COMITÉ FRANÇAIS DE MÉCANIQUE DES SOLS ET DE GÉOTECHNIQUE

Demi-Journée Scientifique et Technique du CFMS
06 OCTOBRE 2022

A procedure to estimate the lateral force in clay-pipe interaction after breakout

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A procedure to estimate the lateral force in clay-pipe interaction after breakout

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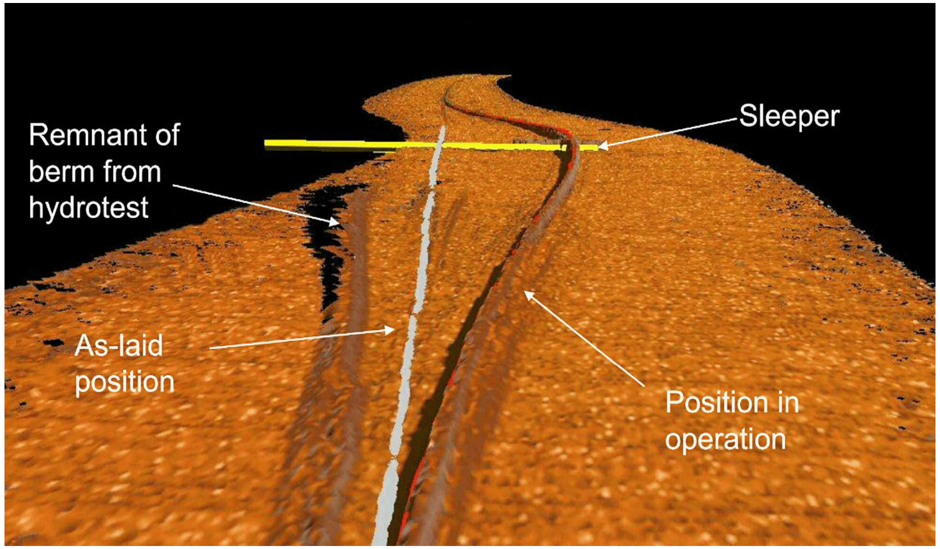
Outline

- Introduction
- Centrifuge tests set up
- Soil parameters and model preparation
- Test results
- A procedure to evaluate clay-pipe interaction lateral forces
- Conclusions

Introduction

Long subsea pipelines tend to move over time due to temperature variations in connection with interruptions in production.



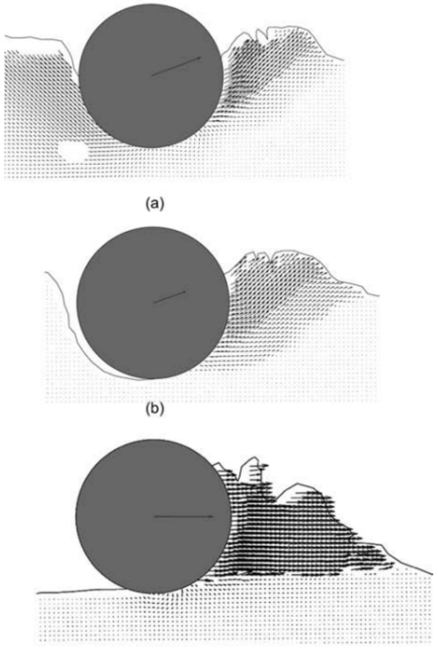
Source: https://www.upstreamonline.com/upstreamtechnology/anchor-issues/2-1-187160

Displacements occur when the soil/pipe friction is exceeded – Lateral buckling.

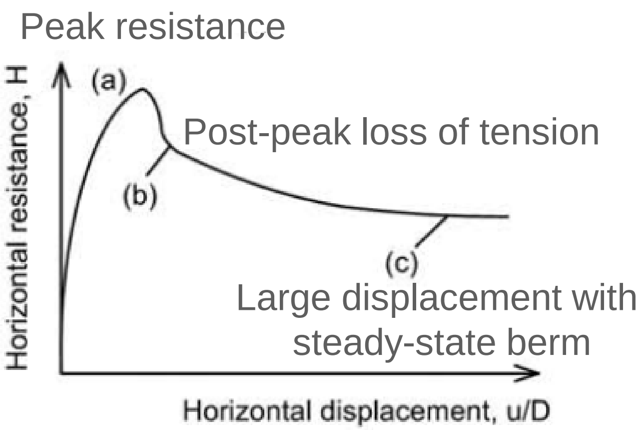
If uncontrolled, lateral buckling can create strains and cyclic loads that may cause damage to the flowline.

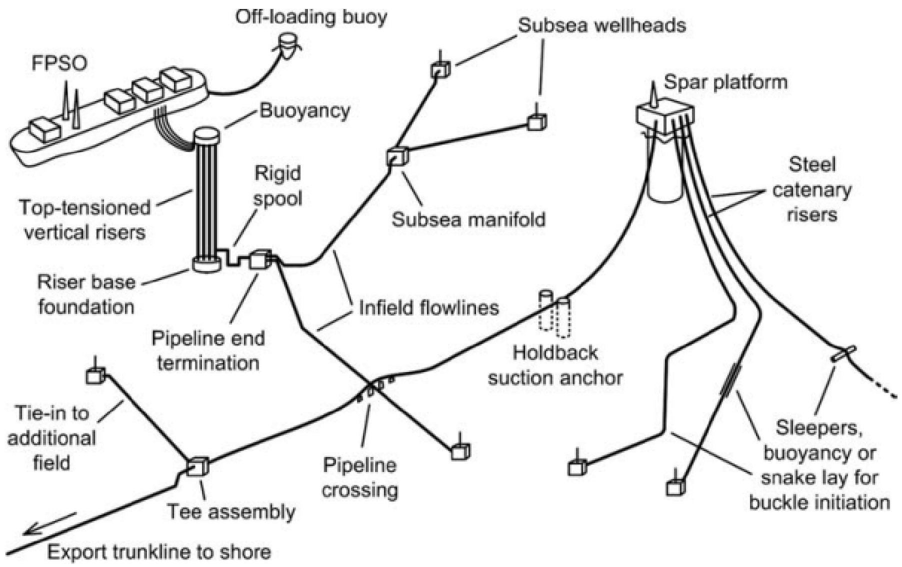
Introduction

As the pipeline moves, soil berms develop leading to a restriction of lateral pipeline displacements.



