From prediction to reality

Gas transmission pipeline protected with a surface slab

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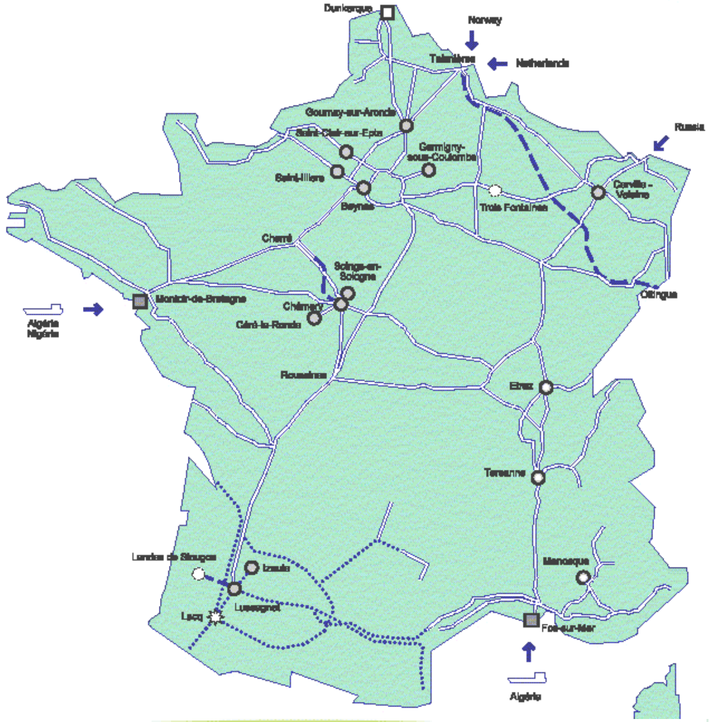
Introduction

Gaz de France transmission pipeline

- Operated by GRTgaz (subsidiary of Gaz de France)
- 32 000 km
- Diameter from 80 mm to 1100 mm
- Operating pressure 67.7 bar
- Depth > 0.8 m



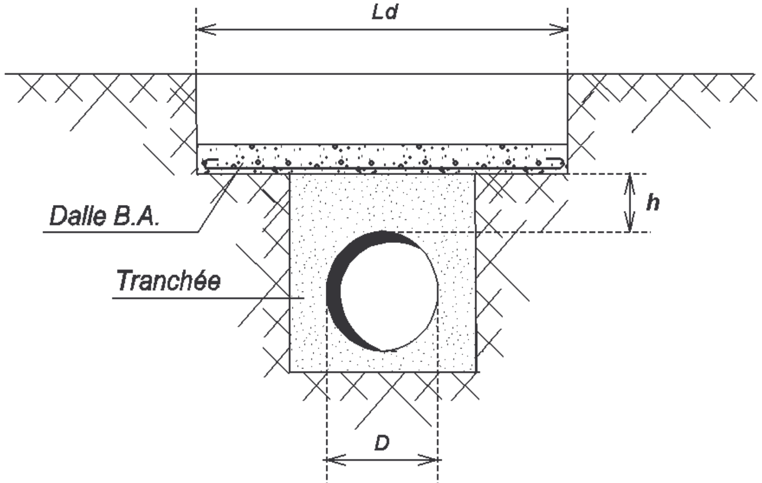
Introduction

- Gaz de France Research & Development centre
- Transmission technologies section
  - Pipe diagnosis
  - Defect assessment and repair
  - Risk management
  - New materials and technologies

Issue

- It is necessary to protect buried pipeline against heavy load traffic

- Common protective measure : concrete slab or steel plate



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Issue

- How does the system (pipe + soil + slab) reacts to heavy loadings ?
- What is the maximum stress in the pipe ?
- What are the minimum dimensions of the slab ?
  - Small enough to be laid in semi-urban area
  - Large enough to be fully efficient

Equipment

- Experimental tank
  - dimension : $3^m \times 3^m \times 3^m$

Equipment

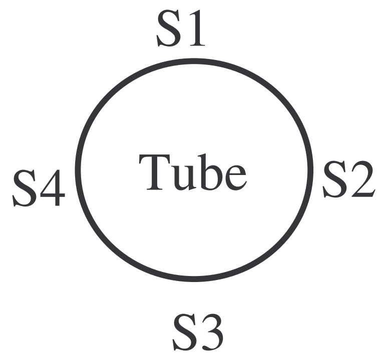
- Hydraulic jack
  - Maximum load = 100 tons

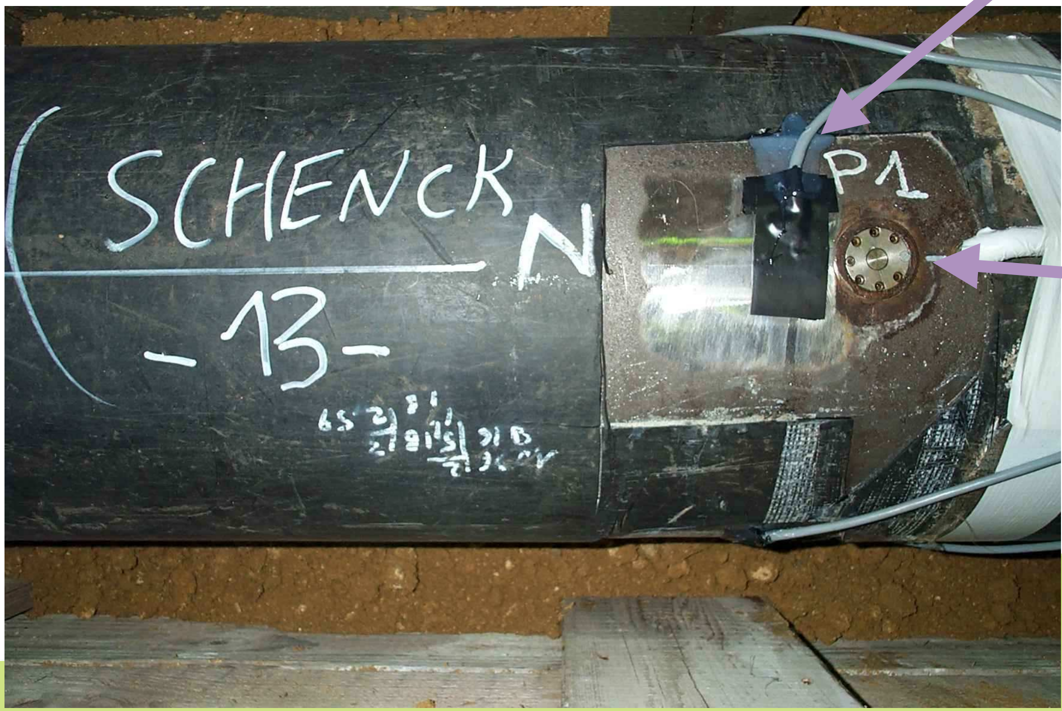
Equipment

Instrumented pipe

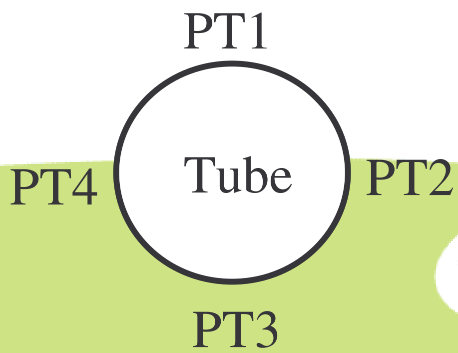
- External Diameter = 323.9 mm
- Wall thickness = 7.7 mm

