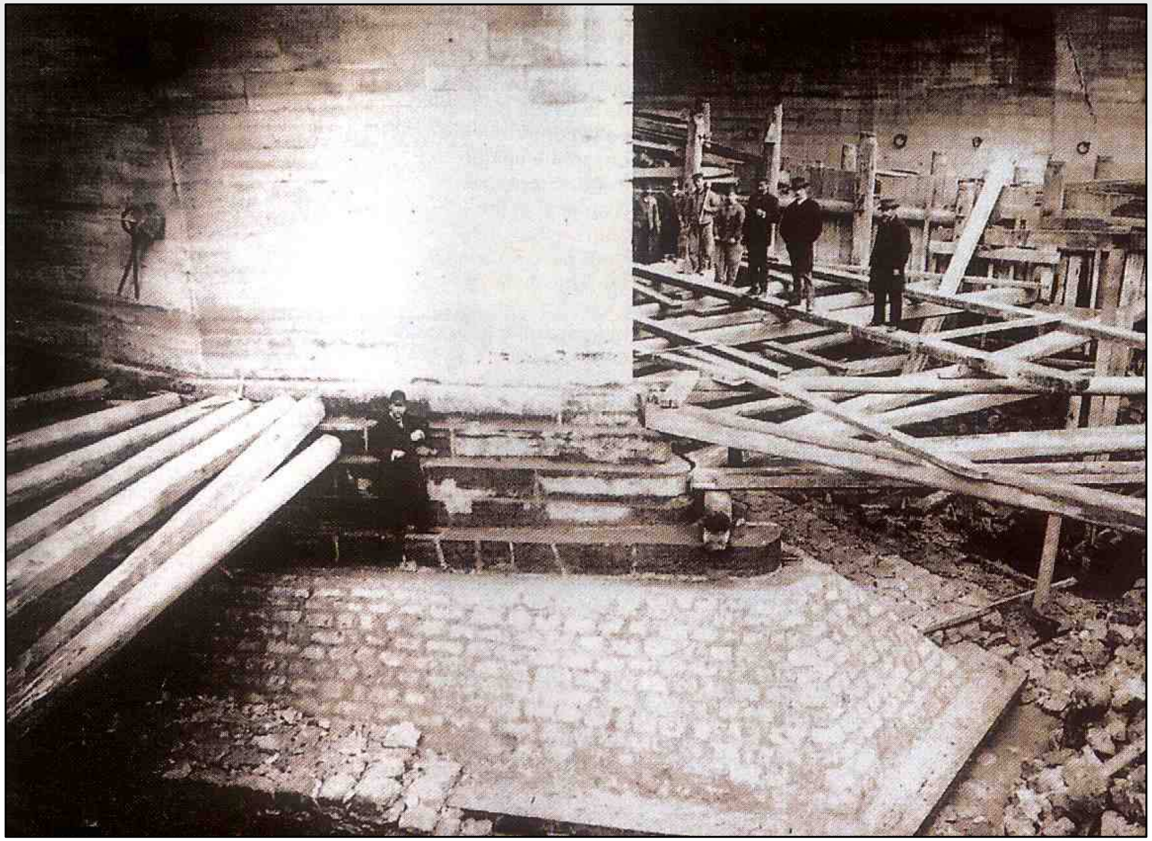
8. CONCLUSIONS (2/2)

The good design conception is like a good film.

- The Producer must be implicated.
- The script must be well written.
- All the actors must be professional (geotechnician = 1st role).

The objective being to construct the « best engineering structure possible ».

Le Pont Neuf - 4 centuries



Repair of a subsiding support in 1890 with numerous « observers »

THANKS YOU FOR YOUR ATTENTION