Randolph and Gourvenec, 2011





Rigid Pipeline diameters from 0.1 m to 1.5 m

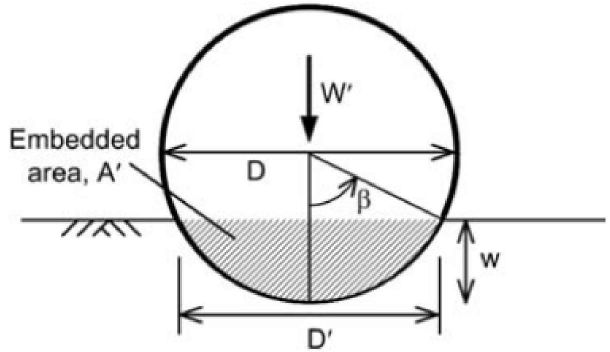
Introduction

Objective: to study the lateral clay-pipe interaction

Conditions: at large deformations – this means the formation of berms

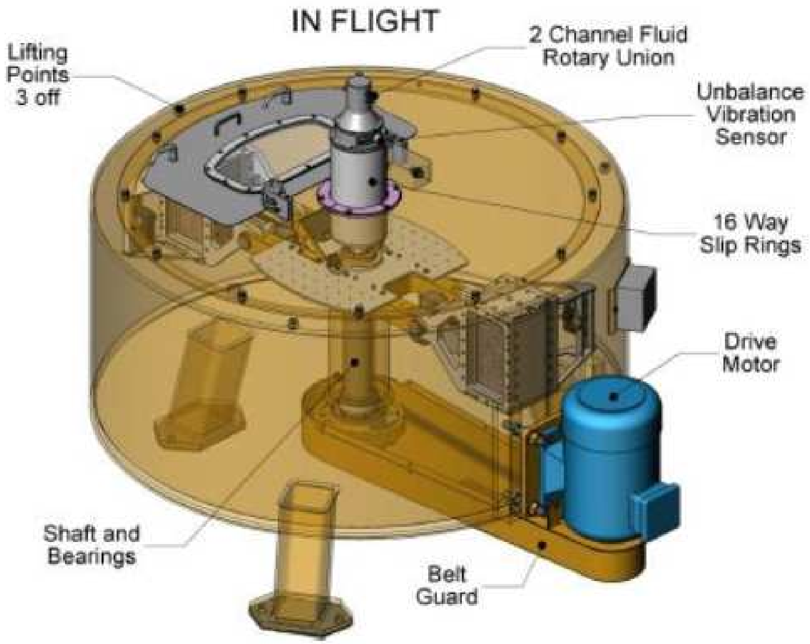
Parameters: different burial depths (w/D).

Randolph and Gourvenec, 2011



Centrifuge tests set up - Equipment

LM2C - UFRJ geotechnical centrifuge
Fabricated by Broadbent
Max g-level = 300 g
Diameter= 1.2 m