Strain gauges





Soil pressure cells on the pipe



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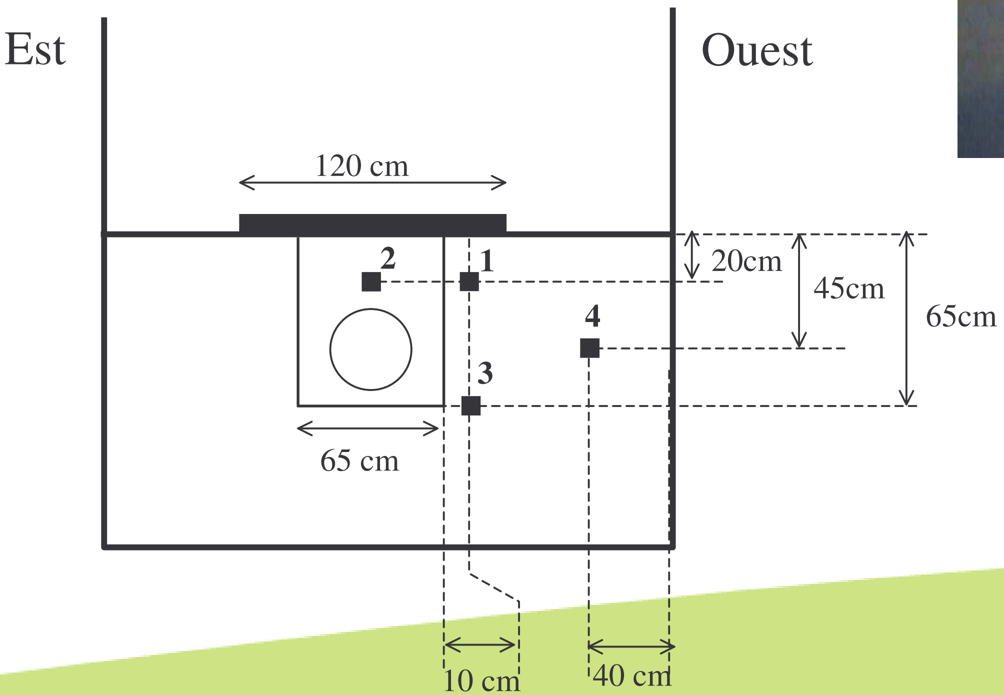
Equipment

- Soil pressure cells



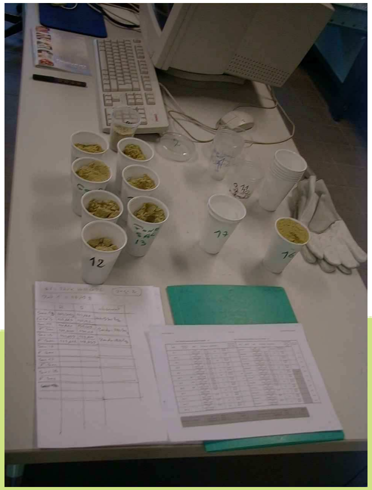
Soils

- Sandy soil
  - Purchased from a construction material shop
- Clayey soil
  - Taken from a construction site (south suburb of Paris)

- Triaxial tests
- Grains size
- Atterberg limits

Tank filling

- The soil is put in place layer by layer (5 cm thick)
- Compaction of the layers with a manual dam
  - Control of the density at 9 points
  - Control of the water content at 9 points
  - Control of the strength with a scissometer at 9 points



