
PANDA® CASE STUDIES
SOL SOLUTION
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BUREAU D'ÉTUDES
GÉOTECHNIQUE / GÉOPHYSIQUE
MATÉRIELS GÉOTECHNIQUES
RECHERCHE ET DÉVELOPPEMENT
FORMATIONS



PANDA® CASE STUDIES SUMMARY

SOL SOLUTION

1. Undrained shear strength sediments of a water damming – slides 4-9
2. Dams diagnosis in Laos – slides 10-13
3. Ground settlement risk estimation – slides 14-16
4. Determining the depth of the interface between Aeolian and cemented sands - slides 17-19
5. Determine the thickness of silts – slide 20
6. Geotechnical feasibility study – slides 21-23
7. Geotechnical campaign by coupling – slides 24-25
8. Individual houses : Mission G2 AVP (NF P 94 -500) - slide 26
9. Geotechnical Diagnosis : Foundations - slide 27
10. Resin injection - slide 28
11. Determination of the thickness of fractures - slide 29
12. Bearing capacity diagnosis (Belgium) - slide 30
13. Bearing capacity - slides 31-33
14. The lack of ground decalcification underneath bored piles' bedrock (Belgium) - slide 34
15. Deep foundations – Tubulão - slides 35-37
16. Restricted & Confined Access Sites – Slide 38
17. Angled soundings – slopes – Horizontal to vertical tests - slide 39
18. Technical Landfill Center – landfill - slide 40



PANDA® CASE STUDIES SUMMARY

SOL SOLUTION

19. Snowpack diagnosis - slide 41
20. Cultivable fields - Ploughing depth influence - slide 42
21. Freshwater Mussels – slide 43
22. Compaction control – mine tailings – slide 44
23. Compaction and slope stability control – mine tailings – slides 45-50
24. Geotechnical diagnosis - Slope stability – slide 51
25. Landslide in Mexico – slides 52-54
26. Panda variable energy interest in low resistance soils – slide 55-56
27. Characterization of the former lake of Texcoco (Mexico) – slide 57-58
28. The new international airport of Mexico (NAICM) – slide 59-60
29. AIRBUS A400m – CBR measurements – slides 61-62
30. Aviation Runways Expertise – Ivory Coast - Slide 63
31. Comparative PANDA / Water content (W%) – Brazil – slides 64-66
32. Correlation PANDA / SPT (Brazil) – slides 67-72
33. Continuous characterization of the ballast underneath rail tracks – slides 73-80
34. Ballast exploration and diagnosis of the SNIM railway tracks in Mauritania – slides 81-85
35. Lateritics Gravel calibration – Burkino Faso – slides 86-90
36. Shells sand Vibrocompaction calibration (Uruguay) – slides 91-95
37. Controlling the use of expanded clay balls – slides 96-101

UNDRAINED SHEAR STRENGTH SEDIMENTS OF A WATER DAMMING :

Project : partial mechanical dregding of the sediments by lowering the water damming

Aim of the study :

- Determining the undrained shear strength of the sediments
- Determining the bearing capacity of sediments in case of excavation jobs

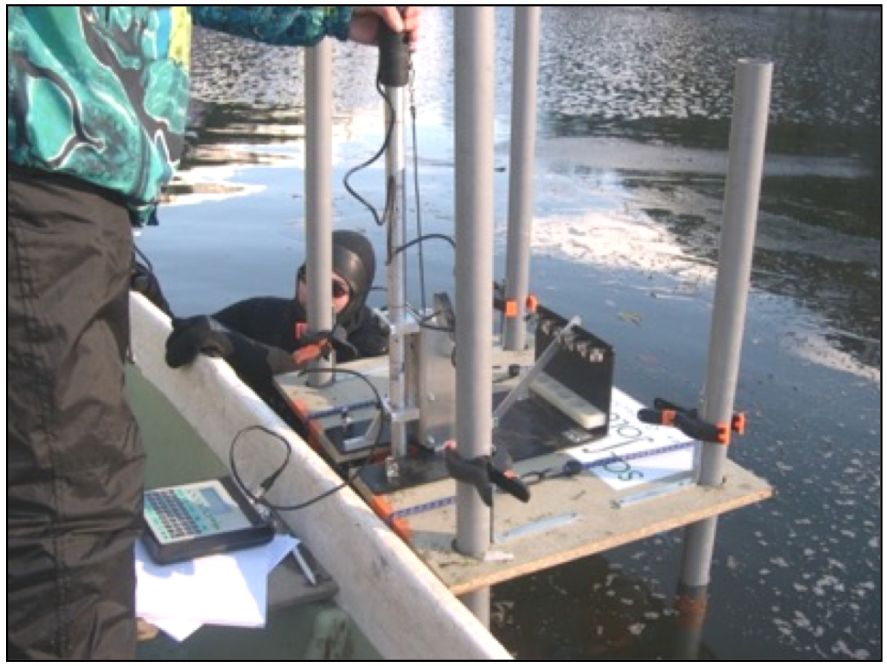


Water damming at Campauleil - centrale de Teich (09)

UNDRAINED SHEAR STRENGTH SEDIMENTS OF A WATER DAMMING :

Access to the site is difficult and the sediments have « weak » characteristics

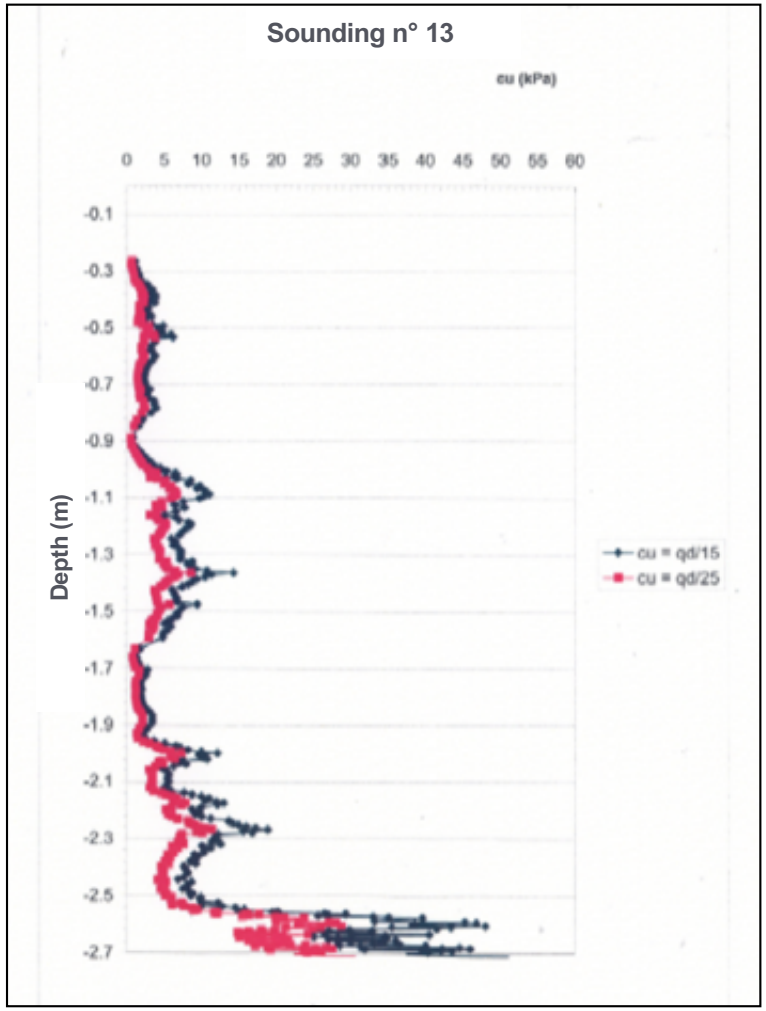
- Use of the Panda® Snow device (lighter and more adapted)
- Barge stabilized by divers
- Platform rooted with PVC tubes planted in the sediments



UNDRAINED SHEAR STRENGTH SEDIMENTS OF A WATER DAMMING :

14 soundings – Correlation between the cone resistance and the undrained shear strength of the sediments of the site.

$$C_U = Q_D / 15 \text{ À } 20$$



UNDRAINED SHEAR STRENGTH SEDIMENTS OF A WATER DAMMING :

EDF bassin in the East of Lyon – total area 150 ha – water sport activities.
Dredging and disposal of the extracted sediments : silts, limes and sands.

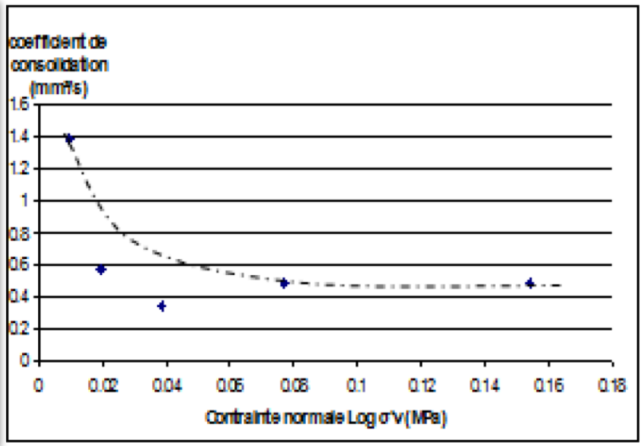
Objective is to know the mechanical behavior of the platform built.

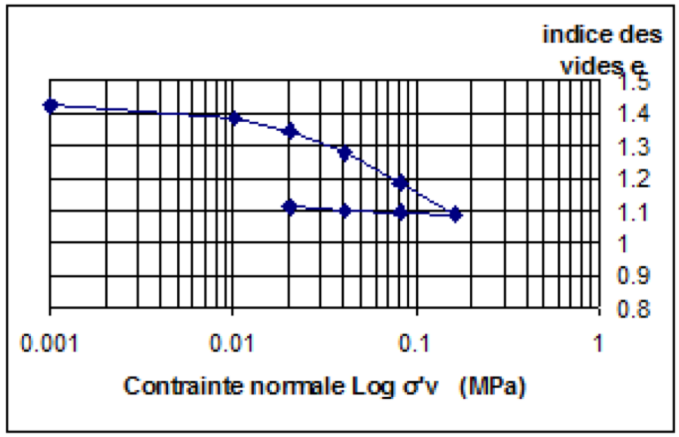


UNDRAINED SHEAR STRENGTH SEDIMENTS OF A WATER DAMMING :

Lab tests : Core sampling
Various tests (oedometer, vane shear test, Atterberg limits, methylene blue test,…)



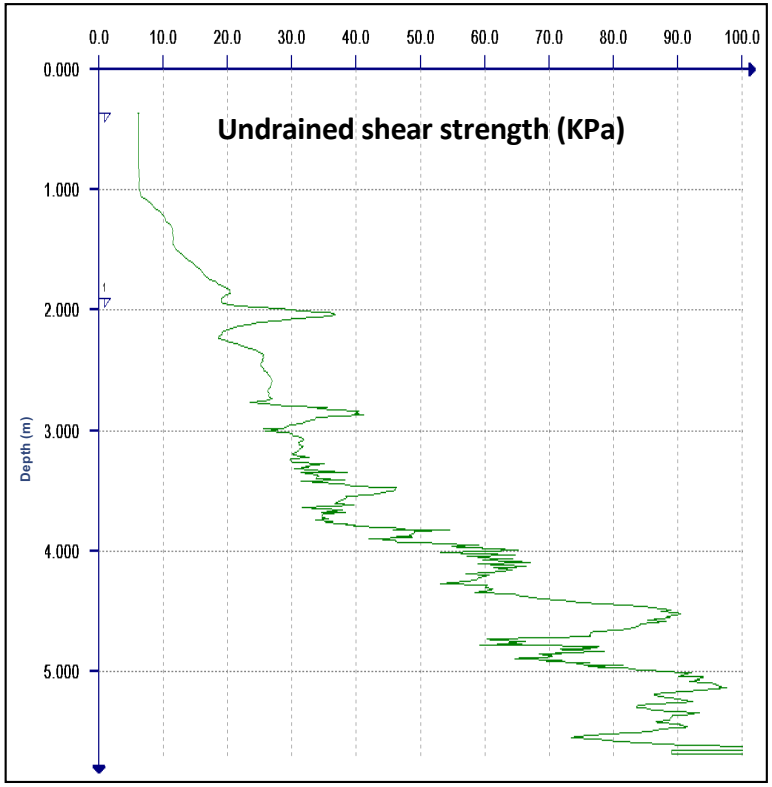




- Undrained shear strength
- Compressibility and consolidation constraint of the materials
- Grains specific weight, dry specific weight, wet specific weight

UNDRAINED SHEAR STRENGTH SEDIMENTS OF A WATER DAMMING :

In situ tests: tests with the Panda® Dynamic cone penetrometer
To establish a continuous profile of hte undrained shear strength (correlation).



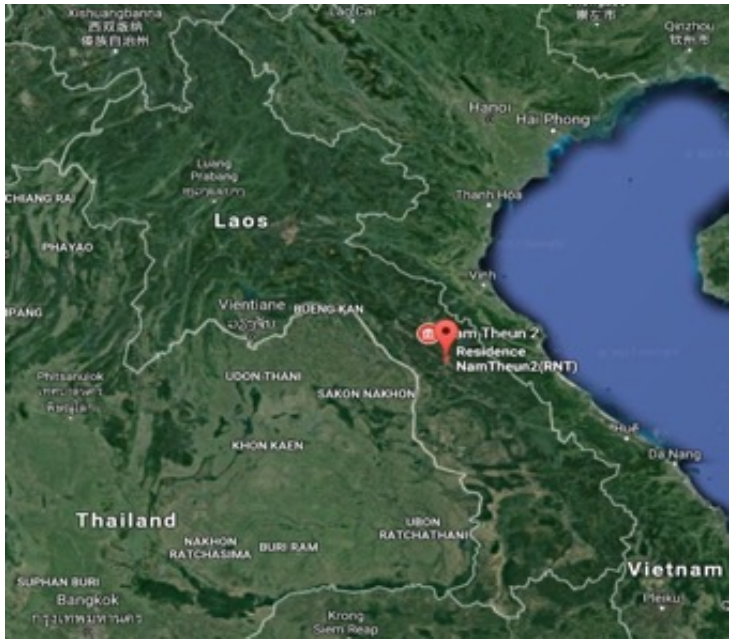


DAMS DIAGNOSIS IN LAOS

NTPC Hyrdropower Project : hydroelectric dams located on the Nam Theun river in Laos

Objectives :