Model container
0.100 m wide, 0.300 m long and 0.180 m high

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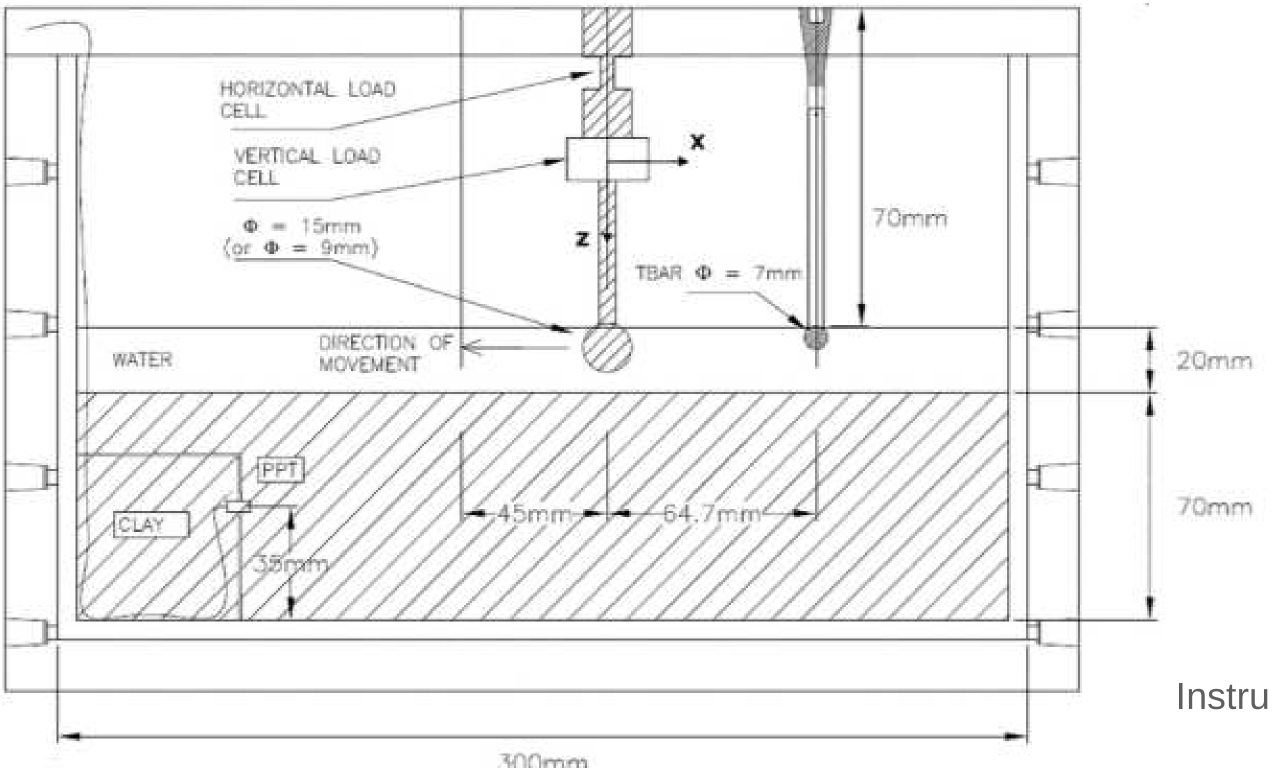
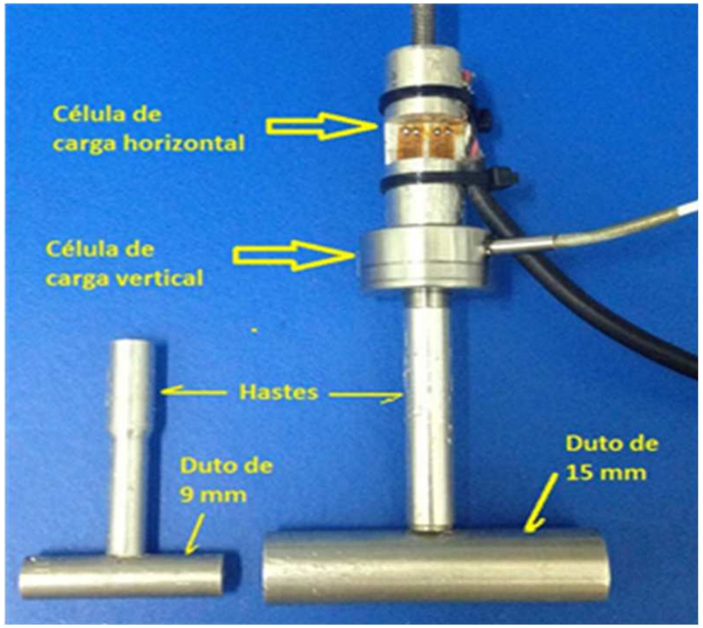
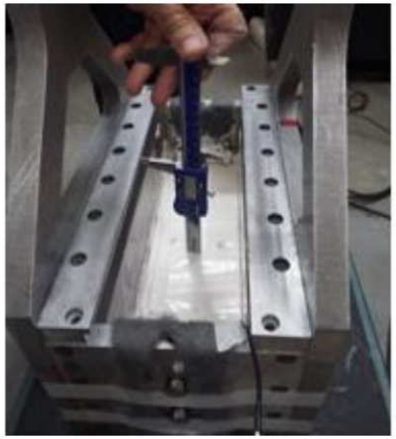
Centrifuge tests set up

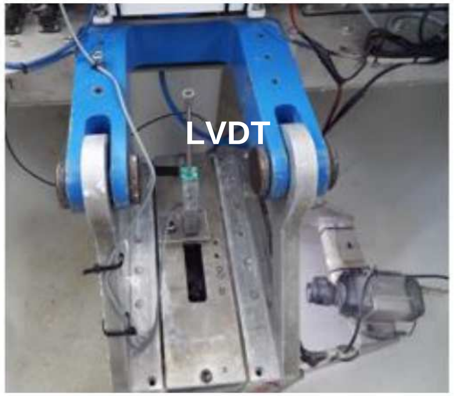




G-level N=33g – D=0.3 m and 0.5 m
Instrumentation: Pore Pressure Transducer (PPT), Load cells (hotizontal and vertical), T-bar for characterization