Tank filling with sandy soil

- Putting in a layer of sandy material

Tank filling with sandy soil

- Putting in the pipe in the sandy soil

Tank filling with sandy soil

- Putting in the slab and the hydraulic jack

Tank filling with clayey soil

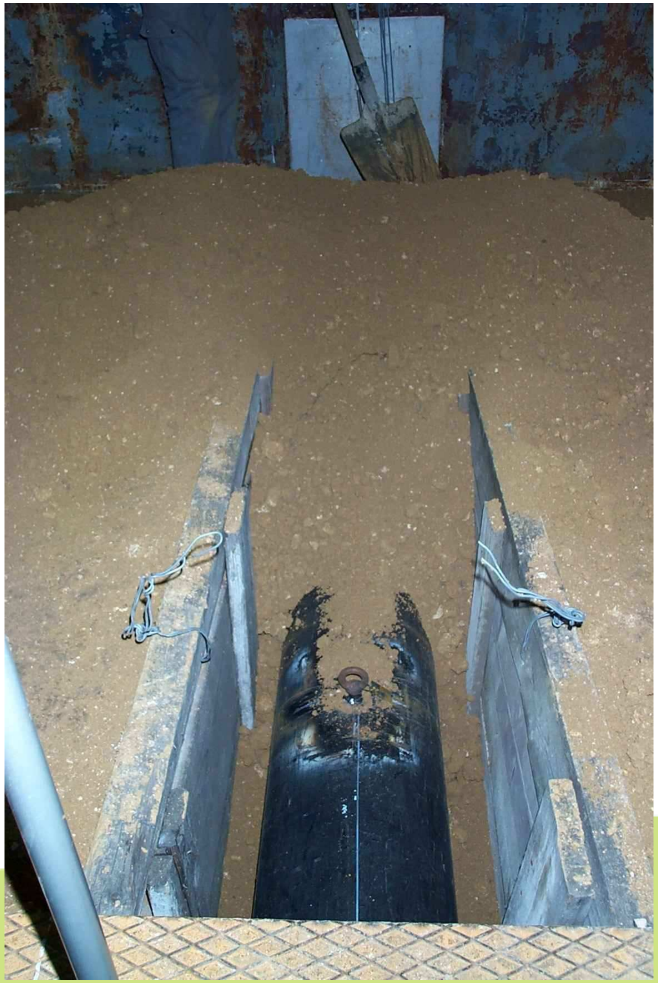
- Trench effect in the clayey soil

Tank filling with clayey soil

- Laying down the pipe in the clayey soil

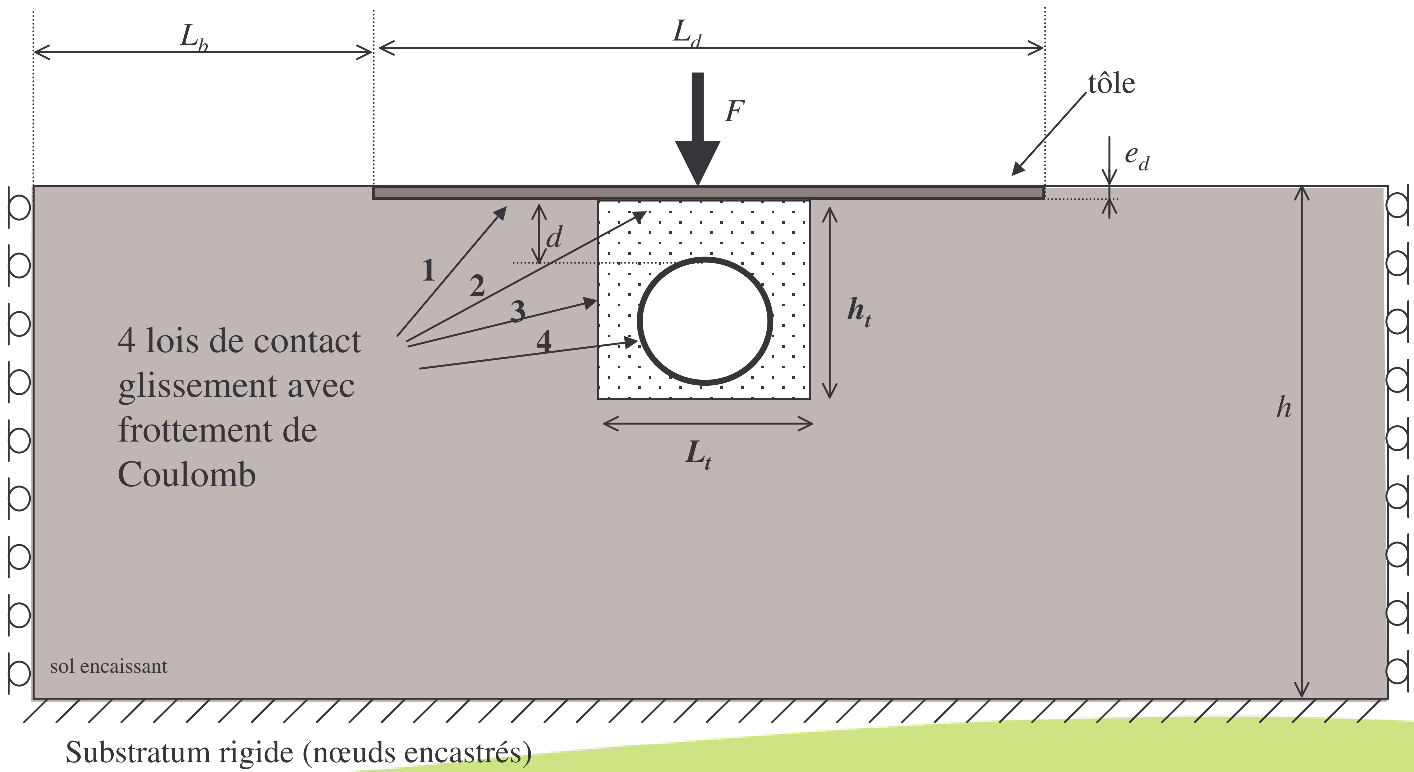
Tank filling with clayey soil

- Filling in of the trench with loose clayey soil (no compaction)