- Highlight any decompressed area
- Identify the bedrock depth below the dam

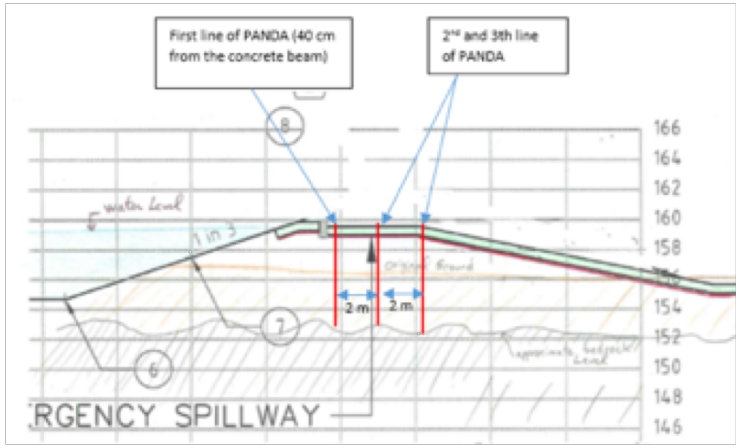




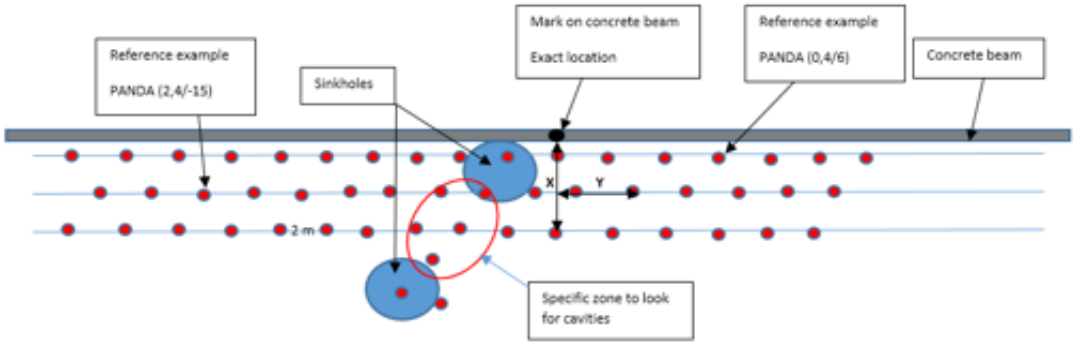
Hydroelectric dam

DAMS DIAGNOSIS IN LAOS

Soundings settled every 2 meters by 3 lines placed 2 meters away from each other



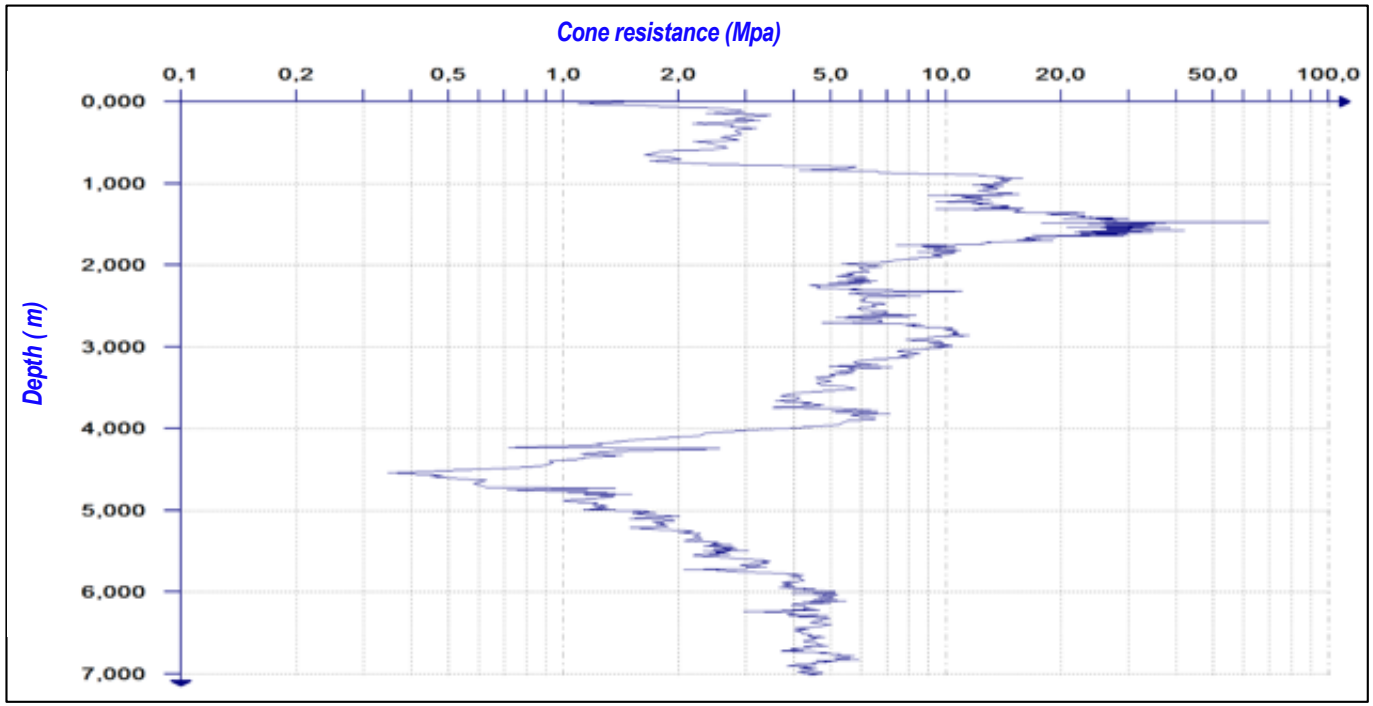




DAMS DIAGNOSIS IN LAOS

Soundings implementation

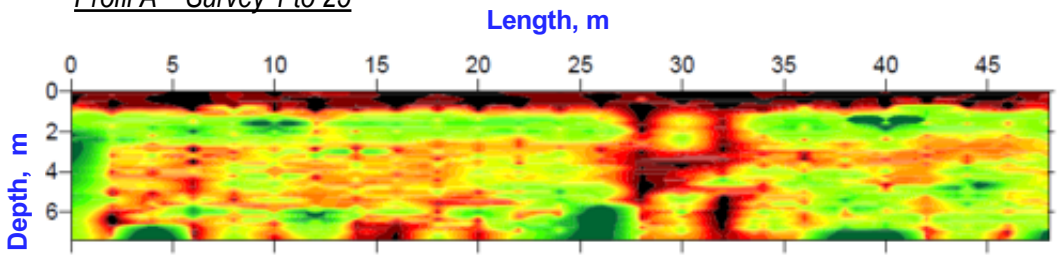




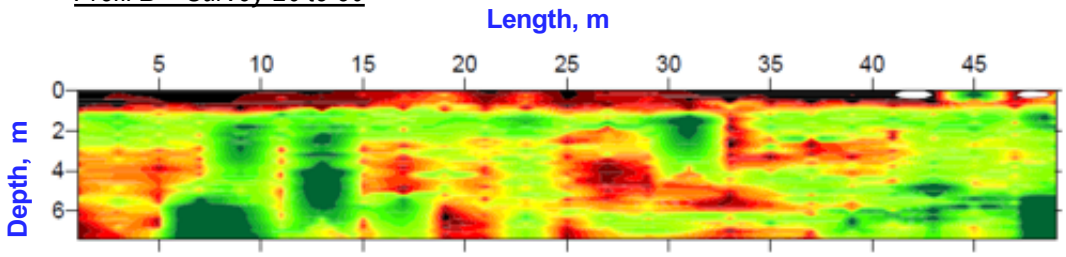
DAMS DIAGNOSIS IN LAOS

The dam reconstitution in 2D

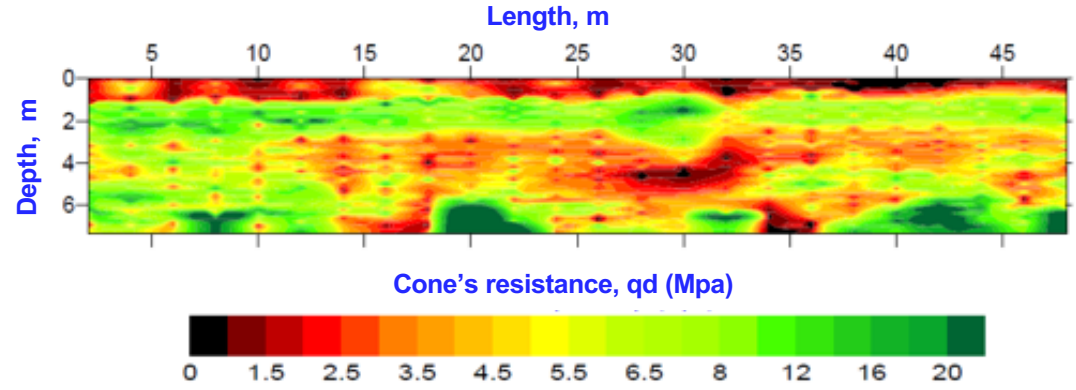
Profil A – Survey 1 to 25



Profil B – Survey 26 to 50

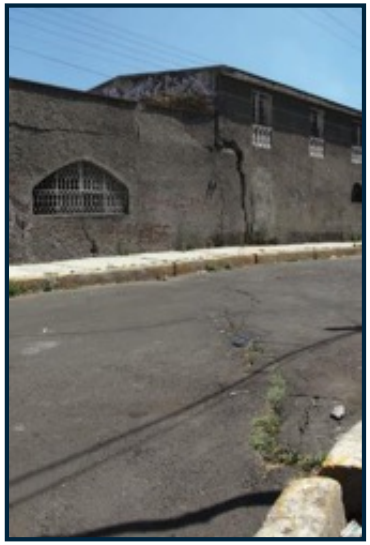


Profil C – Survey 51 to 74



GROUND SETTLEMENT RISK ESTIMATION

Identifying and mapping the settlement areas (range and dimensions) affected by the problem of ground settlement in the Tlahuac delegation (Mexico DF)



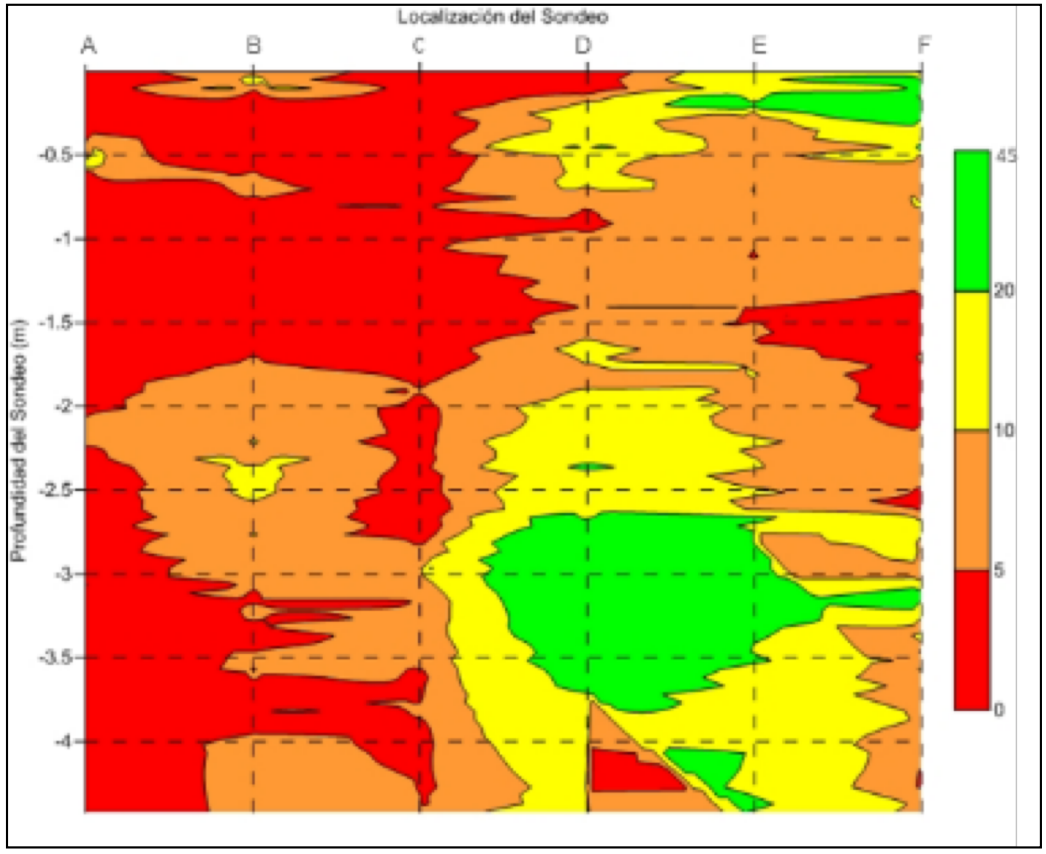




Each year, houses, roadways and infrastructures are affected by huge damages (of different sizes) caused by ground settlement.

GROUND SETTLEMENT RISK ESTIMATION

Construction of a database thanks to Panda® 2 tests.
Export to the software SURFER is done to create the various settlement profiles.

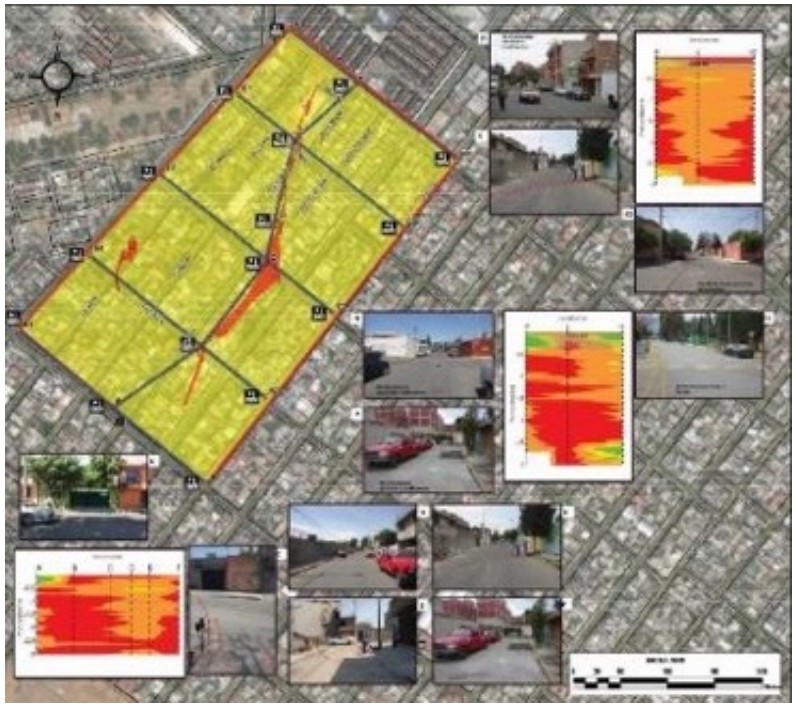




GROUND SETTLEMENT RISK ESTIMATION

Mapping (of the risk of settlement) is done according to the characteristics of the underground materials.





DETERMINING THE DEPTH OF THE INTERFACE BETWEEN AEOLIAN AND CEMENTED SANDS :

On the mediterranean side of the rock of Gibraltar, a 10 hectare slope is covered with corrugated metal plates used to collect rain water.

Perpendicular nailing on the slope was established thanks to several heavyweight machines lashed on top of the rock.





Gibraltar : English territory in the very South of Spain

DETERMINING THE DEPTH OF THE INTERFACE BETWEEN AEOLIAN AND CEMENTED SANDS :

CONDITIONS :

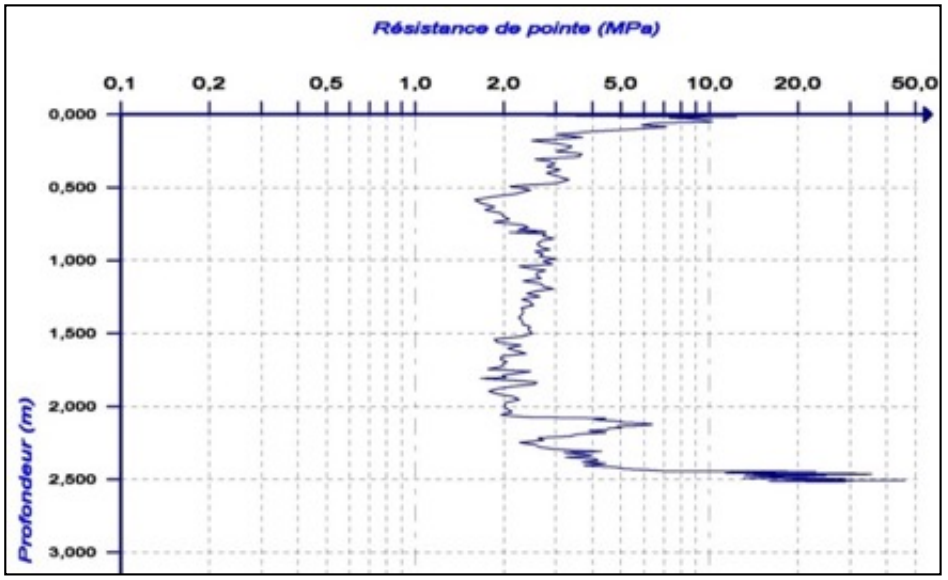
- Work done on a very steep slope
- No heavyweight drilling machine anchored at the top of the rock
- Panda used from bottom to top (secured operator)



DETERMINING THE DEPTH OF THE INTERFACE BETWEEN AEOLIAN AND CEMENTED SANDS :

Objectives of the project:

- To define the thickness of the Aeolian sand (in the range of 2 - 4 meters)
- To determine the cemented sand interface (a few dozens cm) against the rock face.
- Correlation established between the qd of Panda® and the undrained shear strength for the stability of the slope.