Soil parameters and model preparation





To obtain two strength profiles, pre-consolidation pressures of

19.7 kPa and 118.4 kPa

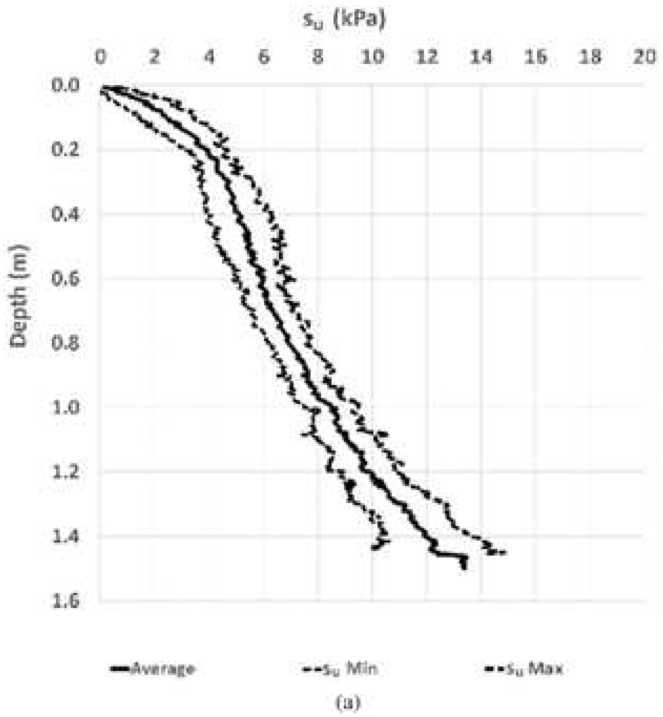
Consolidation at N=100 g

Monitoring by LVDT and PPT

Clay Speswhite kaolin

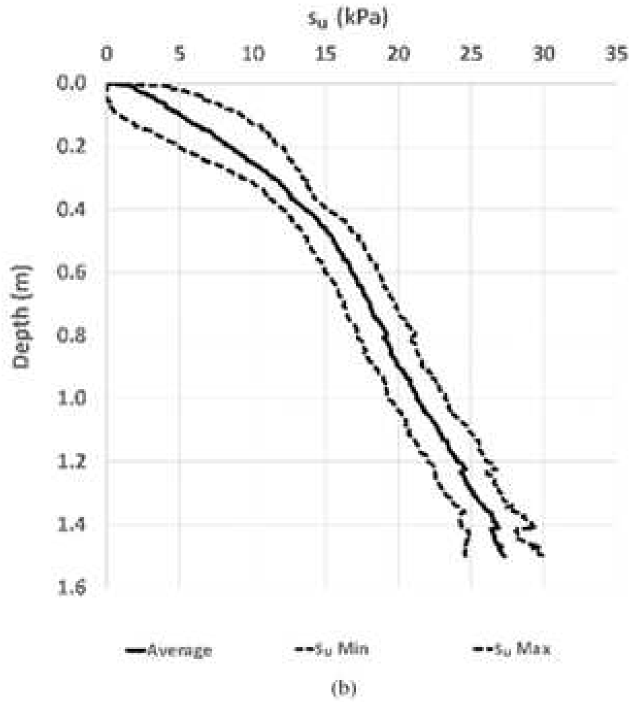
Main elements	42.1% of SiO_2; 36.2% of Al_2O_3
Atterberg limits	$w_L = 54\%$, $w_P = 20\%$
USCS classification	CL-CH
Cam-Clay parameters	$\lambda = 0.107$; $\kappa = 0.015$; $M = 0.93$
Coefficient of consolidation	$c_v = 6.48 \times 10^{-7}$ m^2/s

Soil parameters and model preparation



(a)

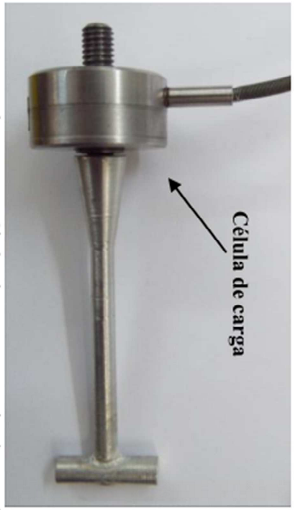
(a) Profile 1



(b)