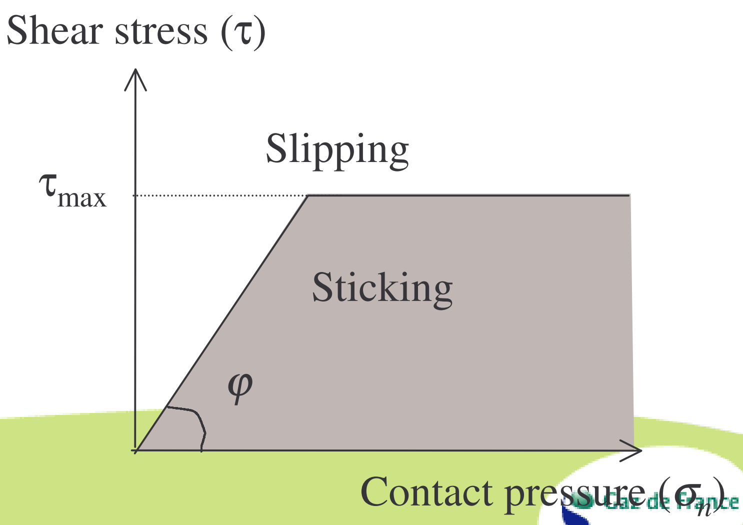
Numerical modelling

- 2D model
- Geometry and boundaries conditions



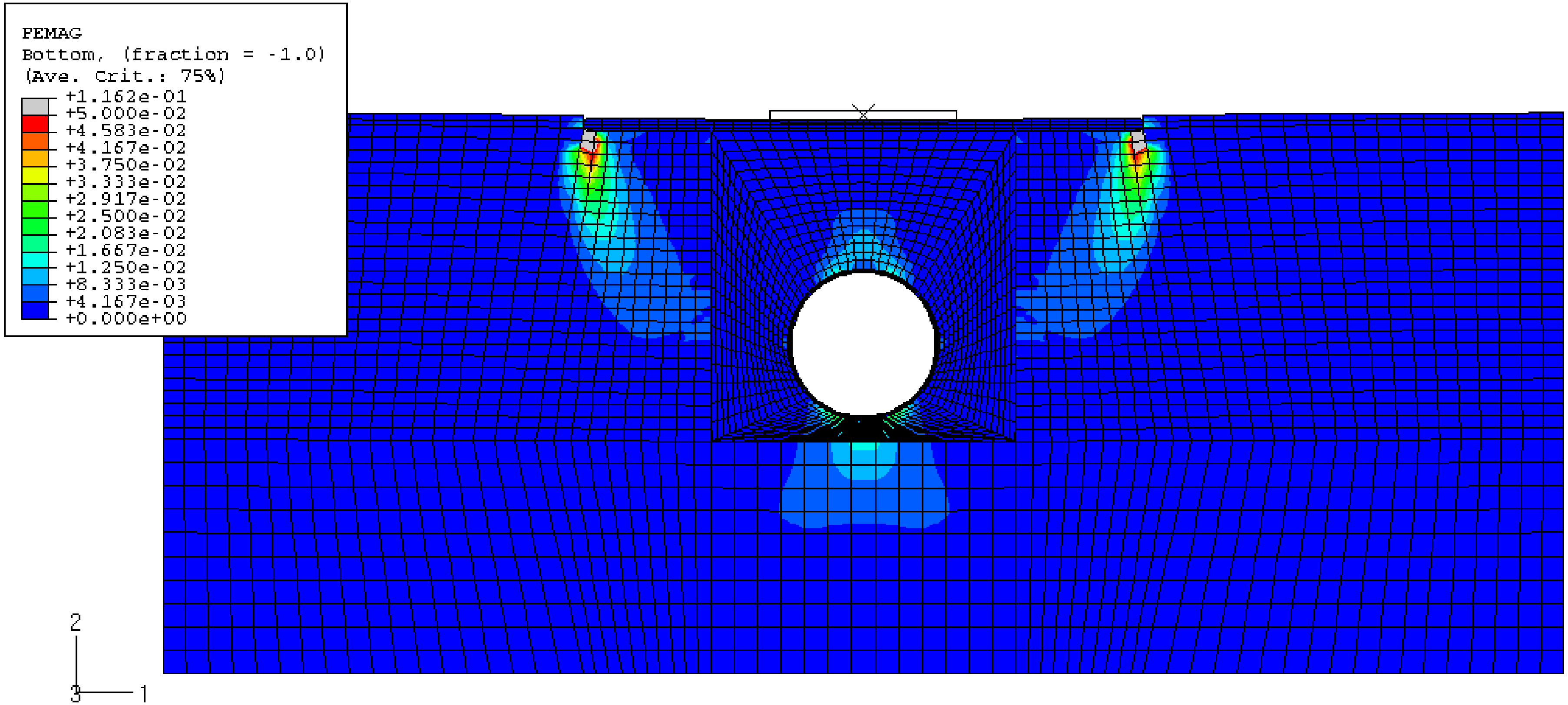
Numerical modelling

- Non linear soil behavior
  - Drucker Prager with a cap
  - Taking into account compaction
  - Calibrated with triaxial tests
- Steel property (slab and pipe)
  - Elastic linear
- Contact law
  - Coulomb friction