DETERMINE THE THICKNESS OF SILTS :

Low bearing capacity







GEOTECHNICAL FEASIBILITY STUDY :

PROJECT : URBANIZATION OF A WIDE AREA (AROUND 80 HECTARES) IN THE EAST OF RIOM (63)

AIM OF THE STUDY :

- Determine the geological and hydrogeological context of the zone
- Determine the type of foundation needed
- Determine the excavation issues (pavement, road work,…),
- Provide general recommendations for project realization

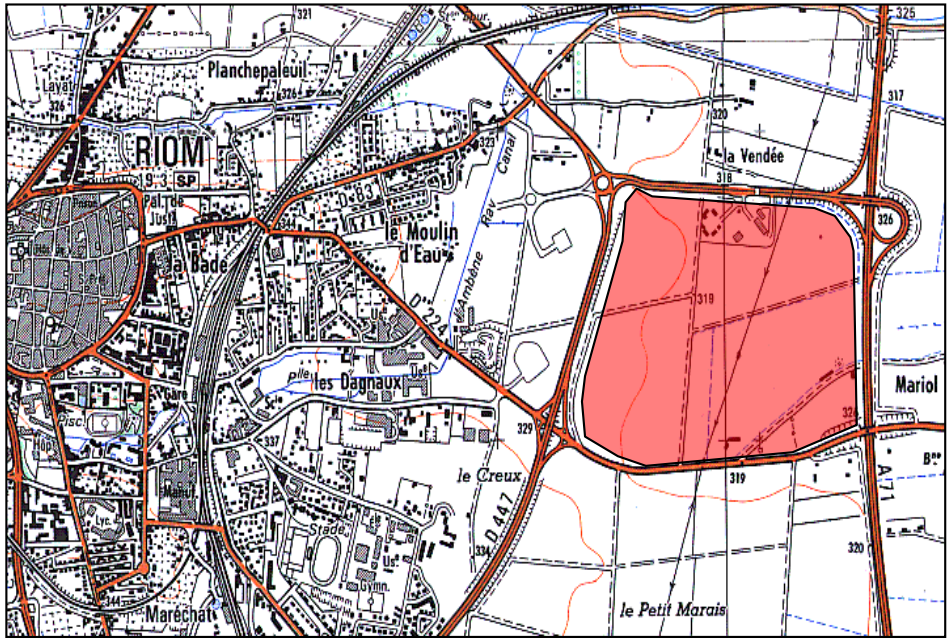
INVESTIGATIONS :

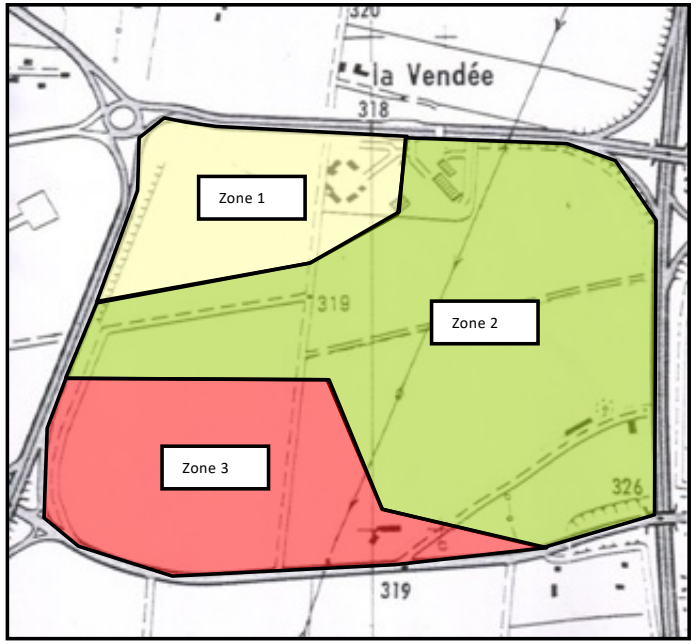
- Tests with the PANDA® dynamic cone penetrometer
- Destructive soundings with mechanical auger
- Test with a pressumeter
- Installation of piezometers
- GTR soil characterization - Atterberg limits of clayish soils

GEOTECHNICAL FEASIBILITY STUDY :

Preliminary studies (wide network of soundings) shall allow to identify 3 areas of investigation according to the global quality of lands

More precise studies are conducted in the 3 previously identified areas.

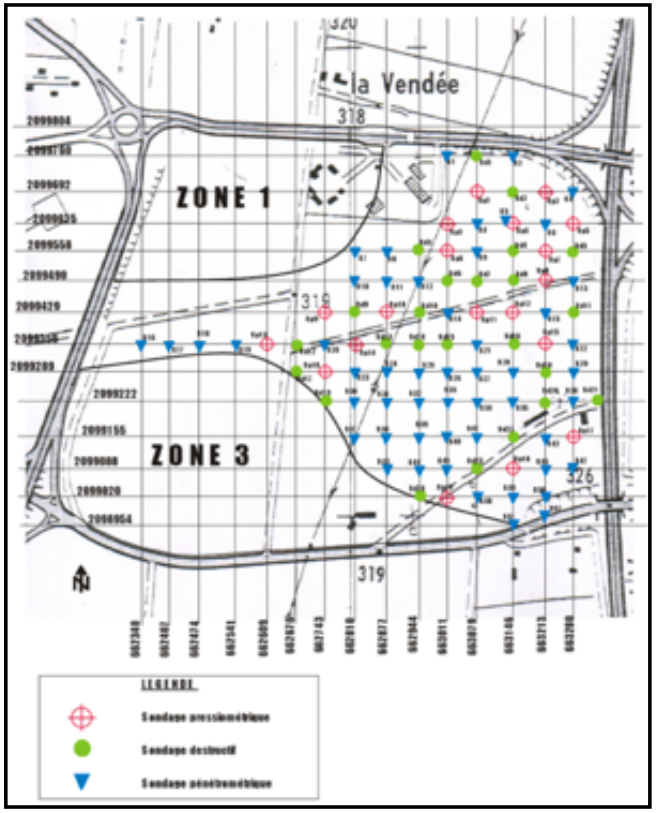




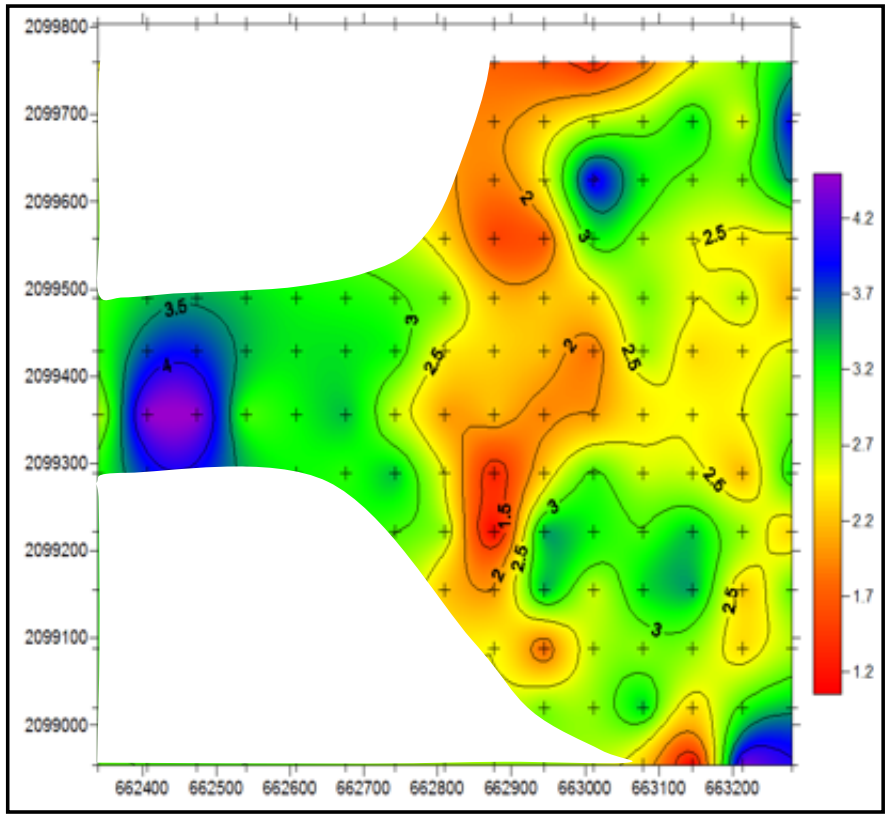
GEOTECHNICAL FEASIBILITY STUDY :

Accurate characterization of each area and mapping of the various facies

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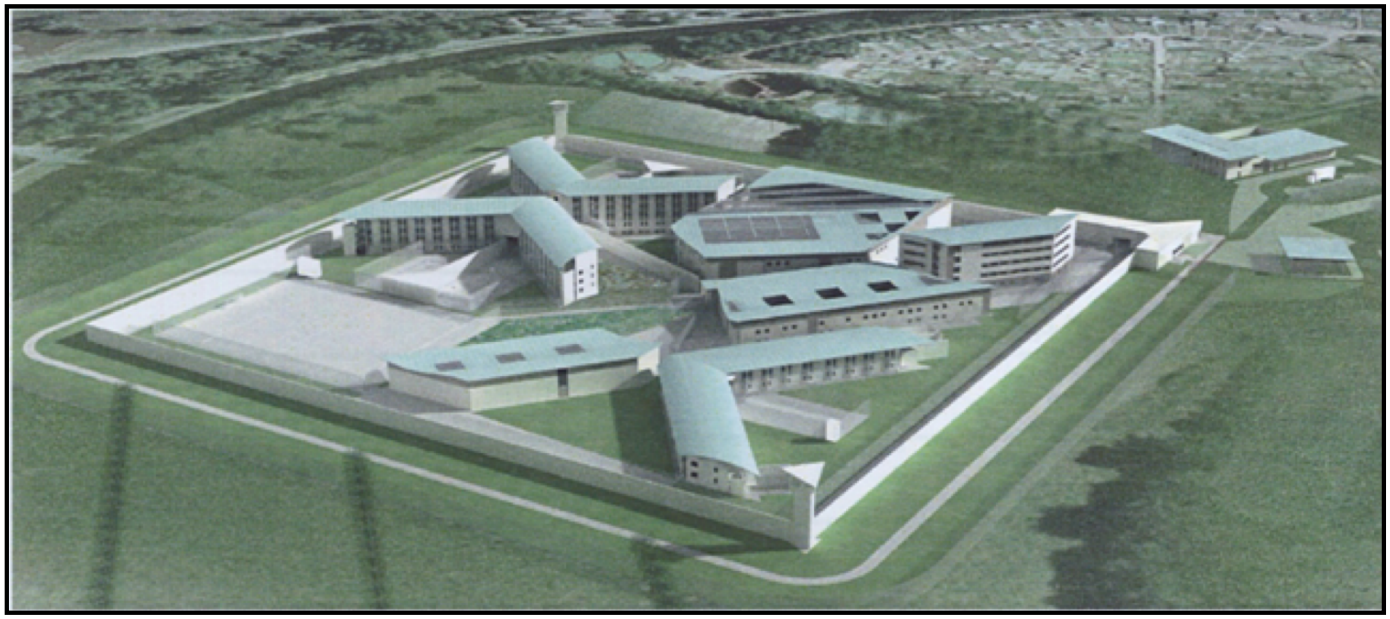
Zone 2 : tests layout



Zone 2 : depth of the marls (meters)

GEOTECHNICAL CAMPAIGN BY COUPLING :

Penitential Center - Roanne (mission G 2 phase 1 – project management)

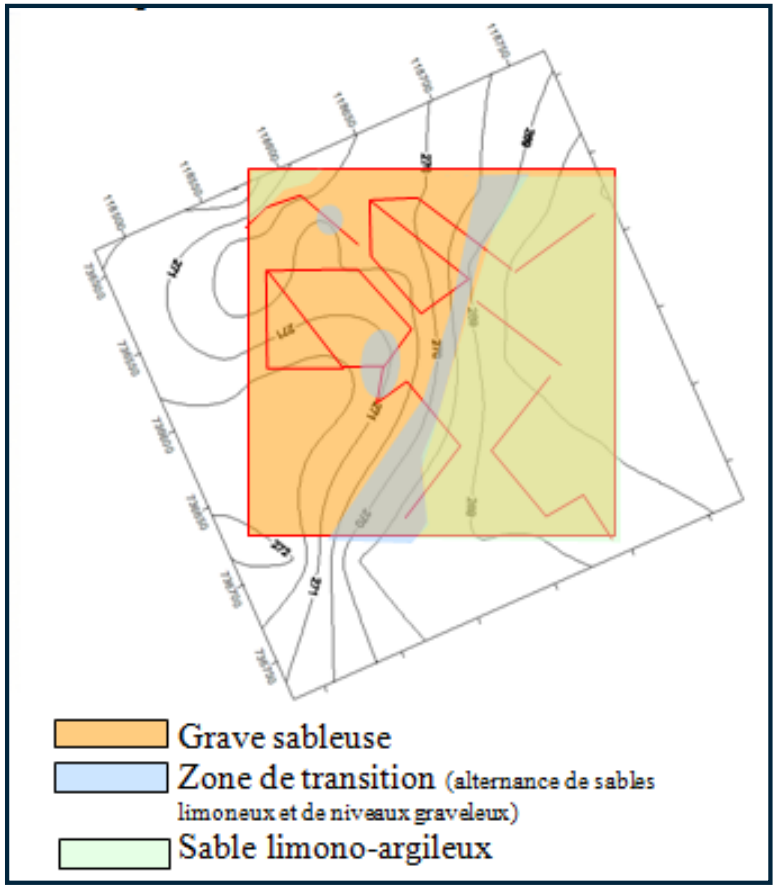


- Electric pannels: 12 pannels – 220 linear meters
- Pressuremeter tests: 80 linear meters
- Destructive soundings: 84 linear meters
- PANDA® tests : 90 linear meters

GEOTECHNICAL CAMPAIGN BY COUPLING :

Geological mapping of the penitential center

- Earthwork optimization
- Dredge material recycling
- Material supply planning
- Optimization of foundation systems
- Paving optimization



INDIVIDUAL HOUSES : *MISSION G2 AVP (NF P 94 -500)* :



Aim of the investigation campaign :

- To know the geology of the site
- To determine the resistance of the land
- To check the water sensitivity of the soil
- To give the characteristics of the foundations of the project

Investigations :

- 2 tests with a 63 mm Auger - 5 m depth
- 2 tests with the PANDA® at 5 meters depth max or until reaching refusal
- Lab tests (water content, grain size distribution, clay content / plasticity)

Report will present :

- The results and interpretation of the tests
- The constructional features
- The specific conditions to carry out the works.



GEOTECHNICAL DIAGNOSIS : FOUNDATIONS

To identify if the problems come from the foundation of the structure. Solutions for the reinforcement of the foundation / pavings





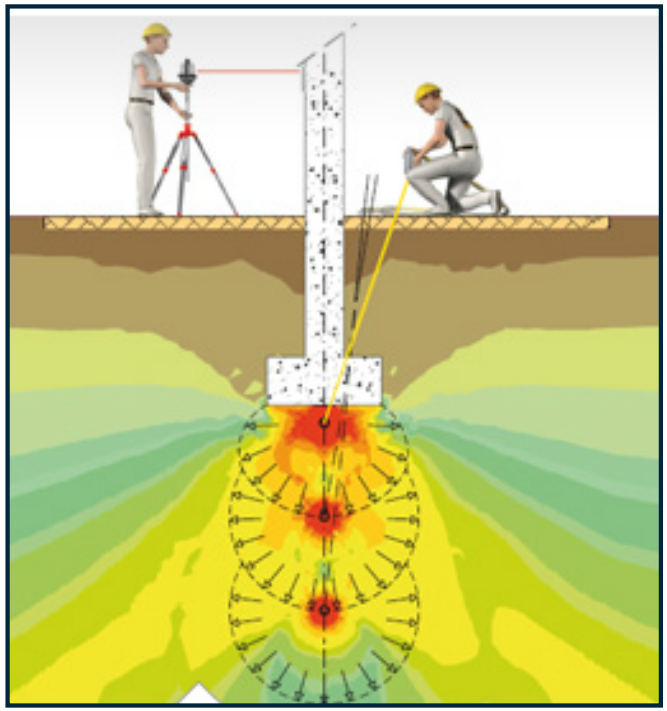
Investigations

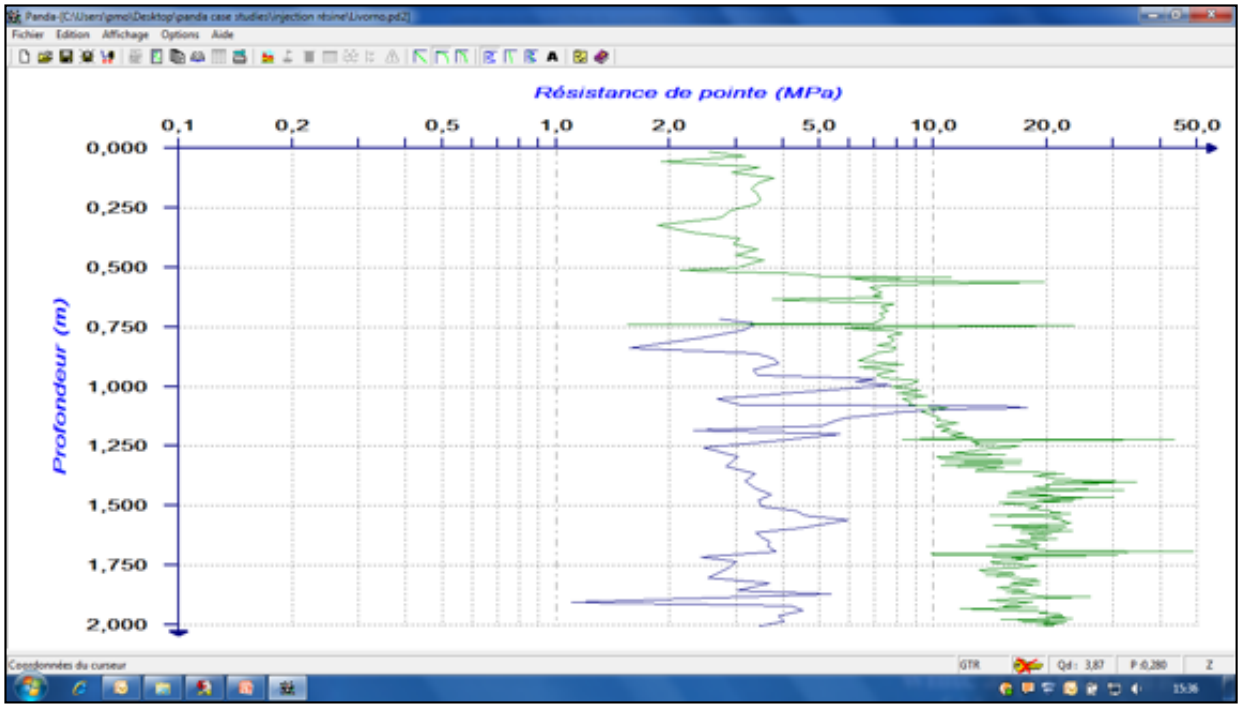
- Test with penetrometers and pressumeters : bearing capacity of the soil
- Soundings (auger,…) : geology and core sampling
- Laboratory analysis
- Foundations : depth of the existing