(b) Profile 2

Undrained shear strength profiles



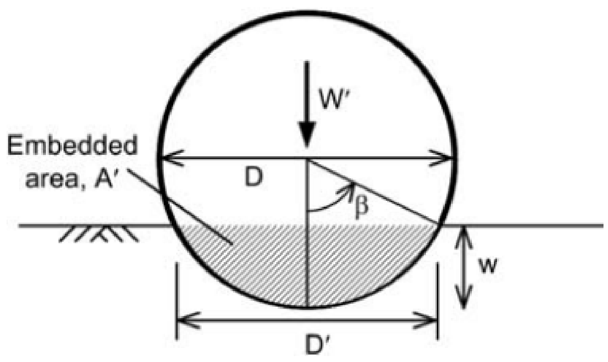
D=5mm
L=20 mm

Test results: experimental programme

31 centrifuge tests varying the w/D ratio (burial depth) – 25%, 50% and 75%

16 tests on profile 1

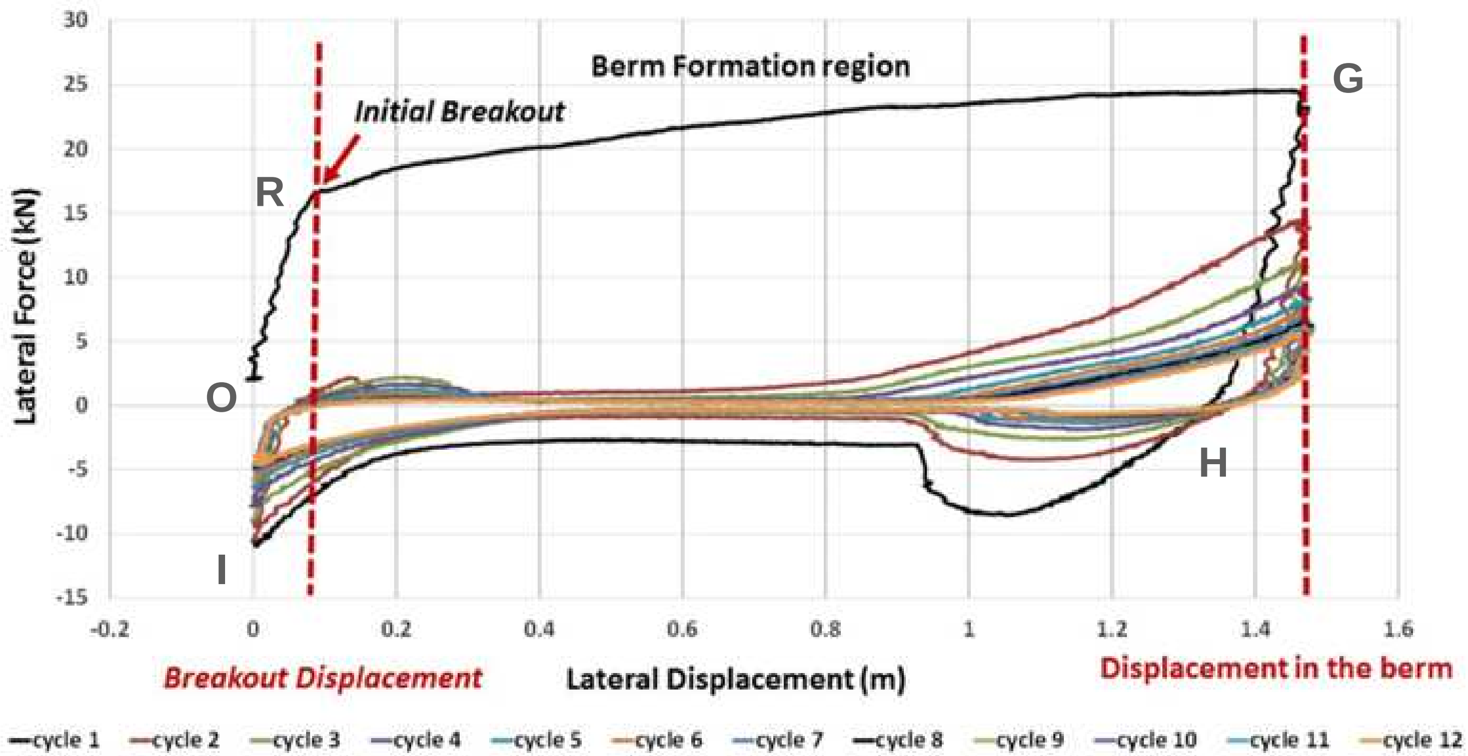
15 tests on profile 2

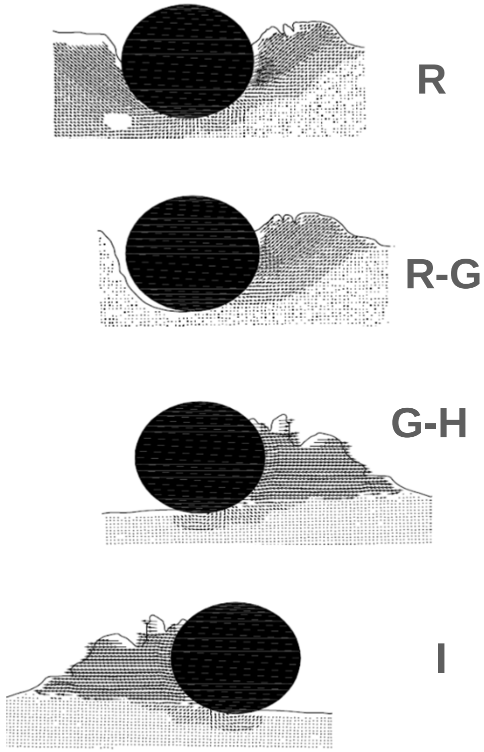


Procedure: Pipe moved laterally forward and backwards for a distance equivalent to 3 diameters and 12 cycles were applied.

v = 0.86 mm/s and v = 1.44 mm/s for the 15 mm and 9 mm diameter pipes.