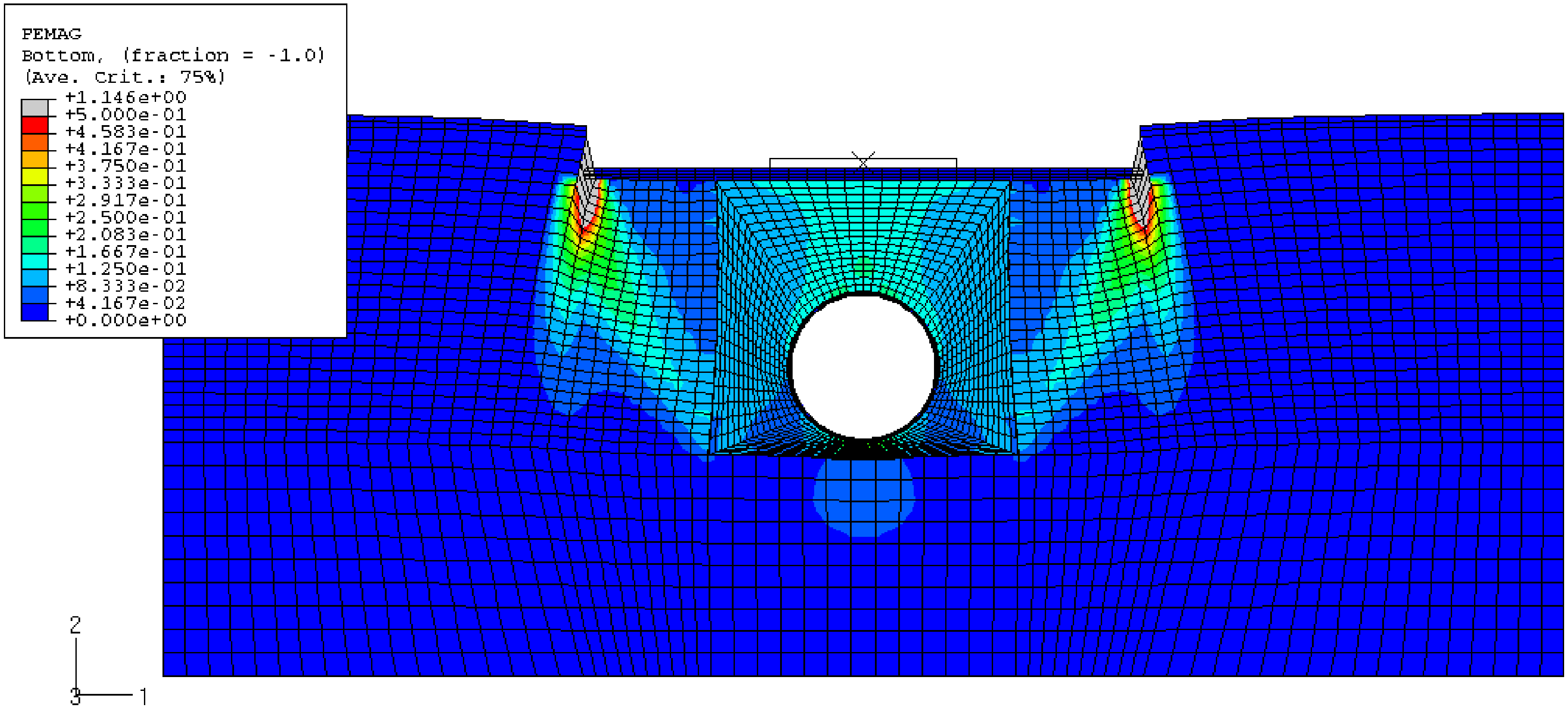
Numerical modelling

- Sandy soil plastic strain



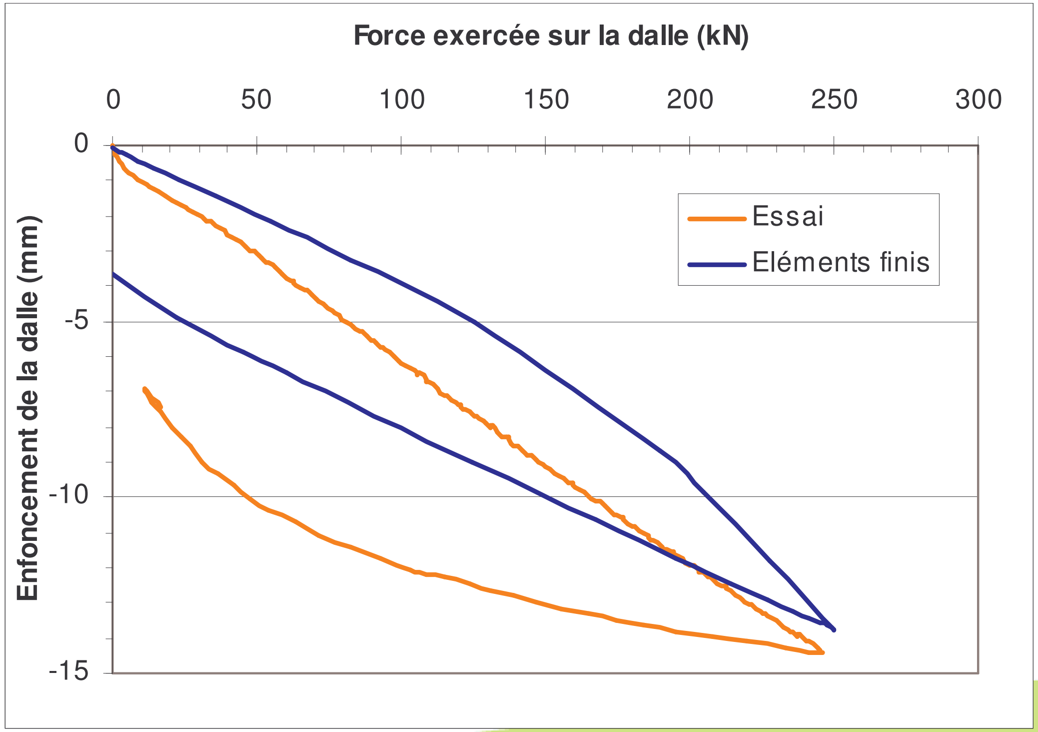
Numerical modelling

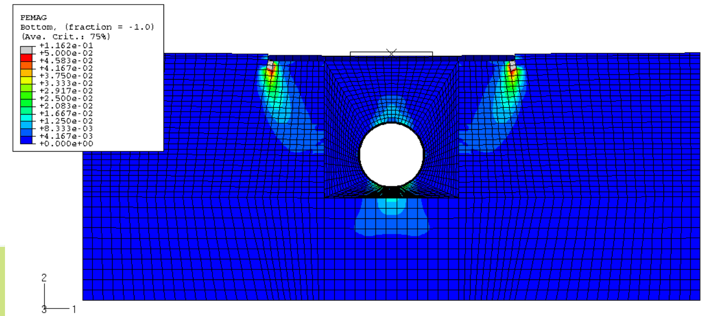
- Clayey soil plastic strain



Results – Sandy soil

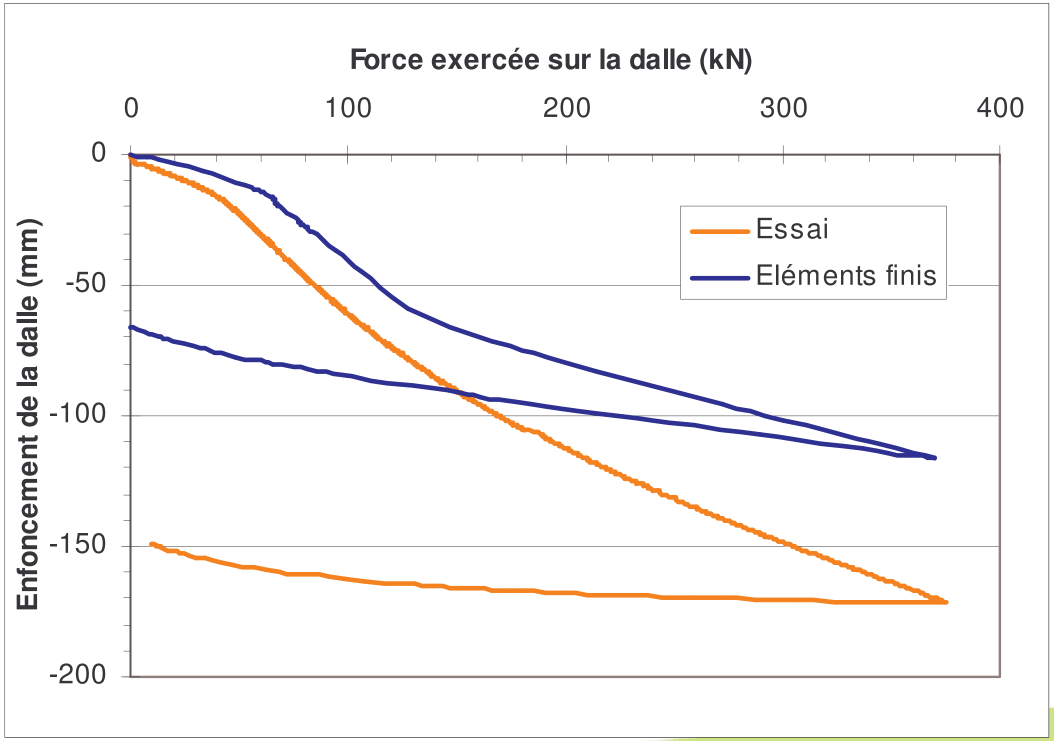
- Vertical displacement vs loading (sandy soil)

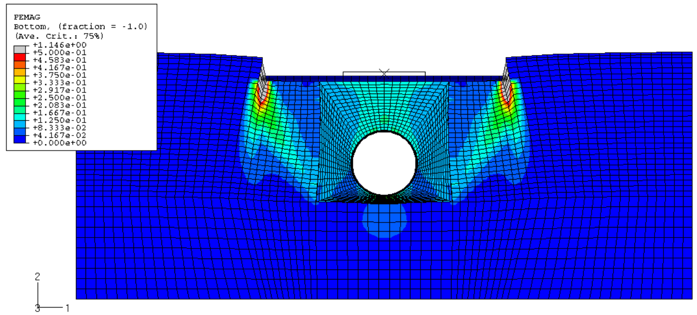




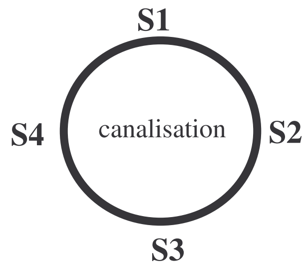
Results – Clayey soil

- Vertical displacement vs loading (clayey soil)
  - Elastic return close to experimental results