RESIN INJECTION :

Ground strenghtening below foundations with the injection of geopolymer expansive Resins

Houses in Livorno (Italy) – Qd before and after injection

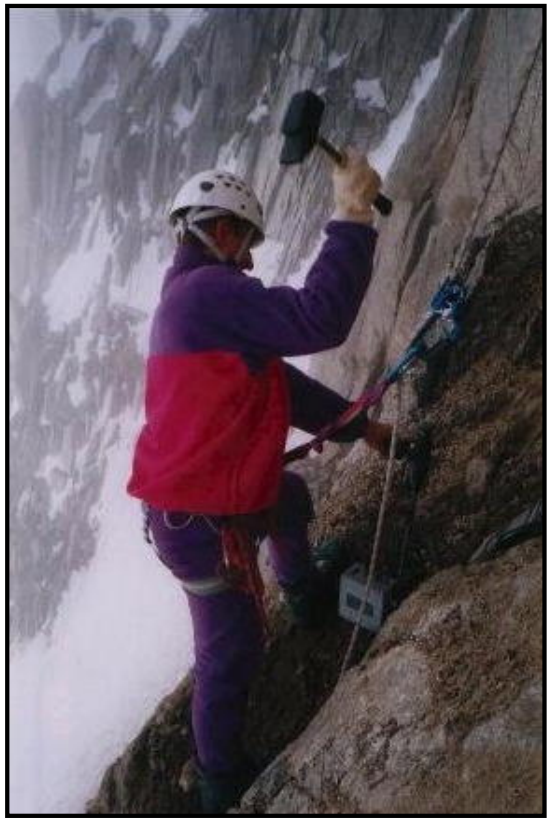




DETERMINATION OF THE THICKNESS OF FRACTURES:

Mont Blanc (Cominges shelter)

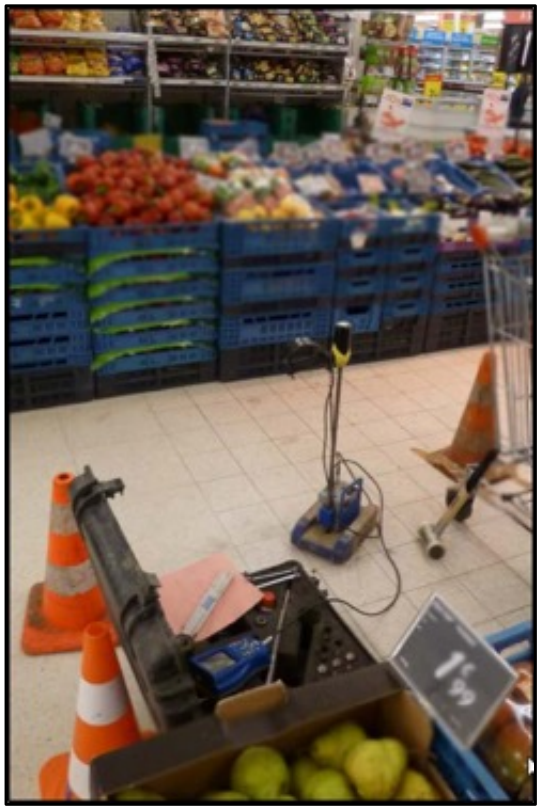




BEARING CAPACITY DIAGNOSIS (BELGIUM)

Within a retail space







BEARING CAPACITY :

Bottom of a trench





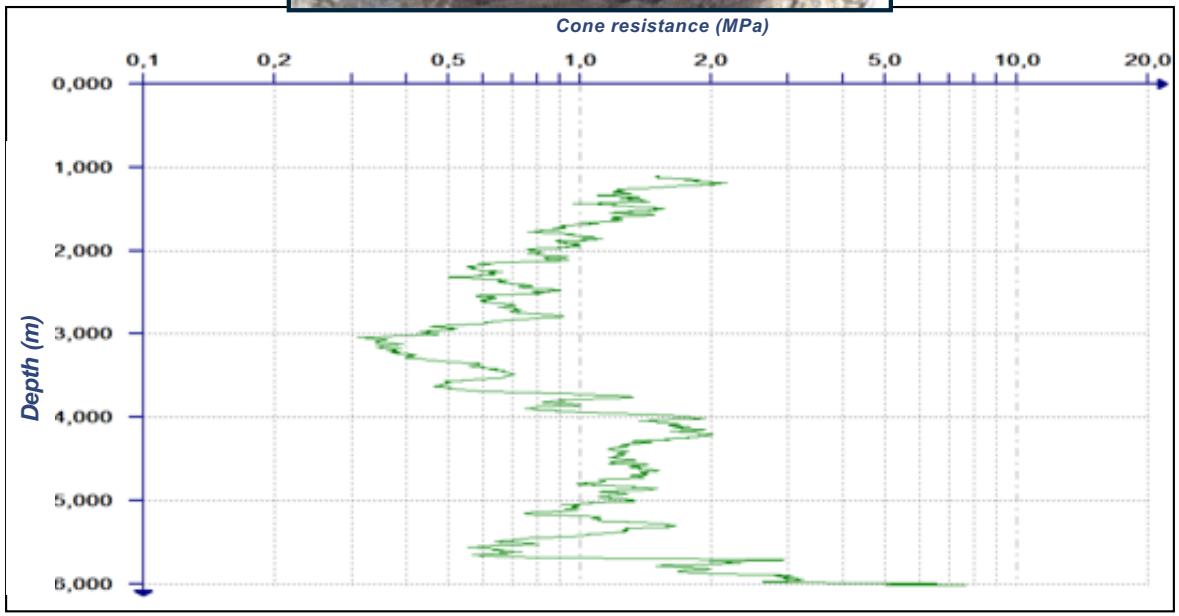
BEARING CAPACITY :

Pylon pad footing









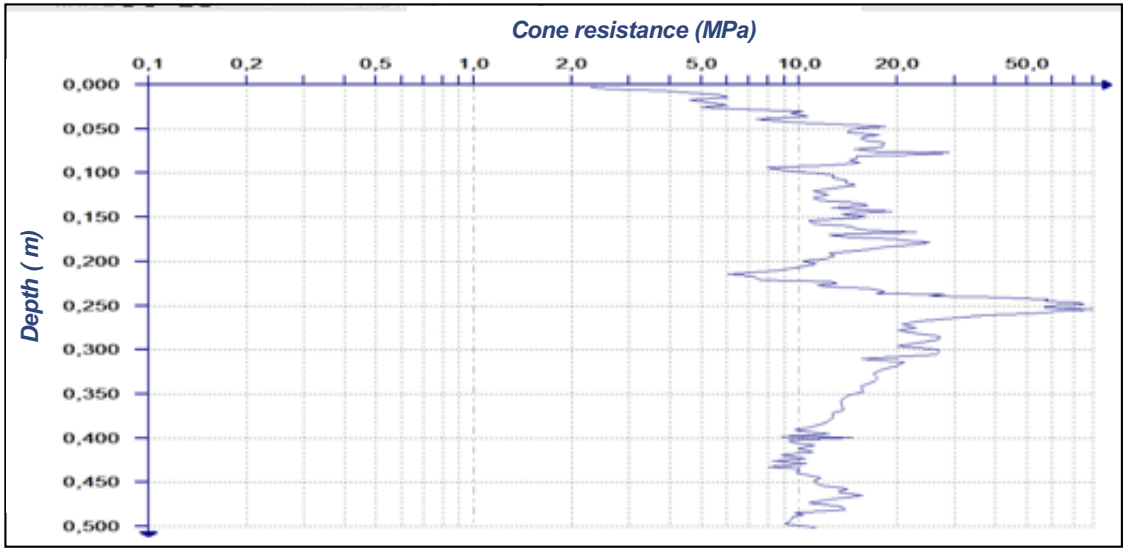
BEARING CAPACITY :

Mirador slope - lift









THE LACK OF GROUND DECALCIFICATION UNDERNEATH BORED PILES' BEDROCK (BELGIUM)



Depth 15 m

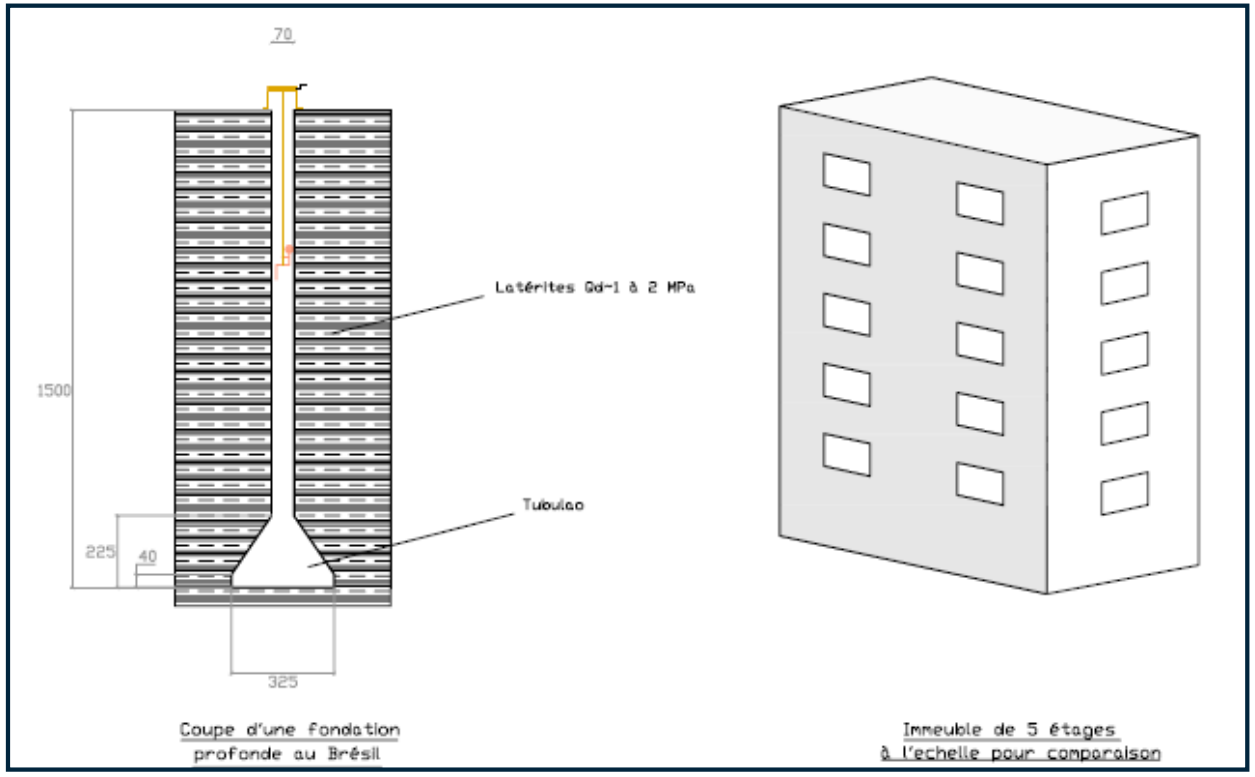


Tests carried out at the bottom of the bored pile



DEEP FOUNDATIONS - TUBULÃO :

Tubulão (brazilian method) are piles drilled to a depth where the ground has been less modified by climatic conditions.
A worker goes to the bottom of the pile and digs into the ground to create a hollow cavity



DEEP FOUNDATIONS - TUBULÃO :

A rope is used to go down a 15 m deep pile (diameter is 70 cm). 1 lamp, temperature is 50 degrees celsius, air saturated with water. 2 hoses used (for oxygene and to blow fresh air down the pile).





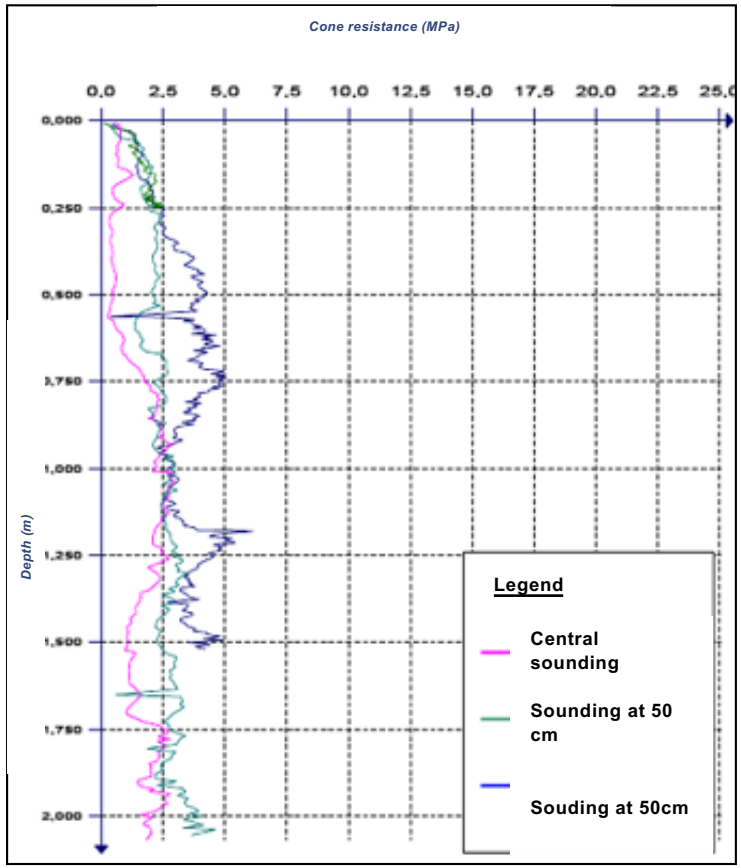


560 housings - Emplavi : General contractor - Embre : foundations

DEEP FOUNDATIONS - TUBULÃO :

Checking bearing capacity- 3 tests : 1 in the middle, 2 at about 50 cm.





PANDA® CASE STUDIES

RESTRICTED & CONFINED ACCESS SITES :







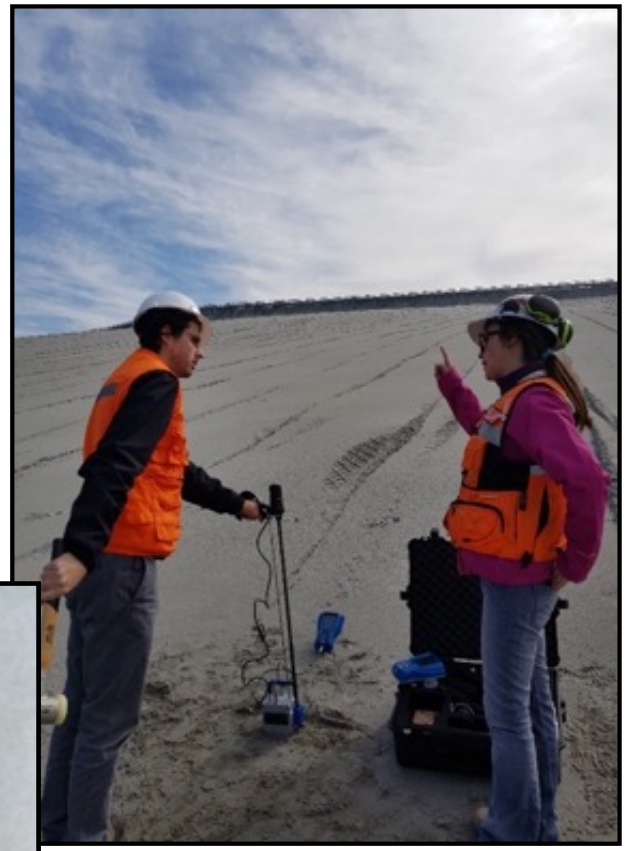


ANGLED SOUNDINGS – SLOPES – HORIZONTAL TO VERTICAL TESTS:









TECHNICAL LANDFILL CENTER - LANDFILL :

Compaction control







SNOWPACK DIAGNOSIS:

