From prediction to reality

Gas transmission pipeline protected with a surface slab

guillaume.l-henoret@gazdefrance.com

25 Novembre 2005
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
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
Instrumented pipe

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

Strain gauges

Soil pressure cells on the pipe

Tube

S1

S4

S3

PT1

PT4

PT2

PT3
Equipment

Soil pressure cells

![Diagram](image.png)
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

4 lois de contact glissement avec frottement de Coulomb

Substratum rigide (nœuds encastrés)
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

\[ \sigma \]
\[ \tau \]
\[ \tau_{\text{max}} \]

\[ \varphi \]
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

Soft area
Bedding
PT3
PT3
Results – sandy soil

Soil pressure on the pipe vs loading (sandy soil)

- PT3
- PT1
- PT2
- PT3

Essai
Eléments finis

Pression (kPa)
Force exercée sur la dalle (kN)
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

<table>
<thead>
<tr>
<th>Pipe</th>
<th>Slab width</th>
</tr>
</thead>
<tbody>
<tr>
<td>DN 100</td>
<td>1.1 m</td>
</tr>
<tr>
<td>DN 200</td>
<td>1.15 m</td>
</tr>
<tr>
<td>DN 300</td>
<td>1.25 m</td>
</tr>
<tr>
<td>DN 600</td>
<td>1.6 m</td>
</tr>
<tr>
<td>DN 900</td>
<td>1.9 m</td>
</tr>
<tr>
<td>DN 1200</td>
<td>2.25 m</td>
</tr>
</tbody>
</table>

Results used in a GESIP guide book

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

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