Test results: Lateral force for w/D = 25% D=0.3m





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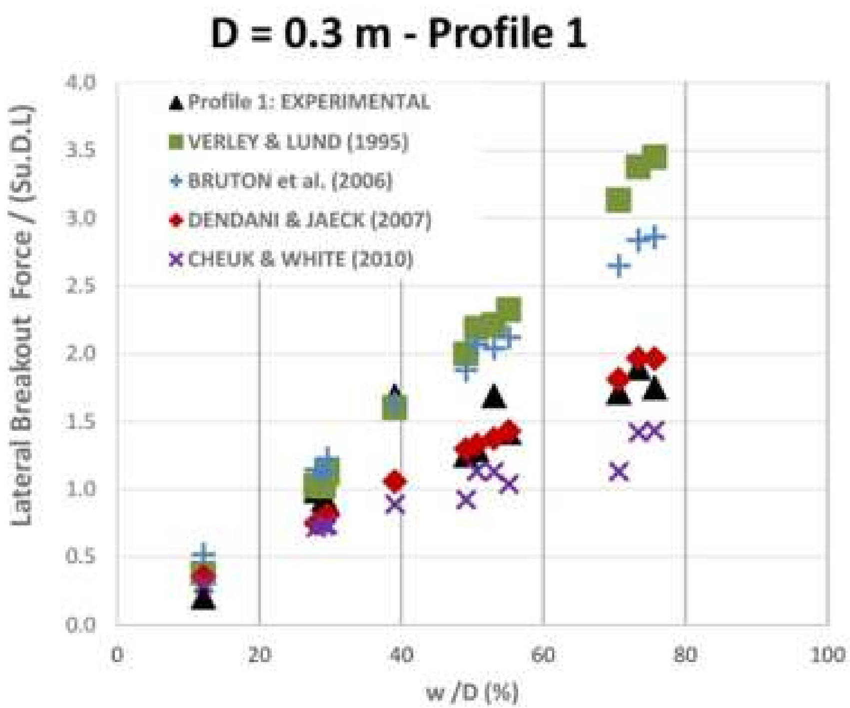
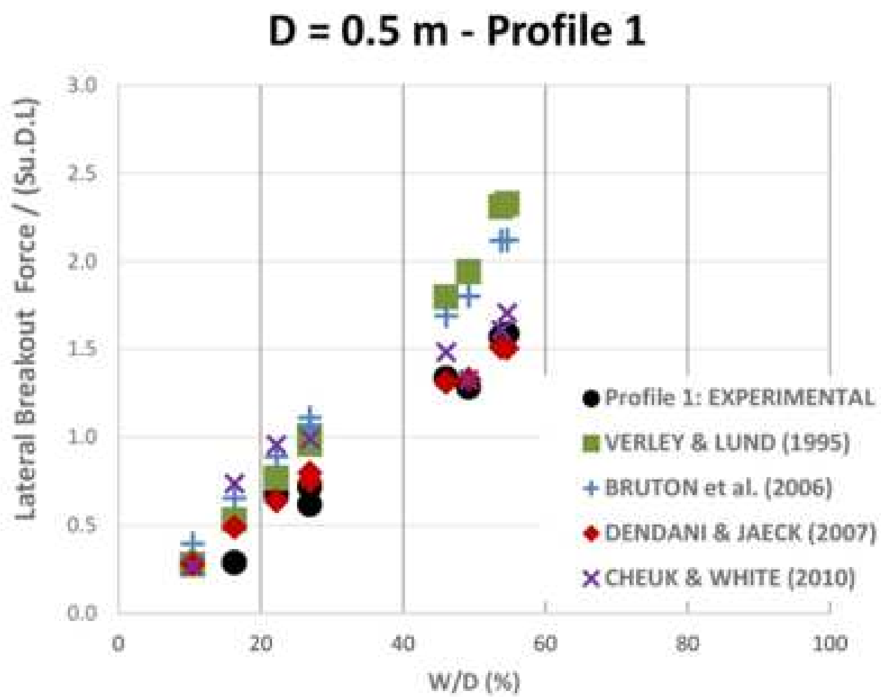
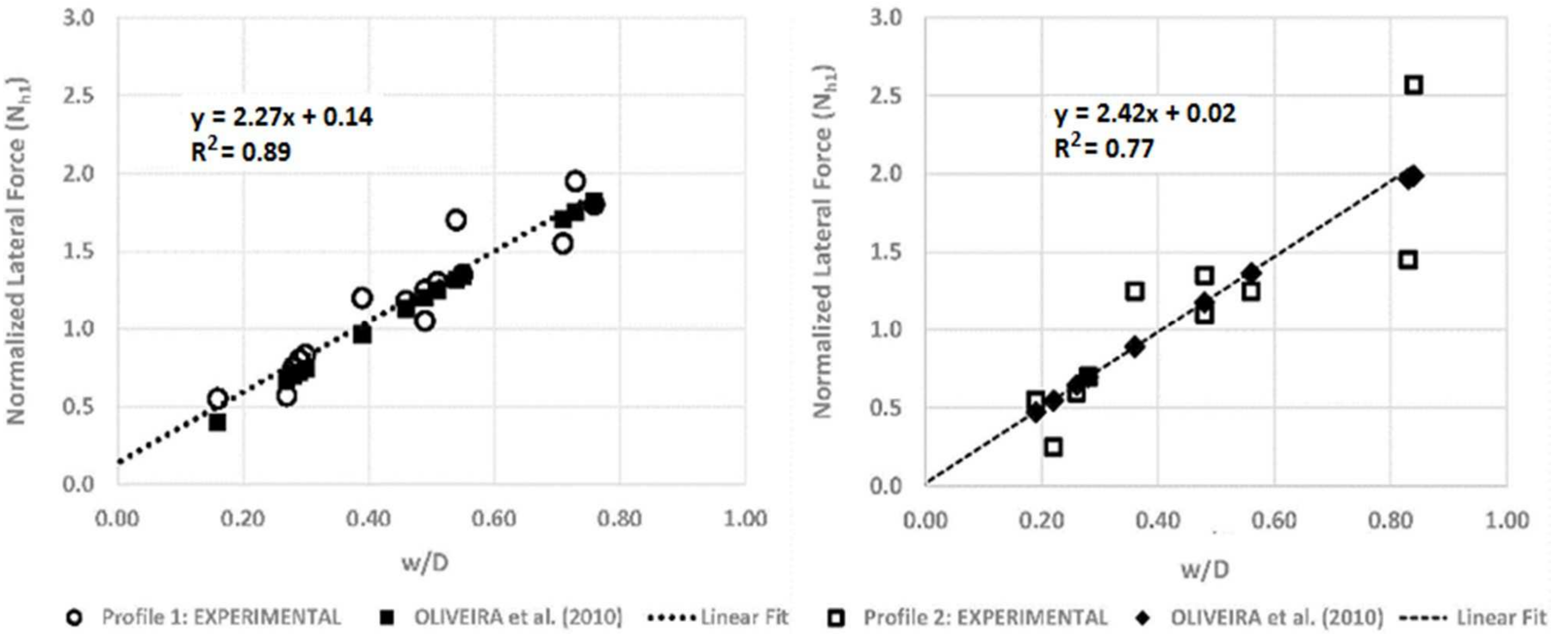
Test results: Normalized lateral breakout forces versus normalized embedment





Test results: Comparison between Oliveira et al. (2010) (data and linear fit) and lateral normalized force data at breakout



Eq. (1):

$$H_b = 5 \cdot Su \cdot D \cdot L \cdot atan\left(\frac{n_0 w}{D}\right).$$

n0 – depends on the soil type 1.0 Guanabara bay clay and 0.5 for Speswhite kaolin

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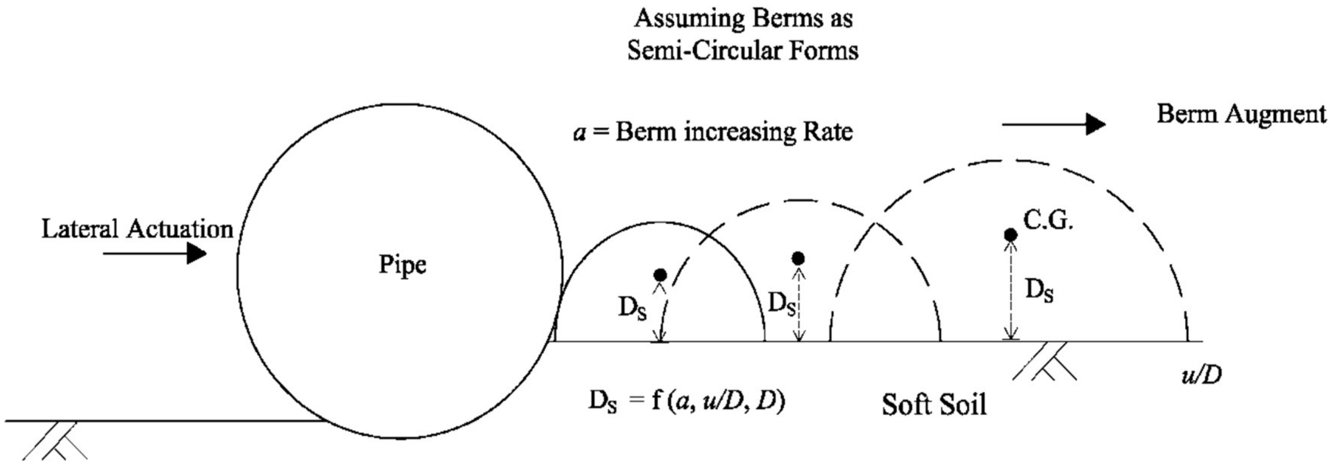
A procedure to evaluate clay-pipe interaction lateral forces: Proposed model of berm increase with u/D