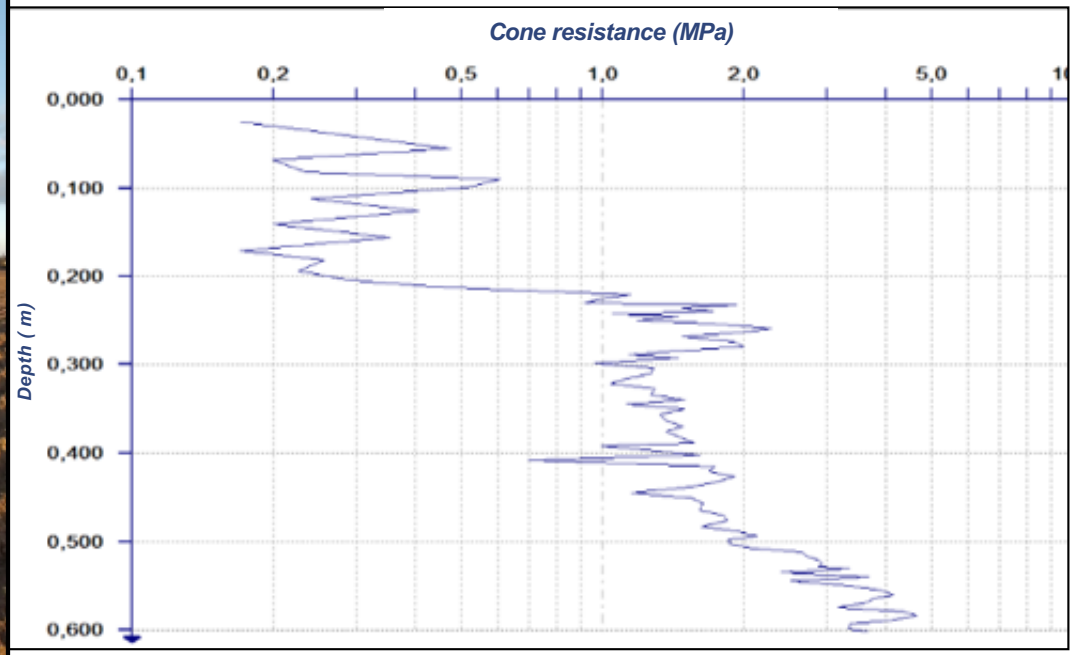
Determination of the layers thickness





CULTIVABLE FIELDS - PLOUGHING DEPTH INFLUENCE :



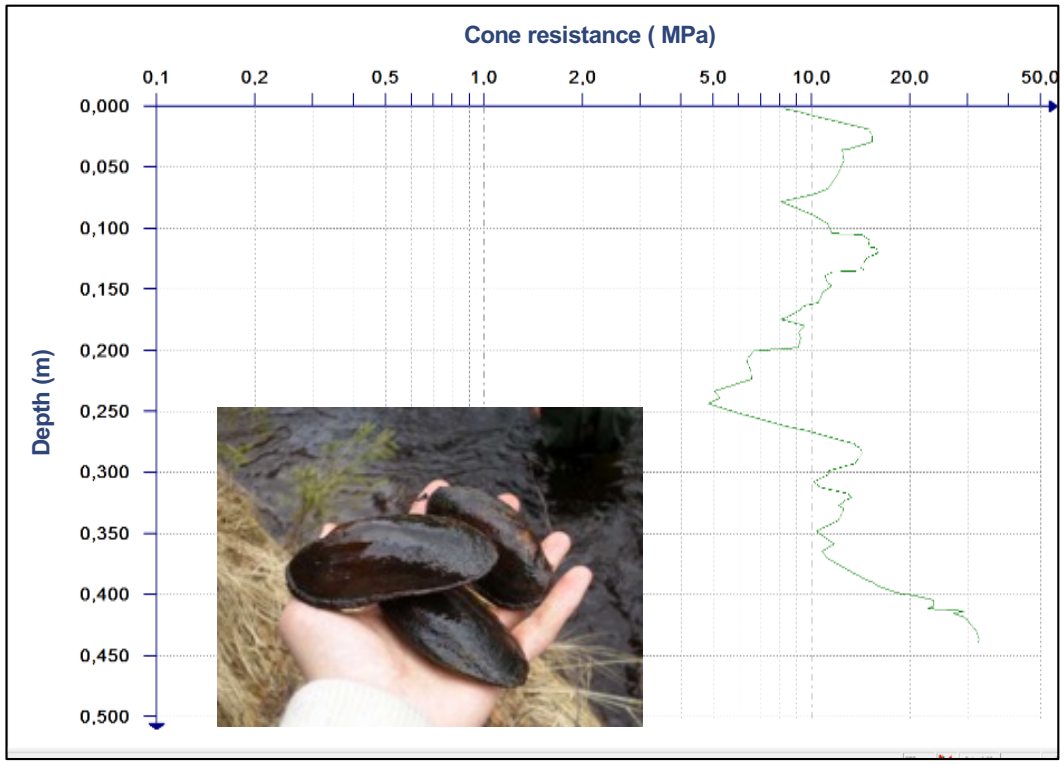


FRESHWATER MUSSELS

Panda® tests in a creek of approximately 40cm deep.

Aim: to make sure the cone resistances were not too high and the gravels were not too tight together so the freshwater pearls mussels can develop.





COMPACTION CONTROL – MINE TAILINGS :

The processing of copper in Chile produces wastes called relaves which are made of fines, water and sand. The sandy elements of these tailings is used to build dikes called tranques retaining the liquid part of these mine tailings.

Structures sensitive to liquefaction and stability issues caused by the nature of stored materials and the seismic activity in the country.



COMPACTION AND SLOPE STABILITY CONTROL – MINE TAILINGS :

Determining relations between Panda® resistance (Qd) / density
Several tranques checked with the PANDA ® by the Geotecnic group at PUCV

Test beds





Material characterization – Shear tests



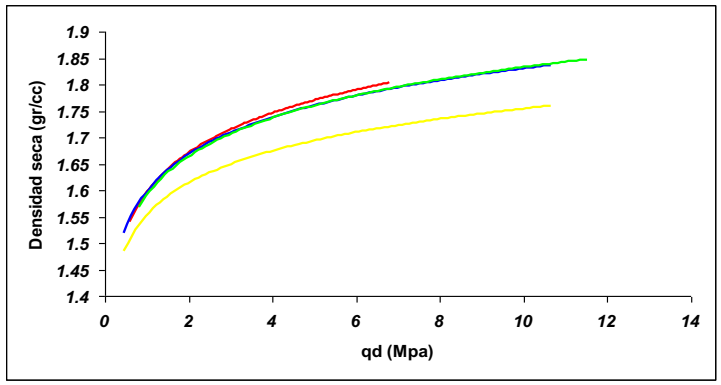


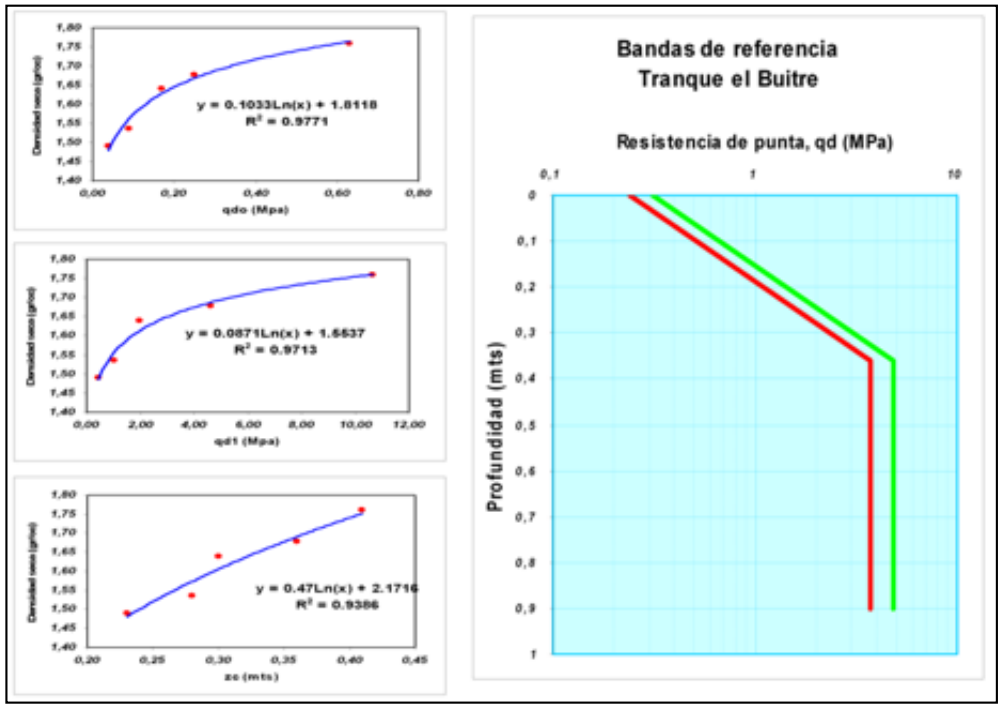
COMPACTION AND SLOPE STABILITY CONTROL – MINE TAILINGS :

Laboratory calibration – Building qd-γd curves







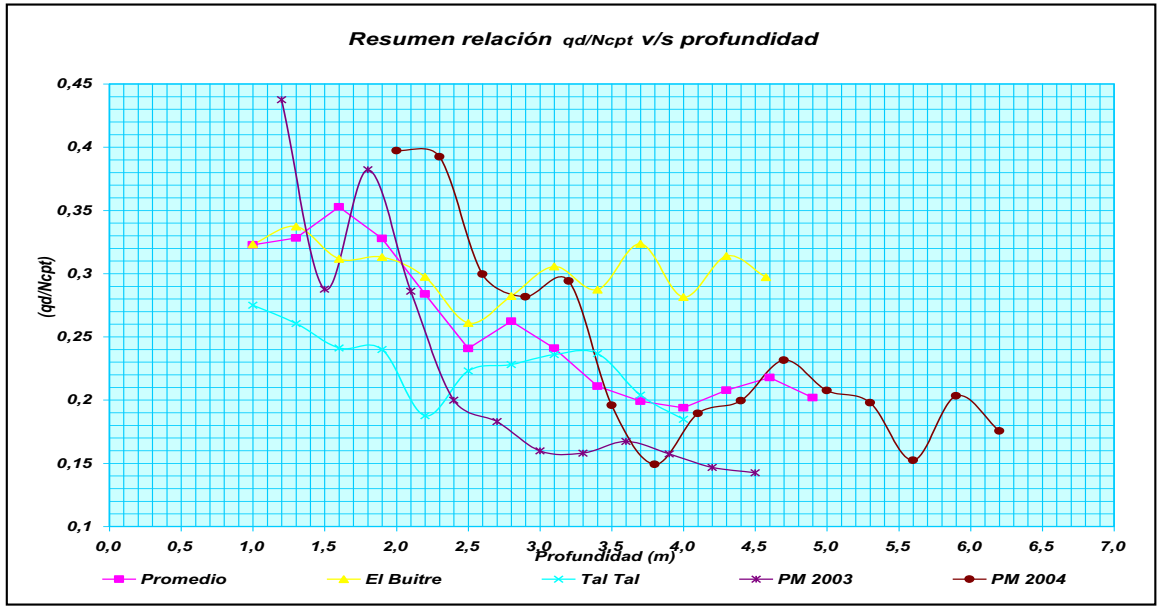


COMPACTION AND SLOPE STABILITY CONTROL – MINE TAILINGS :

Comparative tests between sand cone / DPSH / DCP / SPT.

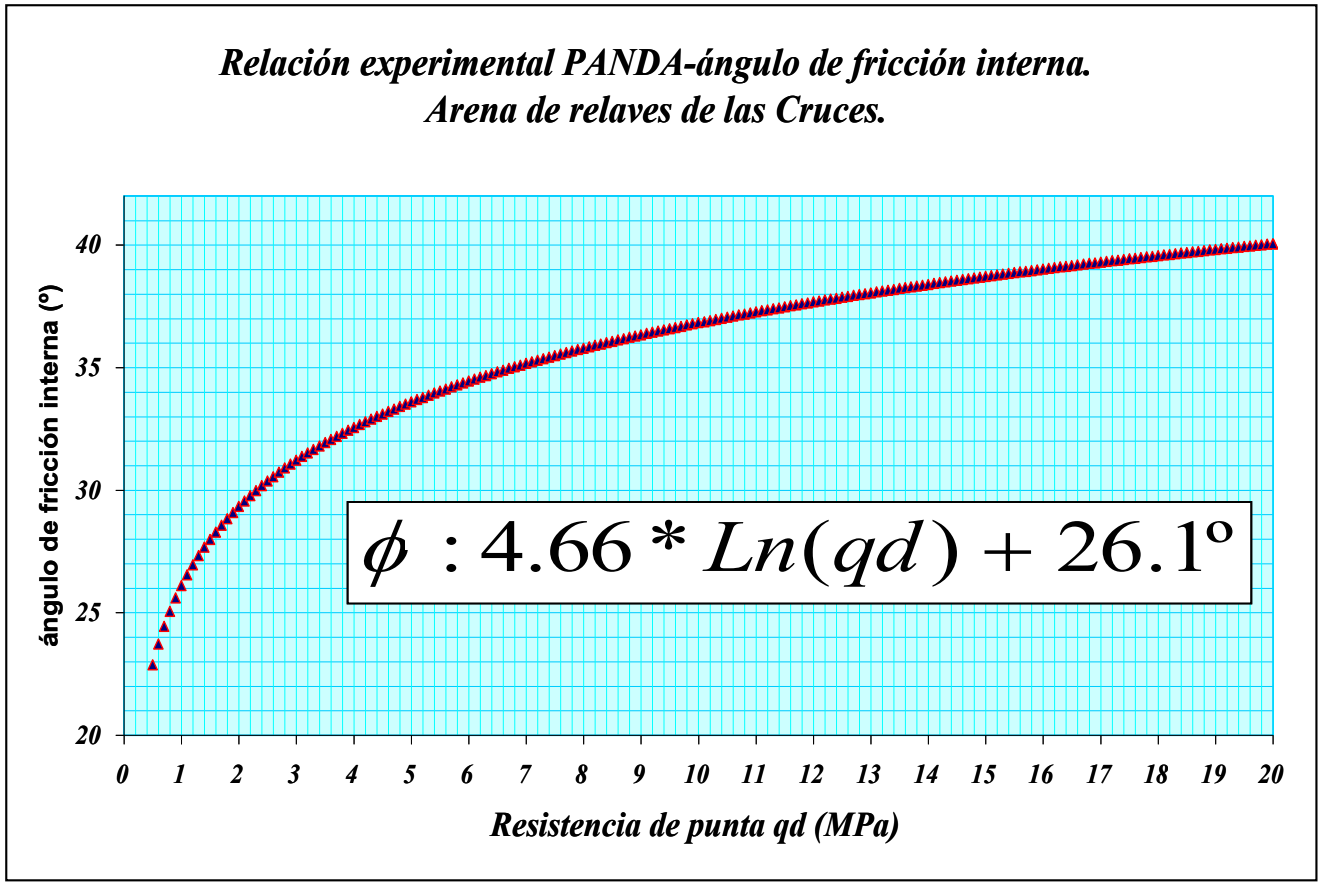






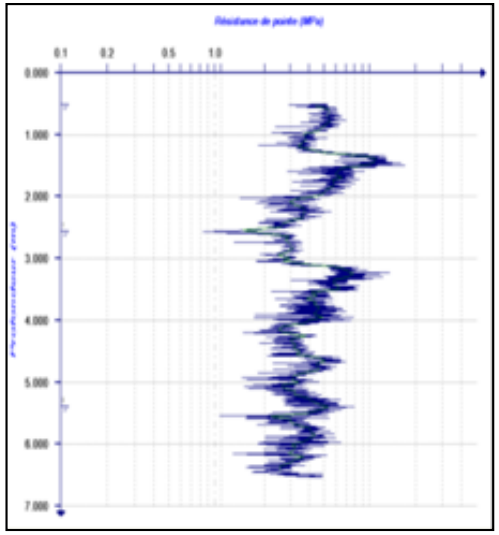
COMPACTION AND SLOPE STABILITY CONTROL – MINING TAILINGS :

Relation qd / friction angle ϕ'



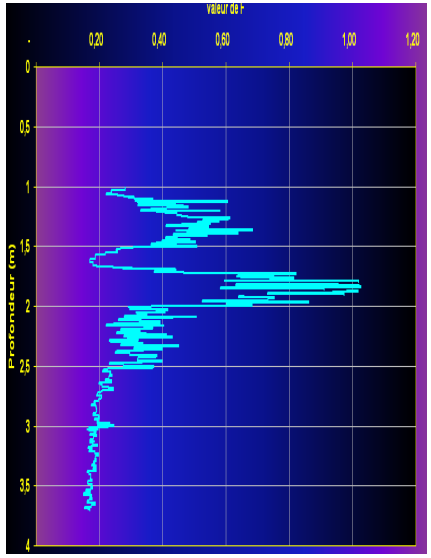
COMPACTION AND SLOPE STABILITY CONTROL – MINING TAILINGS :