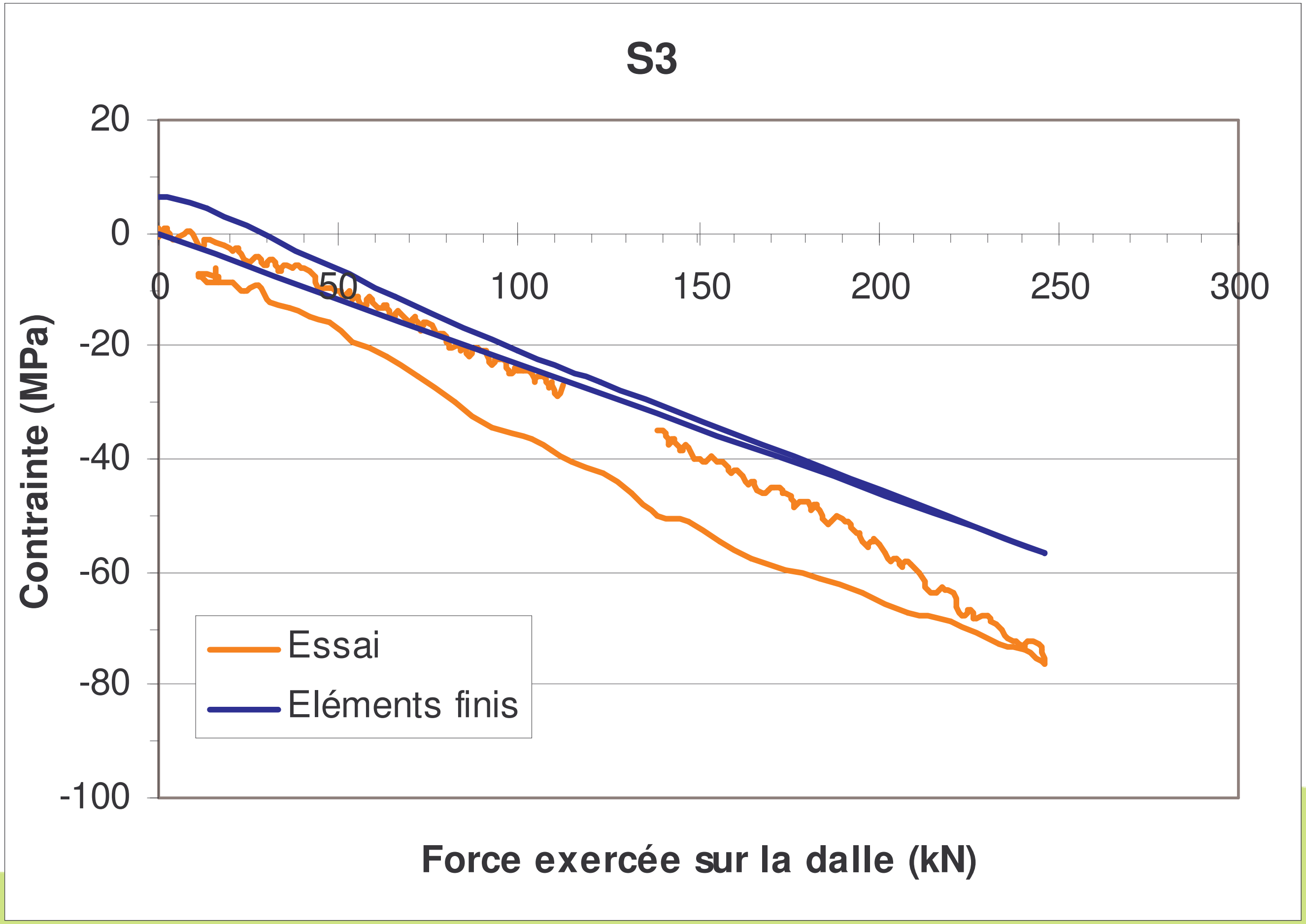




Results – sandy soil

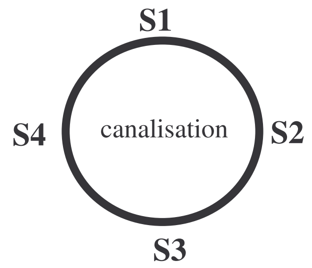


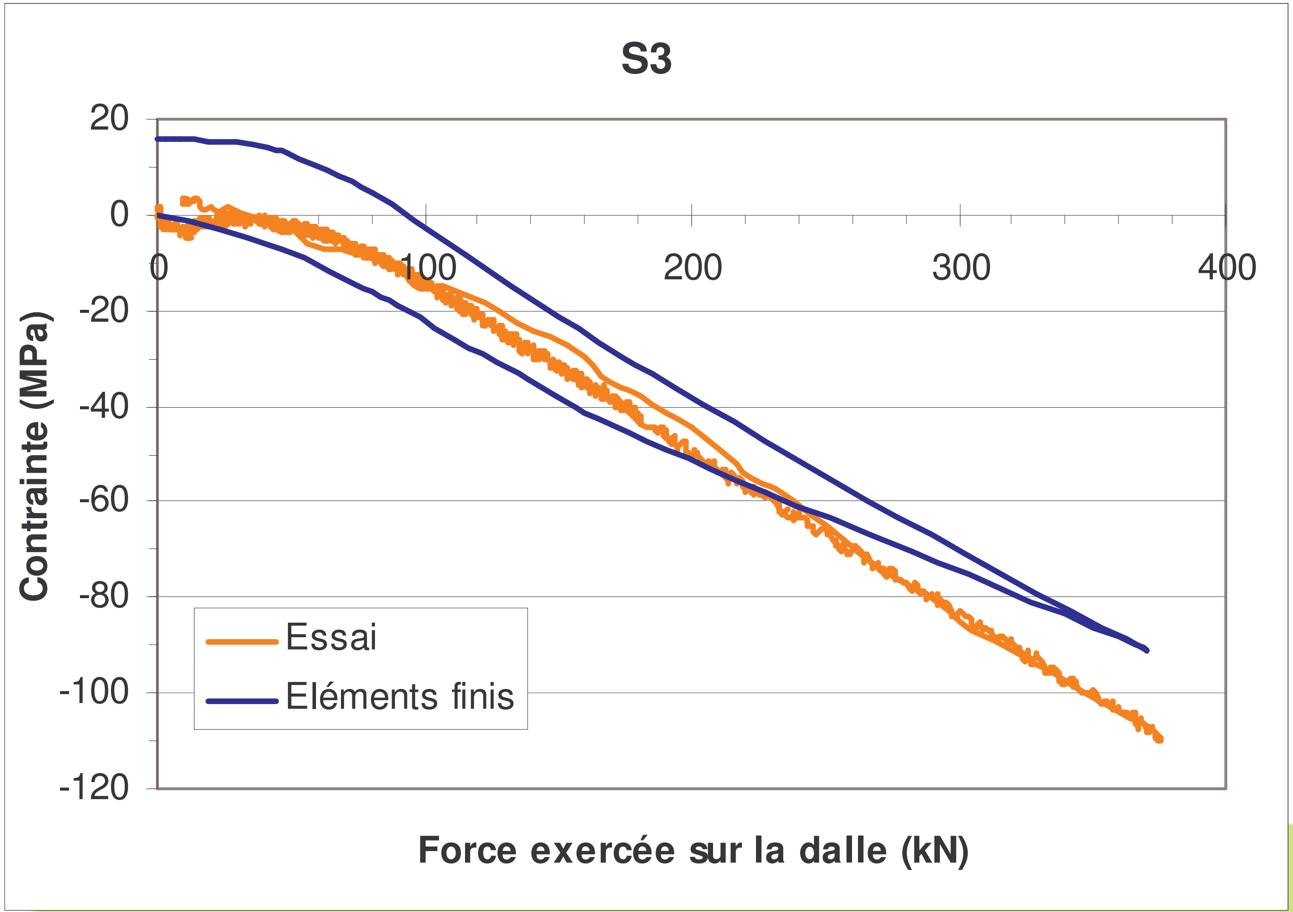
- Hoop stress vs loading (sandy soil)