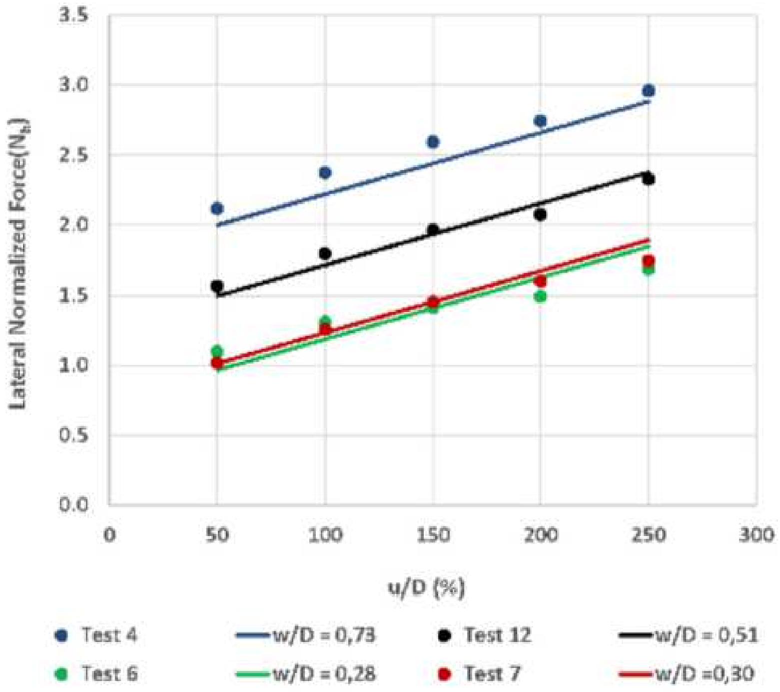
a= increasing rate per length of the berm

u= displacement

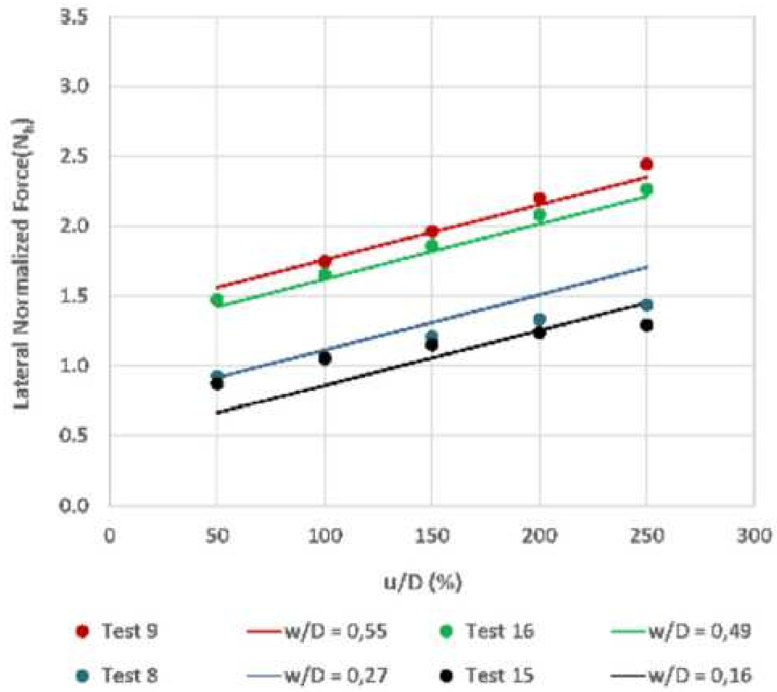
L= length of the pipeline

$$N_h = 5\cdot atan\left(n_0\cdot\frac{w}{D}\right) + \frac{\frac{\gamma(a\cdot u)^2}{2} + 2\cdot S_u\cdot(a\cdot u)}{S_u\cdot L}.$$

Comparisons between experimental values (points) and the proposed model for Lateral Normalized Forces (lines)