Stratigraphy of dikes up to 7 m and determination of liquefaction potential



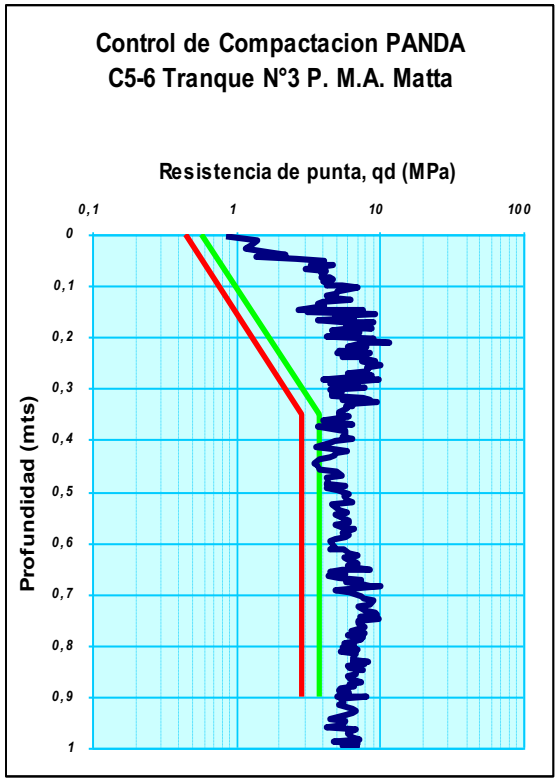


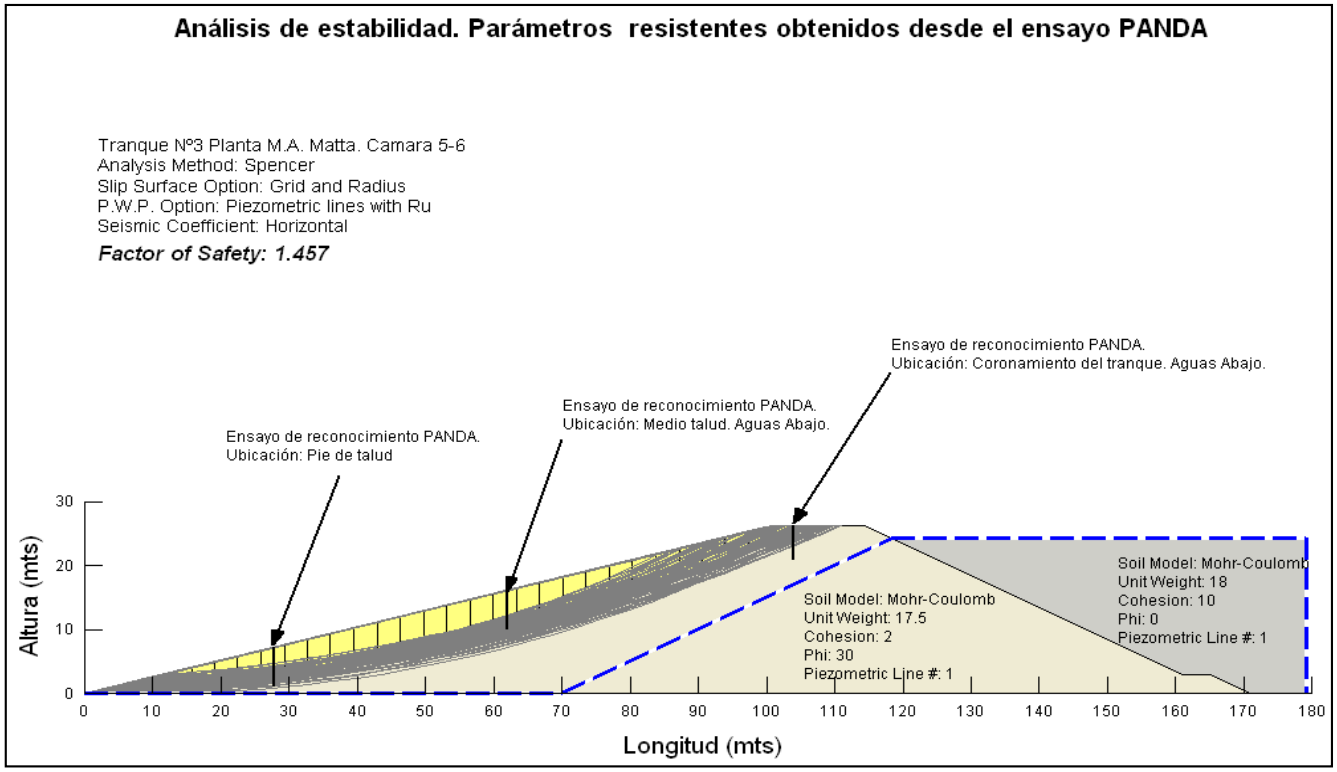




COMPACTION AND SLOPE STABILITY CONTROL – MINING TAILINGS :

Compaction control - Estimation of the stability of slopes





GEOTECHNICAL DIAGNOSIS - SLOPE STABILITY :







LANDSLIDE IN MEXICO

La Pintada, municipality of Atoyac, Guerrero, Mexico – September 2017





LANDSLIDE IN MEXICO

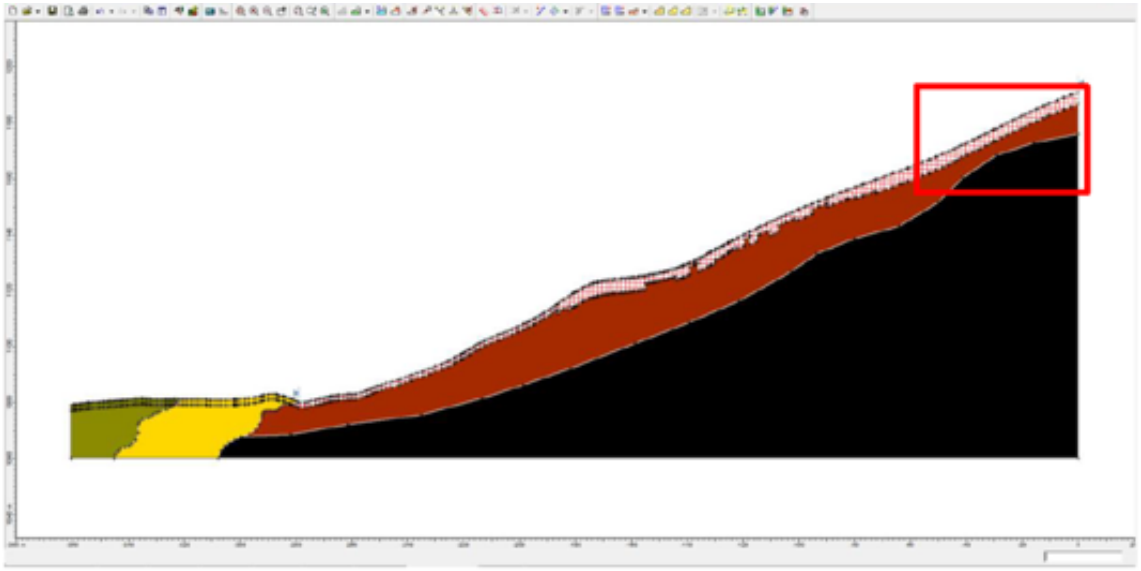
PANDA® tests geolocalisation

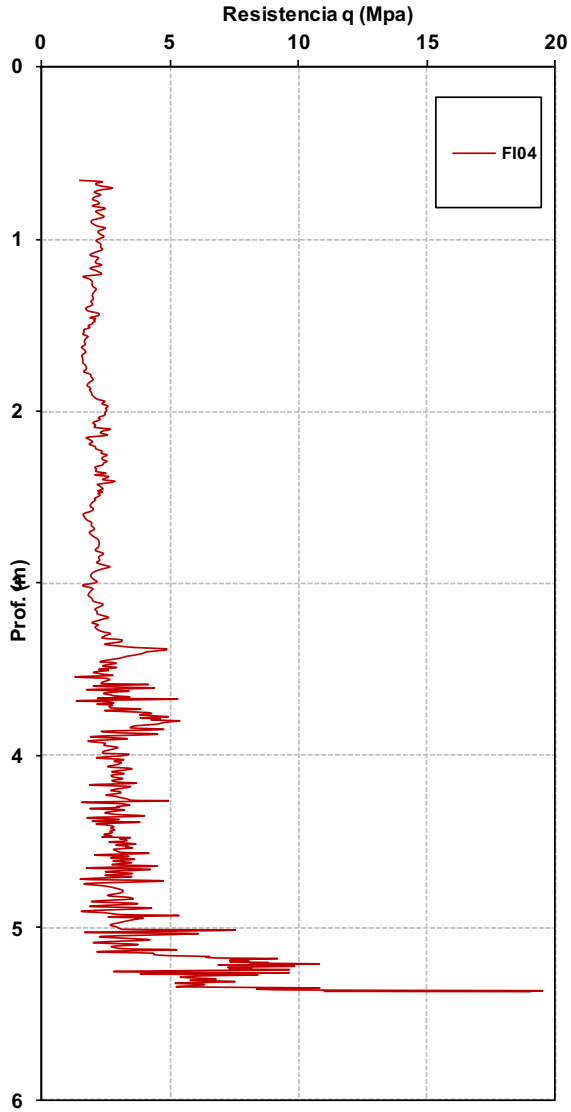




LANDSLIDE IN MEXICO

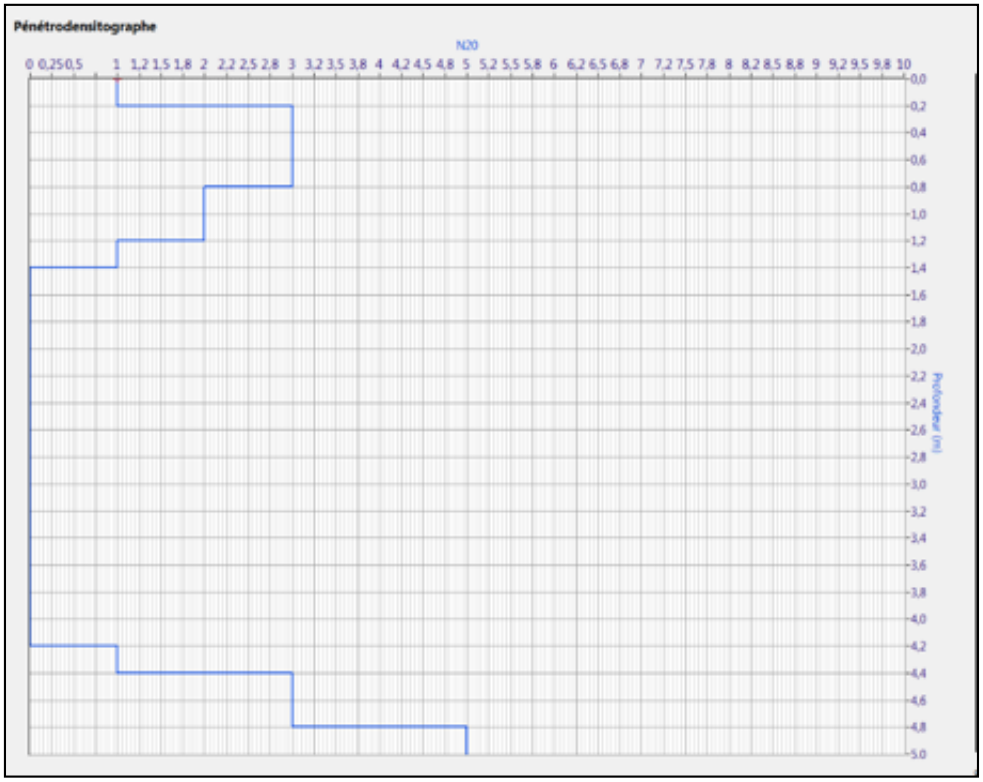
Assess a potential landslide on a ridge

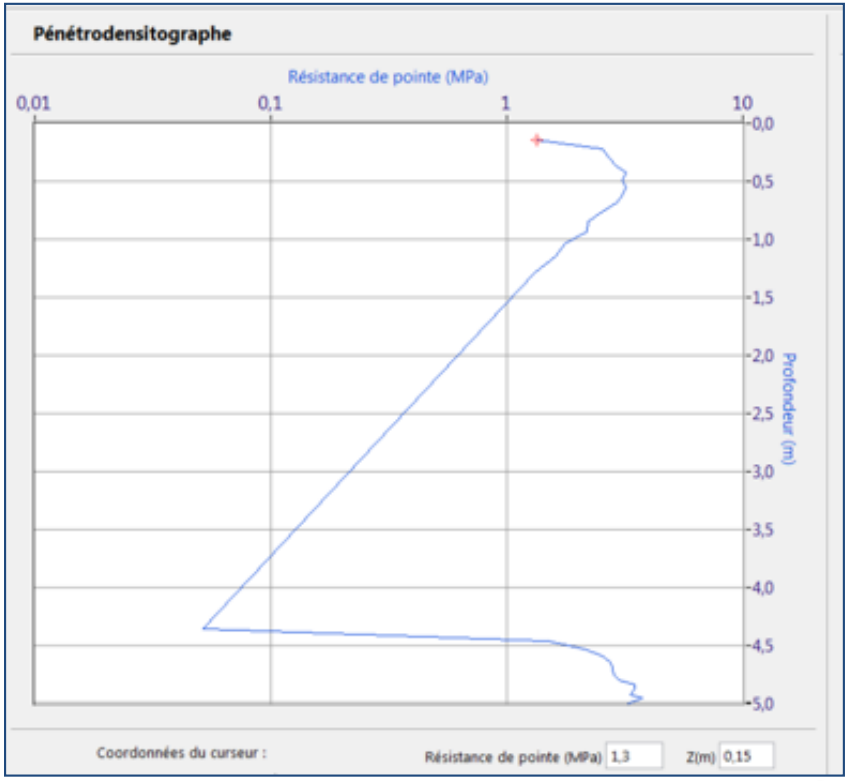




PANDA® VARIABLE ENERGY INTEREST IN LOW RESISTANCE SOILS :

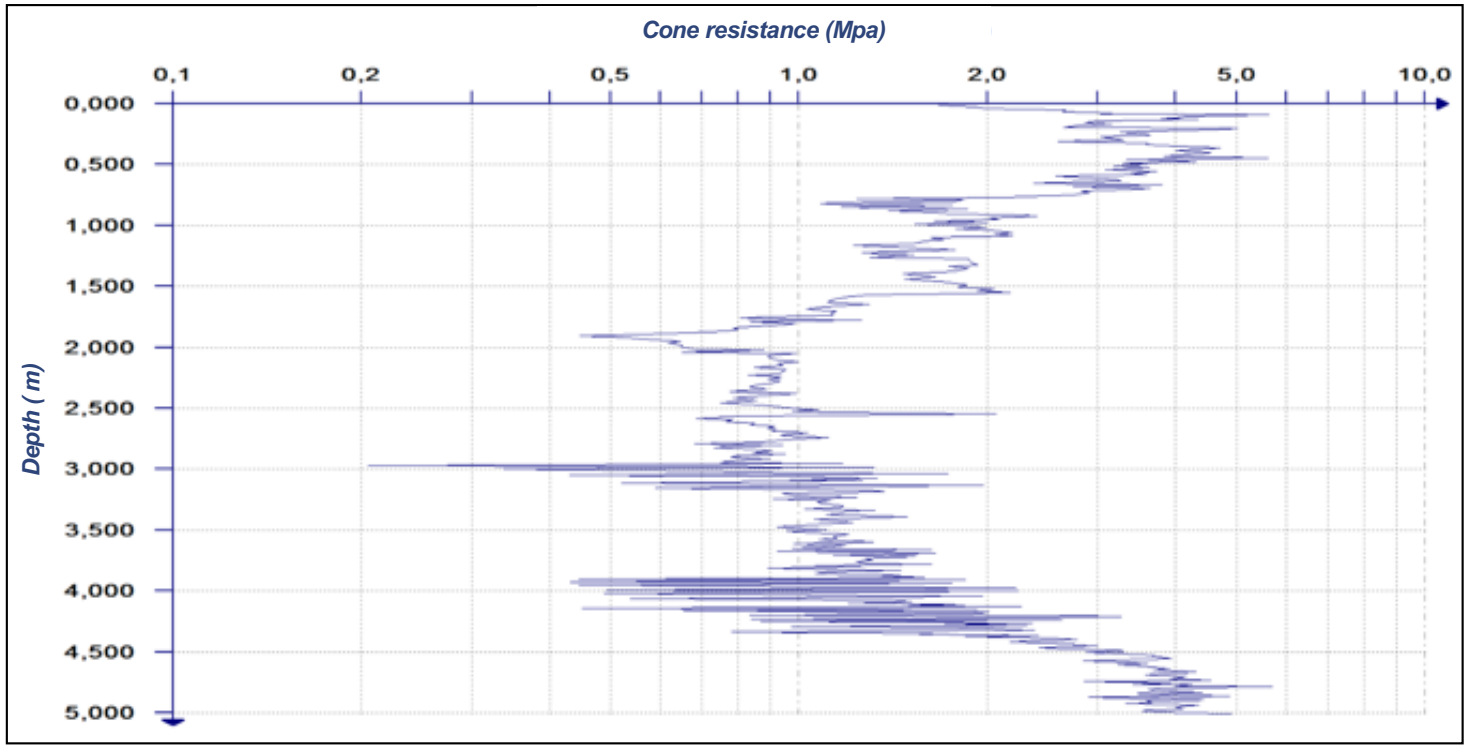
Very soft soil (Zénith d'Auvergne - France) : 3 m static dept without hammering
with heavy penetrometer (DPSH-B)





PANDA® VARIABLE ENERGY INTEREST IN LOW RESISTANCE SOILS :

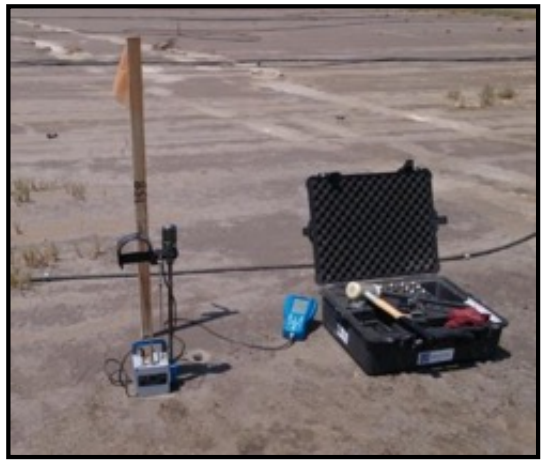
Very soft soil (Zénith d'Auvergne - France) : test PANDA®
388 measures with Panda® / 28 measures with Grizzly (finesse, precision,..)