Results – clayey soil

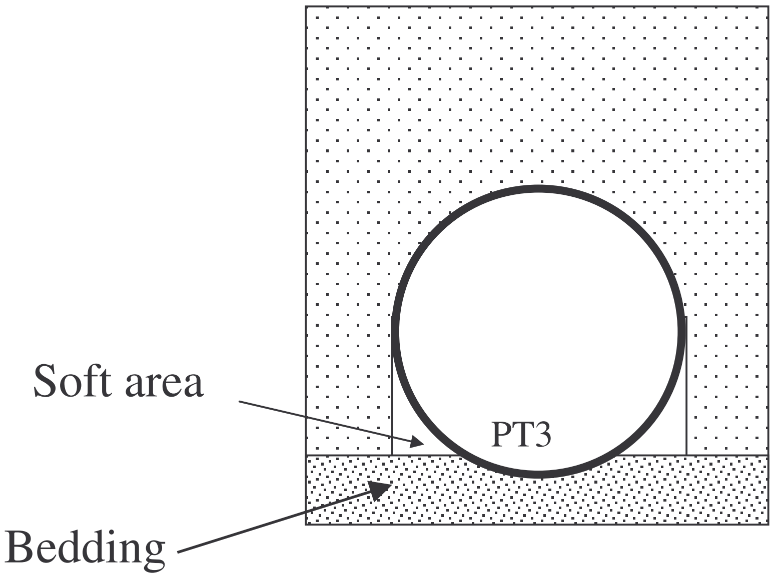
- Hoop stress vs loading (clayey soil)