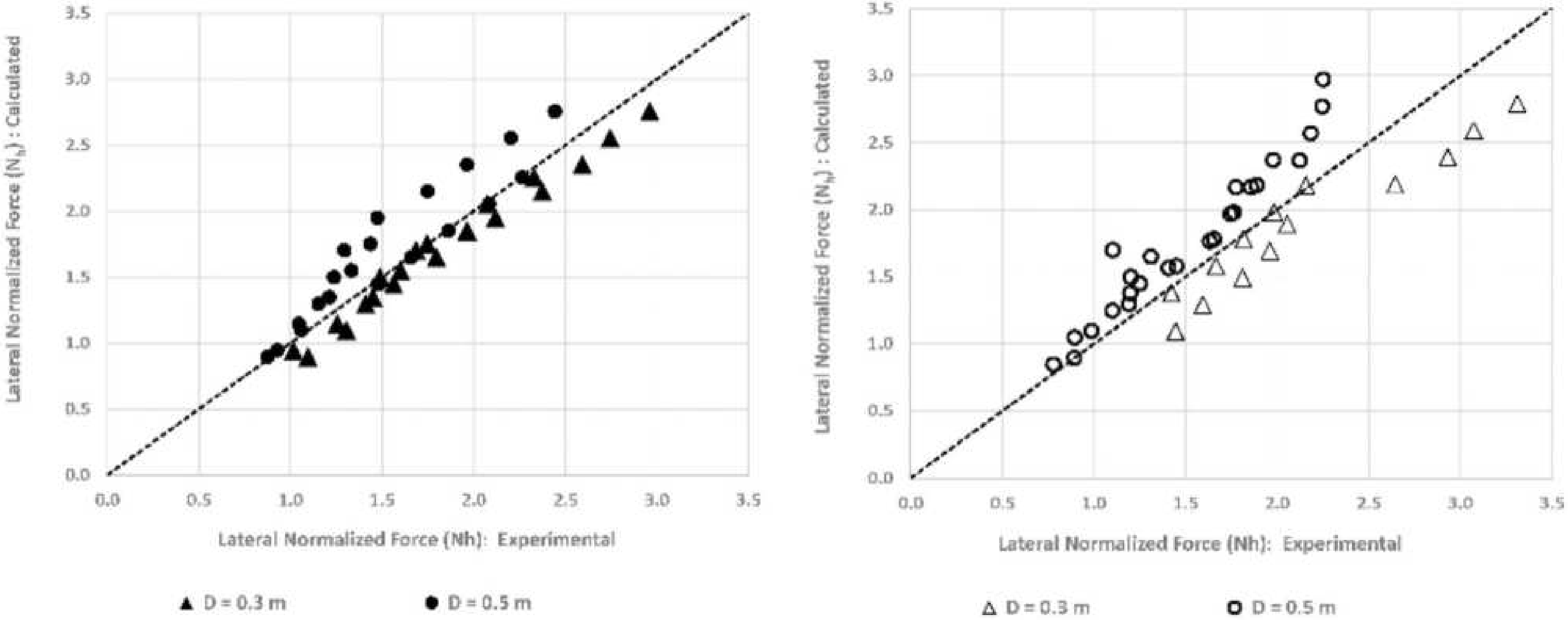
D = 0.3 m



D = 0.5 m

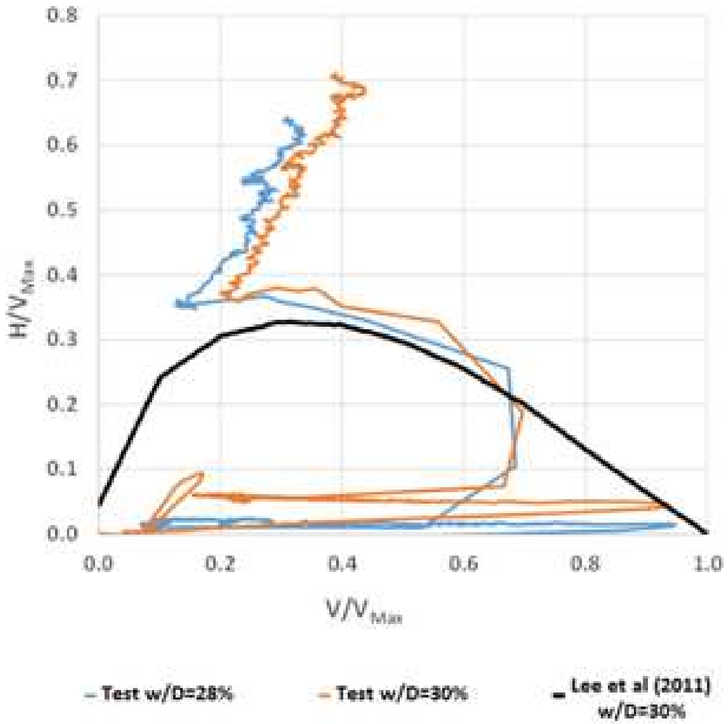
n_0 = 0.50 and a = 0.10

Comparisons between experimental and proposed model values

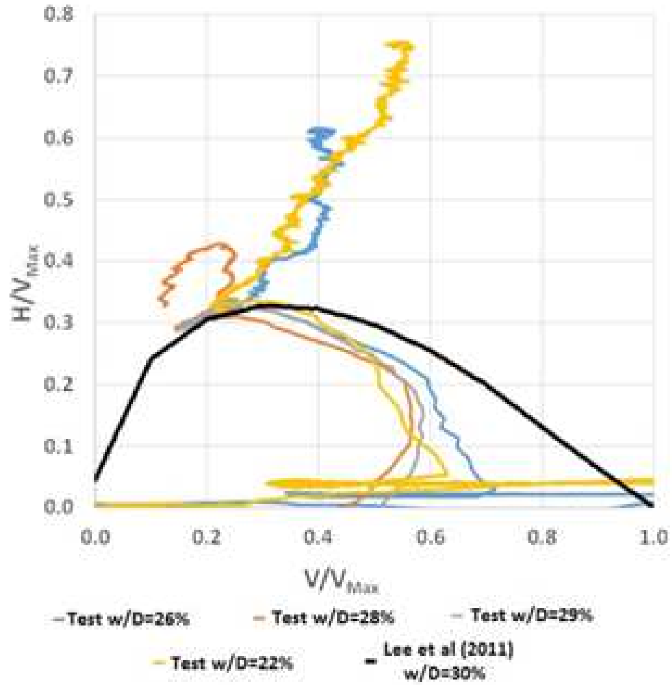


(a) Profile 1 (b) Profile 2

Comparison between test results and envelopes proposed by Lee et al. (2011)



a) Profile 1



b) Profile 2

The horizontal (H) and vertical (V) forces reach very quickly the yield surface, where a hardening phase begins associated with a berm formation in front of the pipe

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Conclusions

- The normalized lateral breakout forces were compared with predictions showing a good agreement.

- The tests also proved to be in accordance with envelope curves proposed by Lee et al. (2011) showing that the forces reach very quickly the yield surface, where a hardening phase begins associated with a berm formation in front of the pipe.

- A simplified procedure was presented to estimate the normalized lateral force, taking into account the breakout resistance and the increase in the force due to berm formation.

- Comparisons between the experimental data and the equation proposed in this work show good correlation but further investigation is needed to validate this approach.

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