CHARACTERIZATION OF THE FORMER LAKE OF TEXCOCO (MEXICO)

More than 300 Panda® tests on several meters depth were done in less than a year.

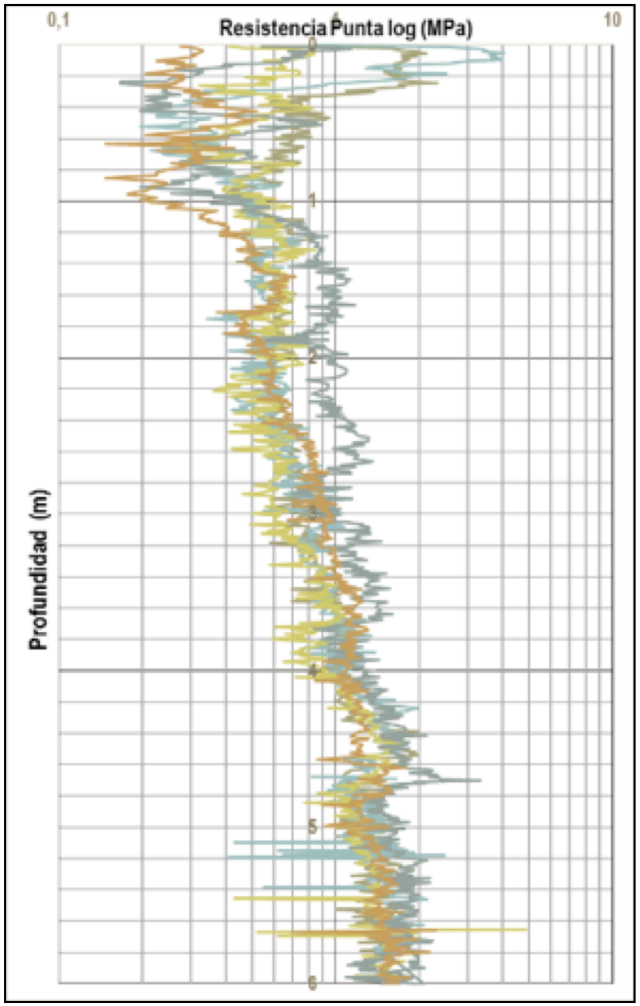




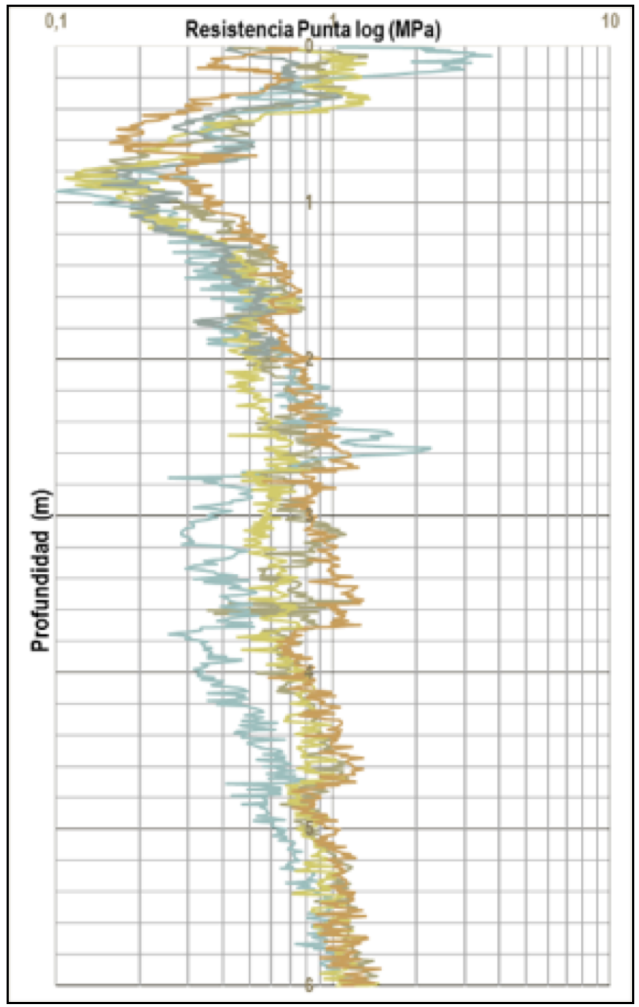


GEOSOL, s.a.de c.v.

CHARACTERIZATION OF THE FORMER LAKE OF TEXCOCO (MEXICO)







THE NEW INTERNATIONAL AIRPORT OF MEXICO (NAICM)

Construction of 3 runways of 5 km long for 2019 on a new site (former Texcoco lake, gradually drought out over the centuries).

- A superficial thin layer of silty and clay material subject to several saturation cycles and drying.
- A clay layer with high water content (often > 400%), very compressible on 20 to 30 meters.
- Some areas are flooded during rainy season . (groundwater table very close to the top).



THE NEW INTERNATIONAL AIRPORT OF MEXICO (NAICM)

Geotechnical investigation program : continuous core sampling, CPT, CPTu, SPT, Panda®, dilatometer, piezometer, geostatistics

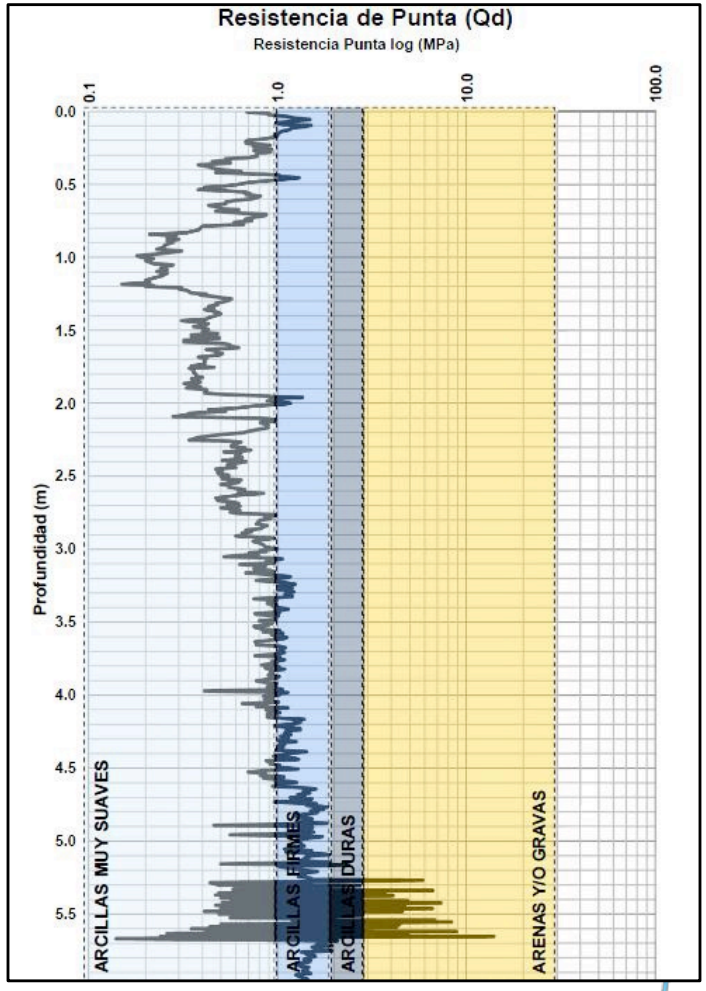
PANDA® 's duty :

- Determine the thickness and the characterization of the superficial layer (70cm) for the access of working site equipment and to design roads and runways.

- Detect some important superficials geotechnicals anomalies (old canals, old dams, material storage areas, etc.).

Ubicación	Cantidad	Profundidad de exploración
Pistas plataformas y calles de rodaje	340	6 m
Área de rellenos	23	Entre 2.5 y 6 m
Tramos de Prueba	72	6 m

435 PANDA® tests carried out at 6 m deep



AIRBUS A400M – CBR MEASUREMENTS

Construction of a 1600 meters unpaved runway in Woodbridge (UK) for the A400M : bentonite and sand material mixture with daily irrigation to obtain a CBR <6.

- Demonstrating the A400M lands and takes off without issues (test with load of 115 tons).
- Guarantee a low bearing capacity (CBR) on an airstrip





AIRBUS A400M – CBR MEASUREMENTS

Airbus protocol for the A400M :

- Investigation depth of 60cm
- CBR every 10cm and average CBR for 60cm





AVIATION RUNWAYS EXPERTISE – IVORY COAST :

Objectives of the 25° RGA (French Army) in support of the UNOCI in the use of its aviation capacity.

- Control the grounds practicability
- Renew their homologations
- Support / advise the local authority on managing their airport infrastructures.



ONUCI

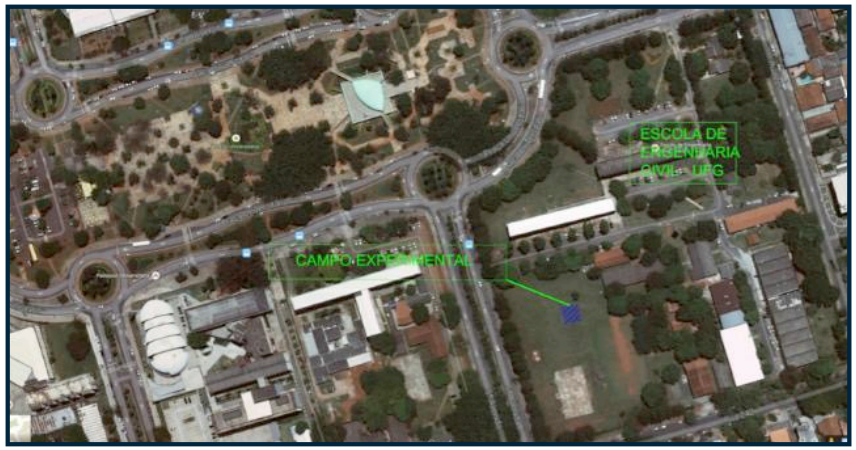




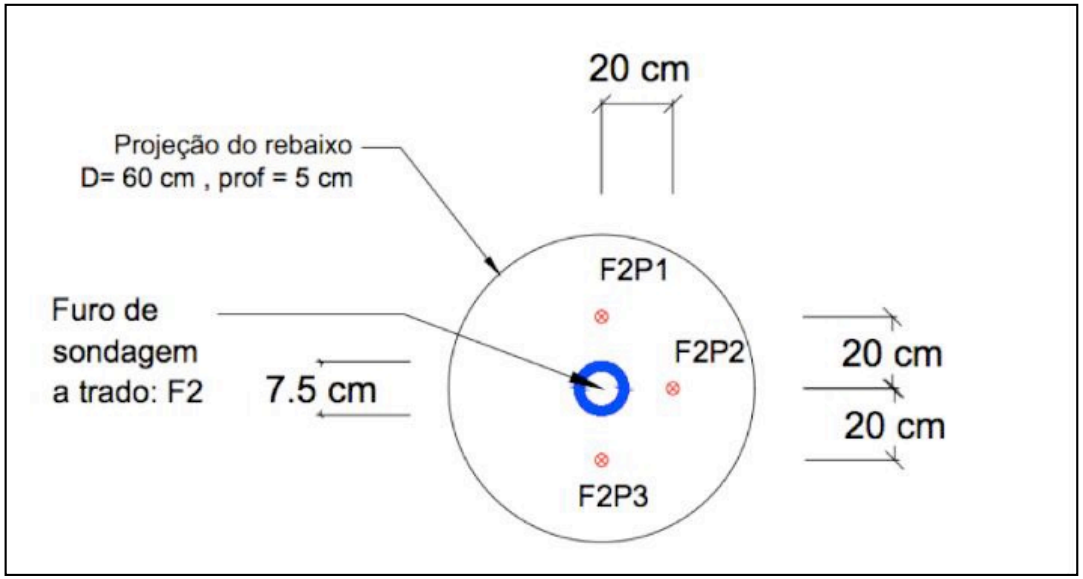
12 acknowledged runways over 3 weeks, 20 hours of flights, 1500 km of road journey

COMPARATIVE PANDA® / WATER CONTENT (W%) – BRAZIL :

Universidade Federal de Goiás (UFG) de Goiânia (Goias)
3 Panda® tests at 5 m around 3 drillings to measure water content profiles

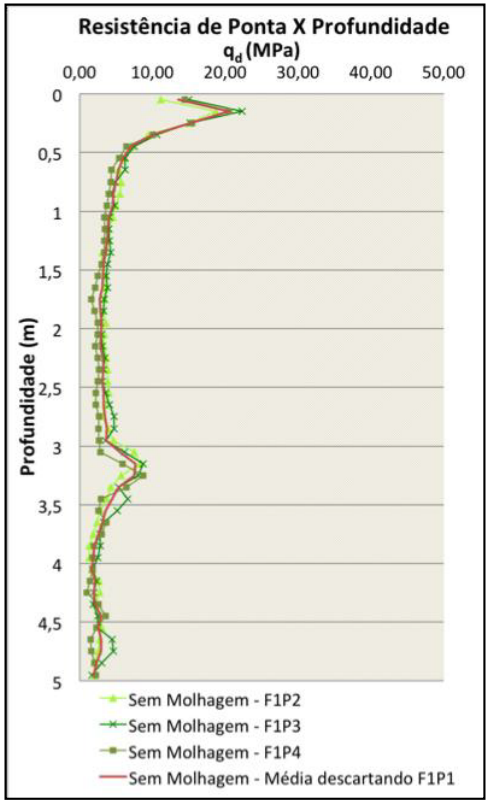


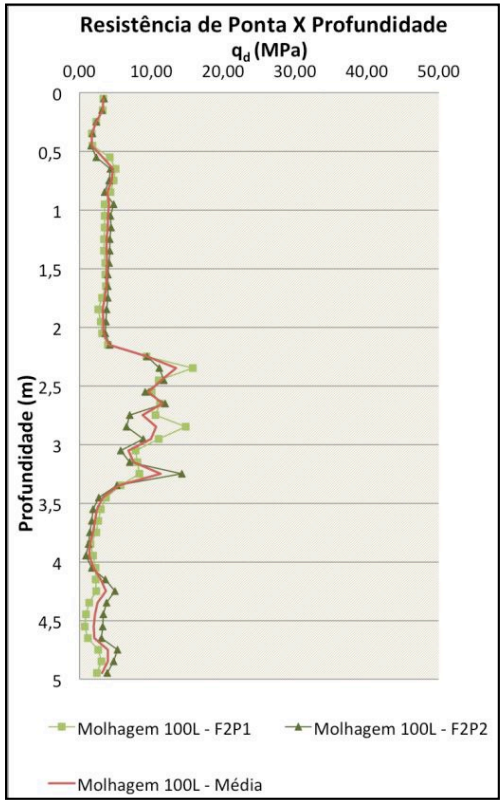
Campus Colemar Natal and Silva

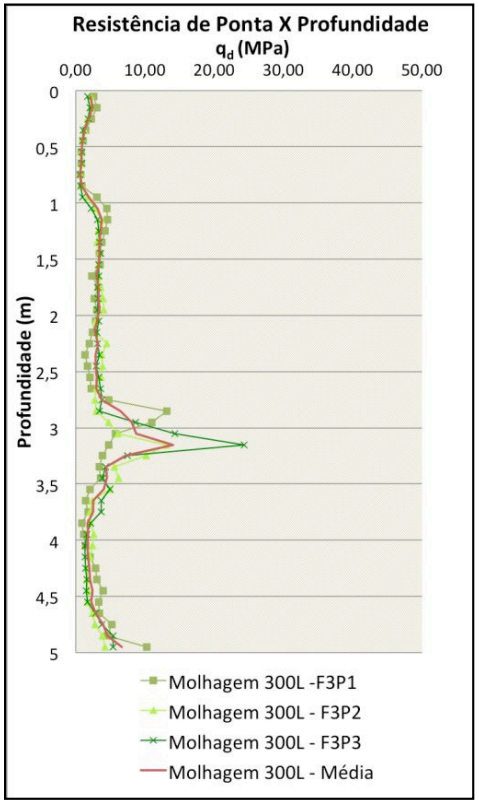


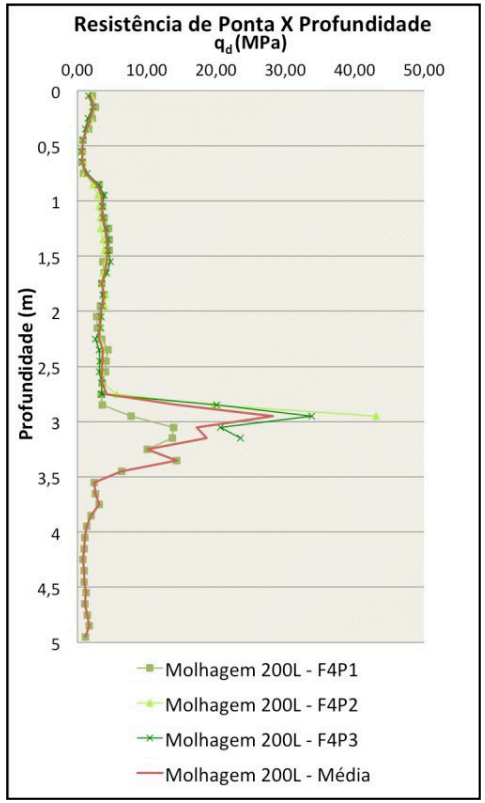
COMPARATIVE PANDA® / WATER CONTENT (W%) – BRAZIL :