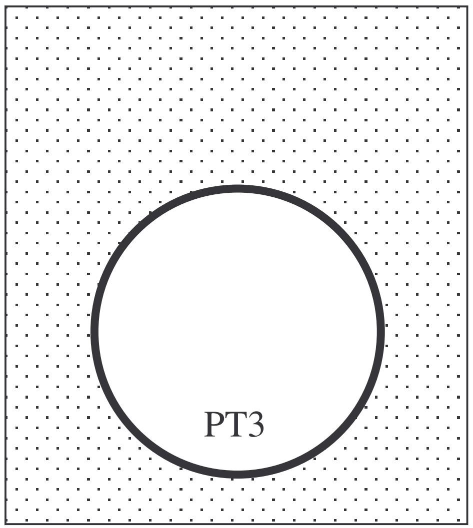


Results

- Importance of the pipe / soil interaction model



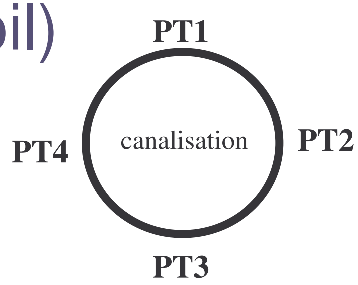
Full scale tests

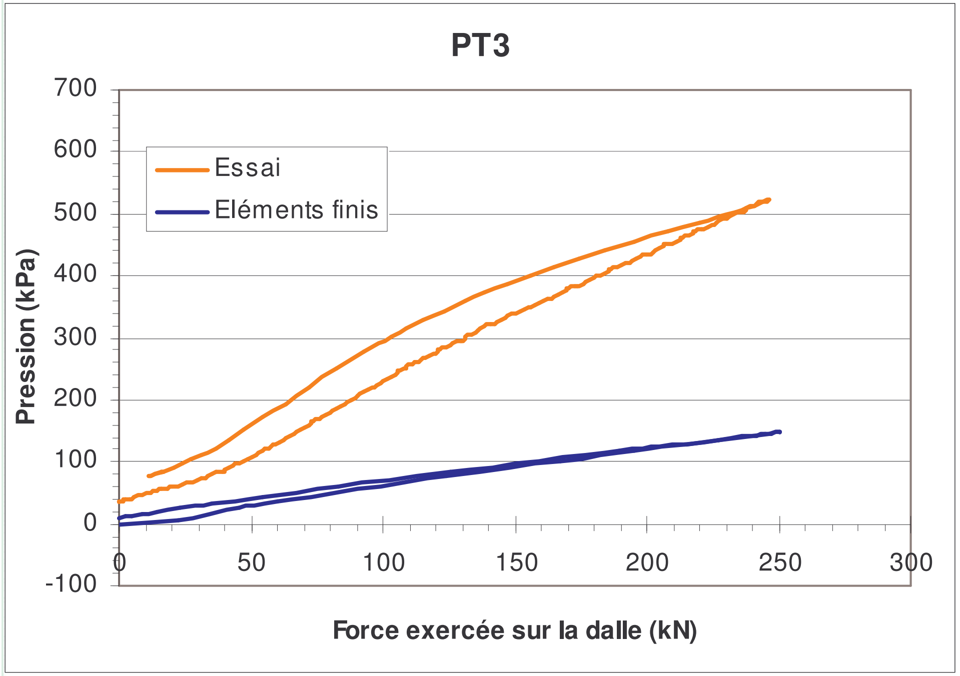


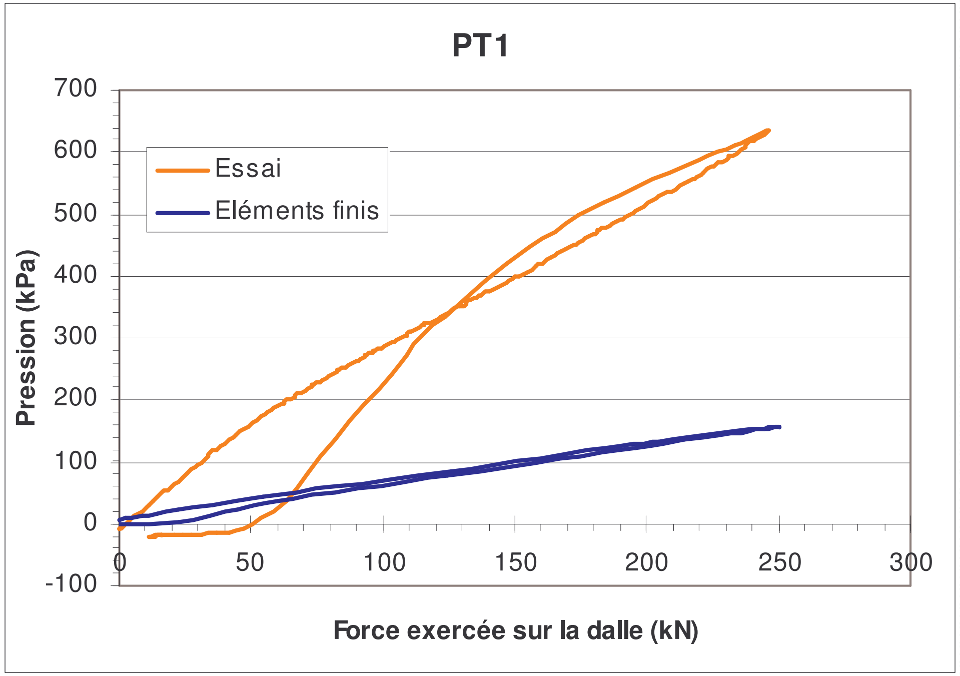
Finite Element models

Results – sandy soil

- Soil pressure on the pipe vs loading (sandy soil)

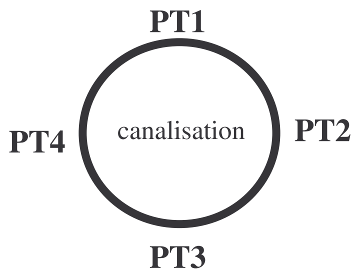


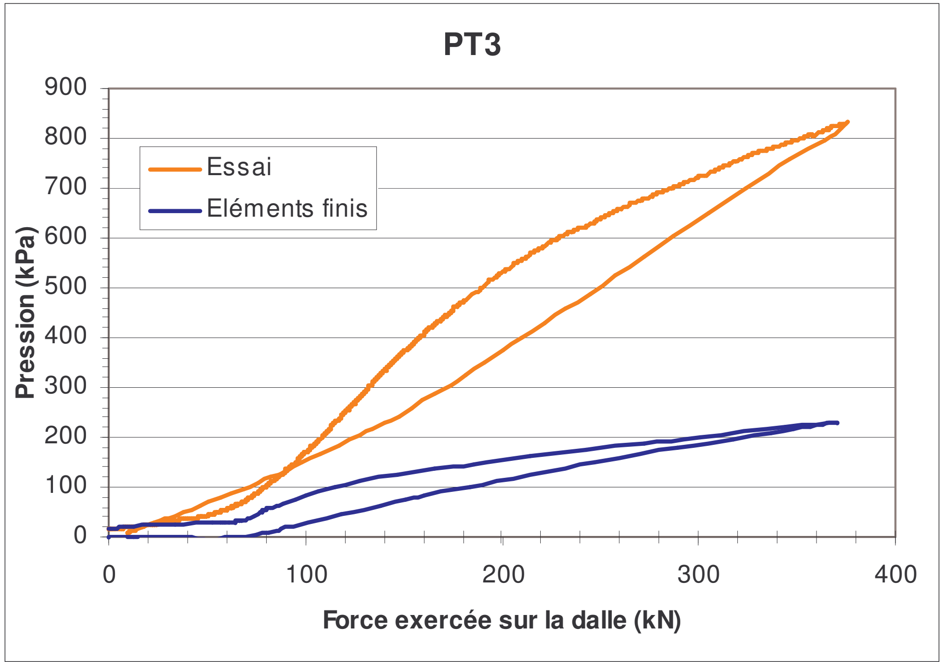


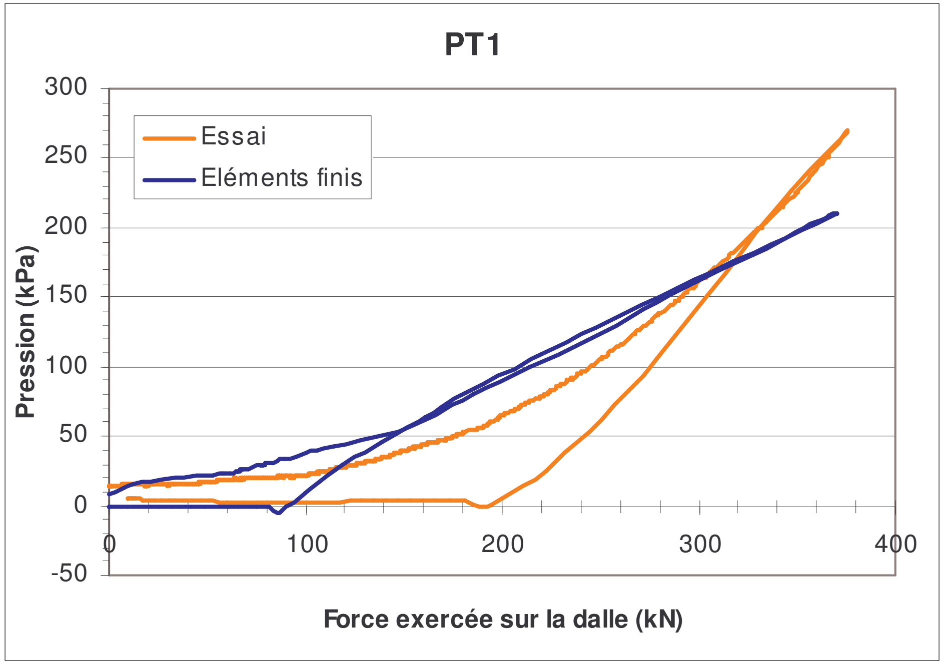


Results – clayey soil

- Soil pressure vs loading (clayey soil)







Conclusion

- The stress in the pipe stay reasonable
  - Less than 110 MPa in both tests
- The vertical displacement of the slab can be important in presence of trench effect
  - 170 mm
- Numerical modelling can reproduce the tests
  - Importance of the soil behavior law and the value of its parameters
  - Importance of an accurate modelling of the pipe/soil interaction

Conclusion

- Field applications
  - Minimum pipe / slab distance = 300 mm
  - Minimum width of slabs in function of the pipe diameter

Pipe	Slab width
DN 100	1.1 m
DN 200	1.15 m
DN 300	1.25 m
DN 600	1.6 m
DN 900	1.9 m
DN 1200	2.25 m

- Results used in a GESIP guide book

(GESIP : Groupe d'Étude de Sécurité des Industries Pétrolières et Chimiques)

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Perspective

- Accurate modelling of the pipe / soil interaction
- Comparison with classic analytical Marston models
- Simulations for field applications