Good results repeatability, capacity to detect resistance (qd) changing



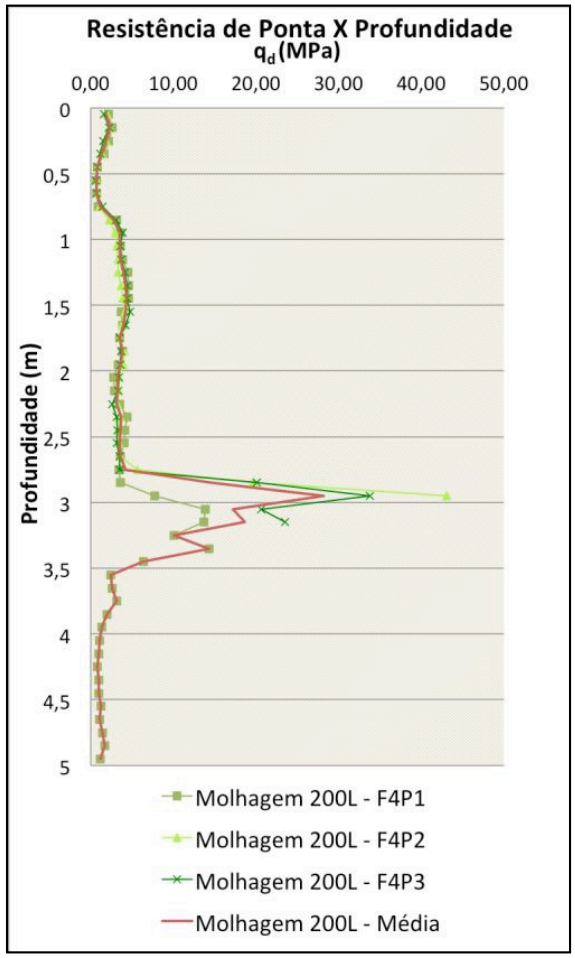


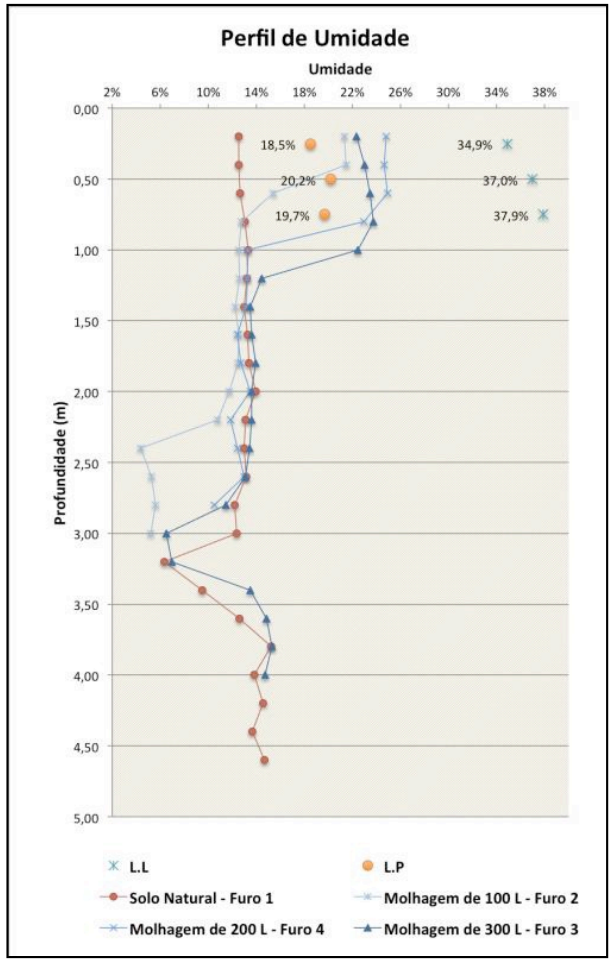




COMPARATIVE PANDA® / WATER CONTENT (W%) – BRAZIL :

Water content profile at 5 m. Good correlation between qd and w%





CORRELATION PANDA® / SPT (BRAZIL) :

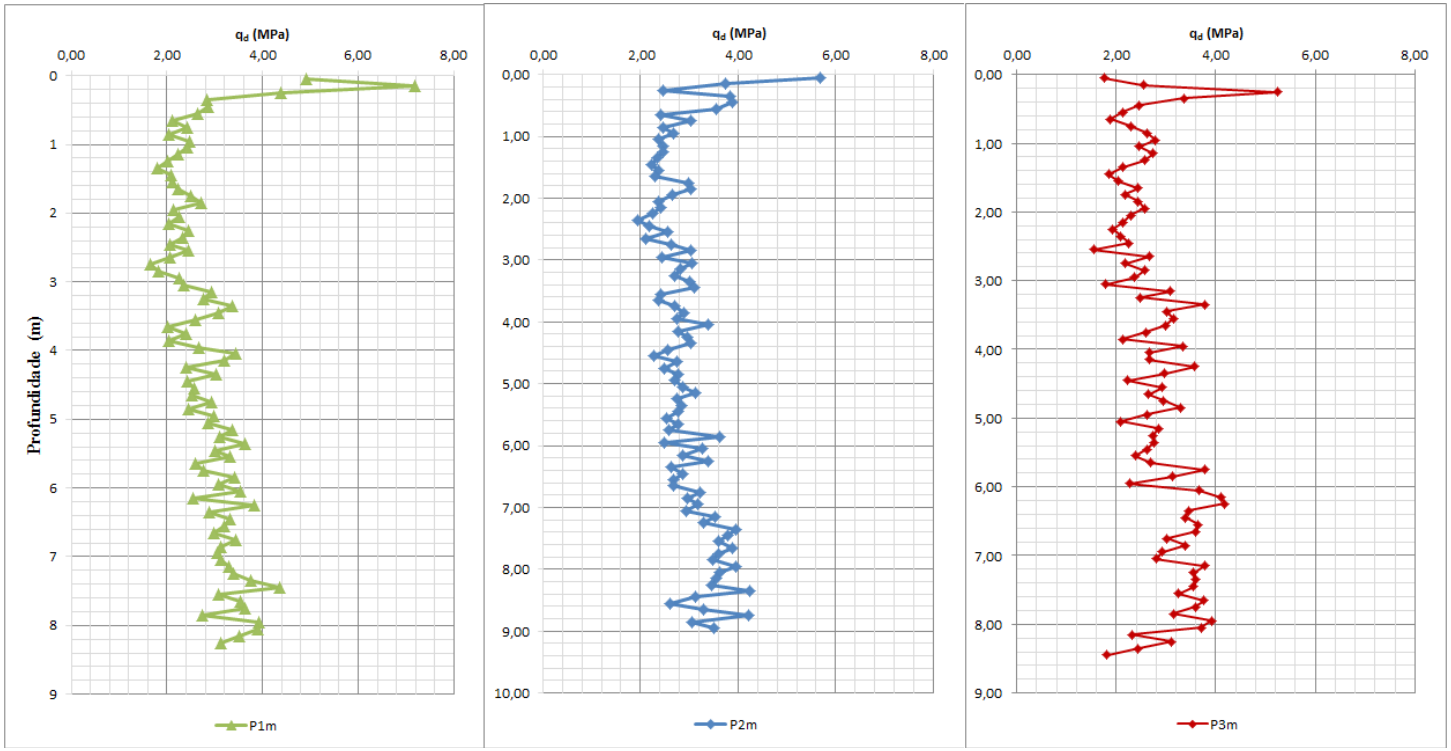
Dam (Ribeirão João Leite) in tropical clay soil compacted upstreamed Goiânia city





CORRELATION PANDA® / SPT (BRAZIL) :

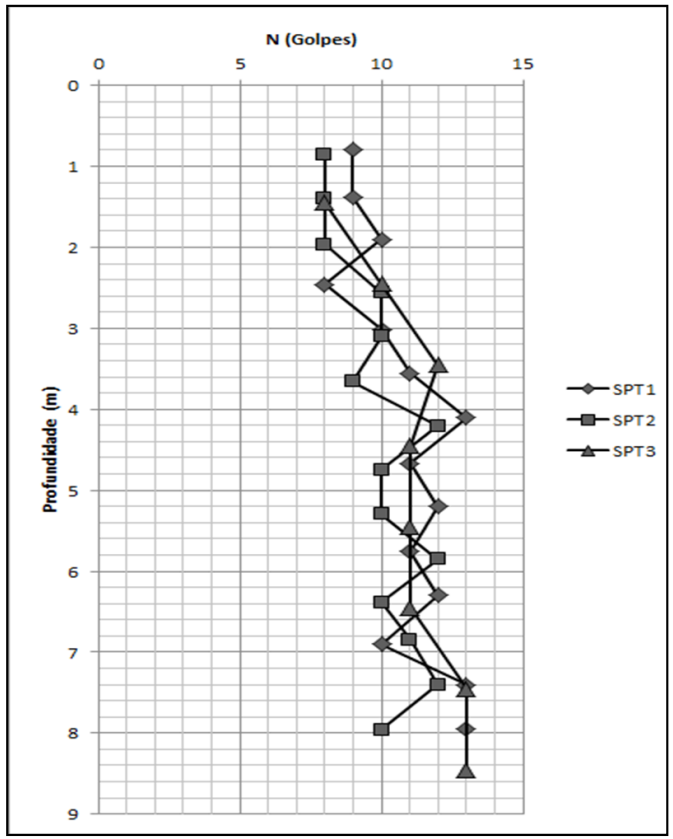
3 PANDA® tests for each SPT test (test at 9 m).

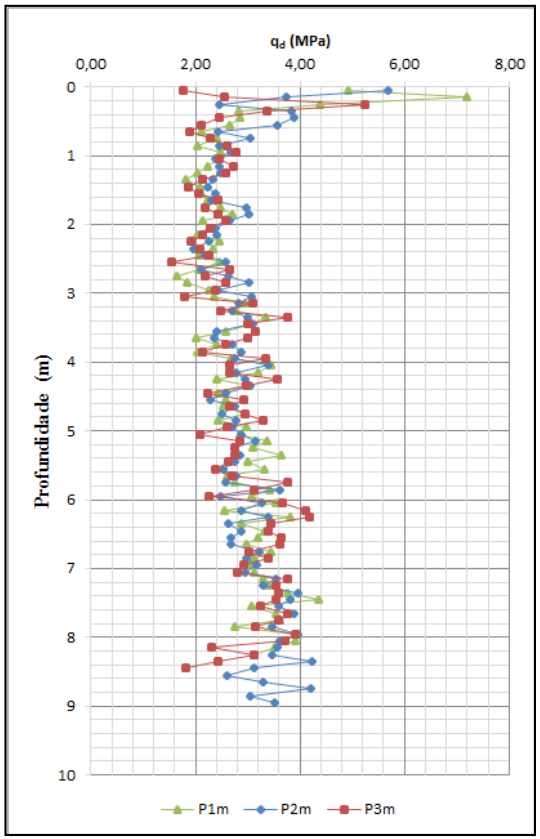


The PANDA ® tests show the compacted enbankment relative homogeneity, with precision, repeatability and reliability.

CORRELATION PANDA® / SPT (BRAZIL) :

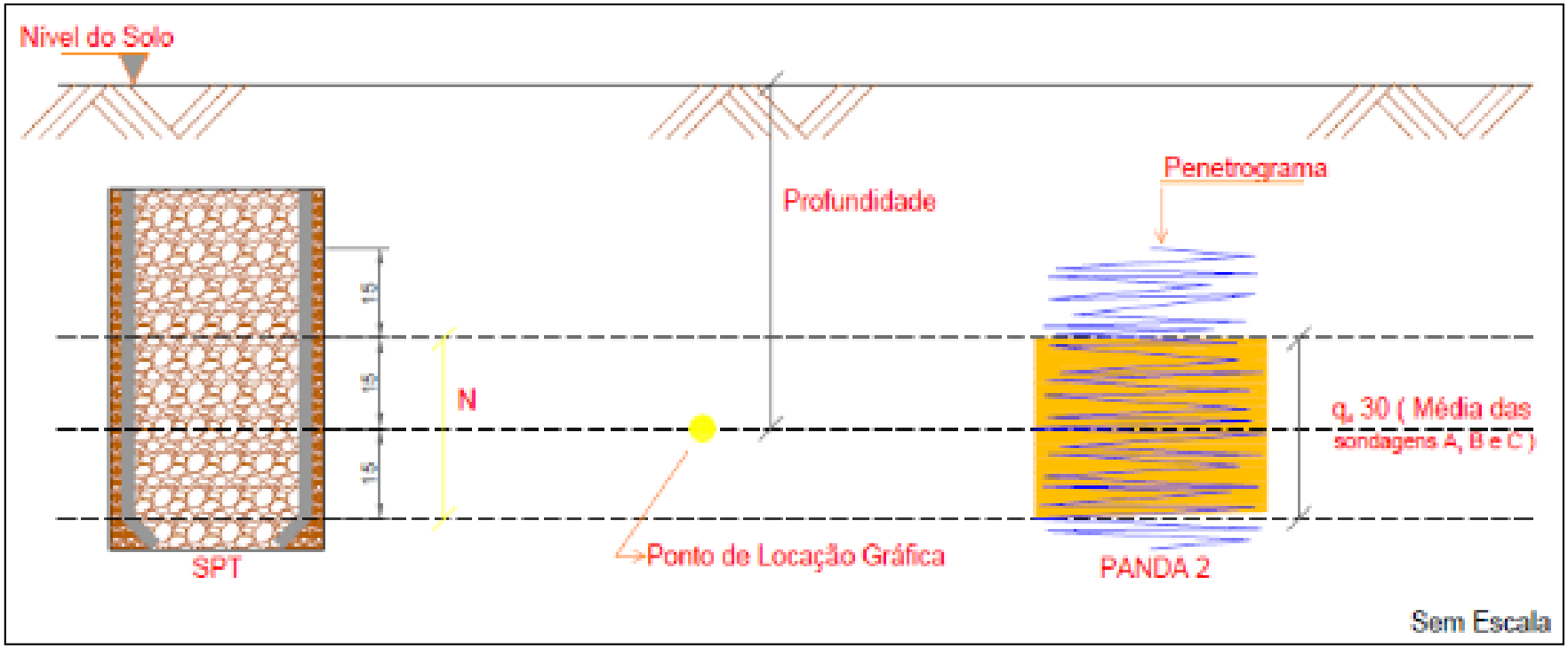
3 SPT with N values between 8 and 13 strokes
9 PANDA® with qd between 2 and 4 MPa





CORRELATION PANDA® / SPT (BRAZIL) :

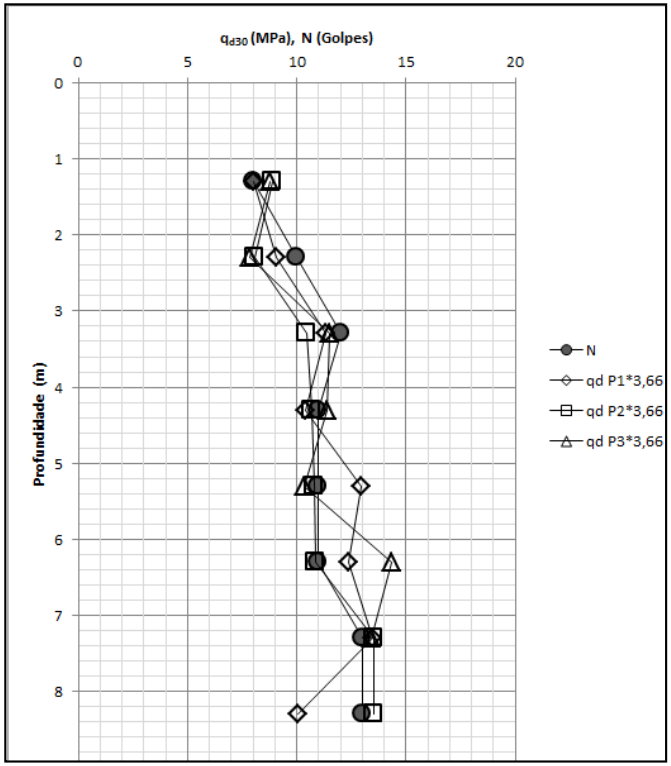
qd30 is the qd average value on 30 cm, corresponding at the 2 last 15 cm of the SPT sampler.



CORRELATION PANDA® / SPT (BRAZIL) :

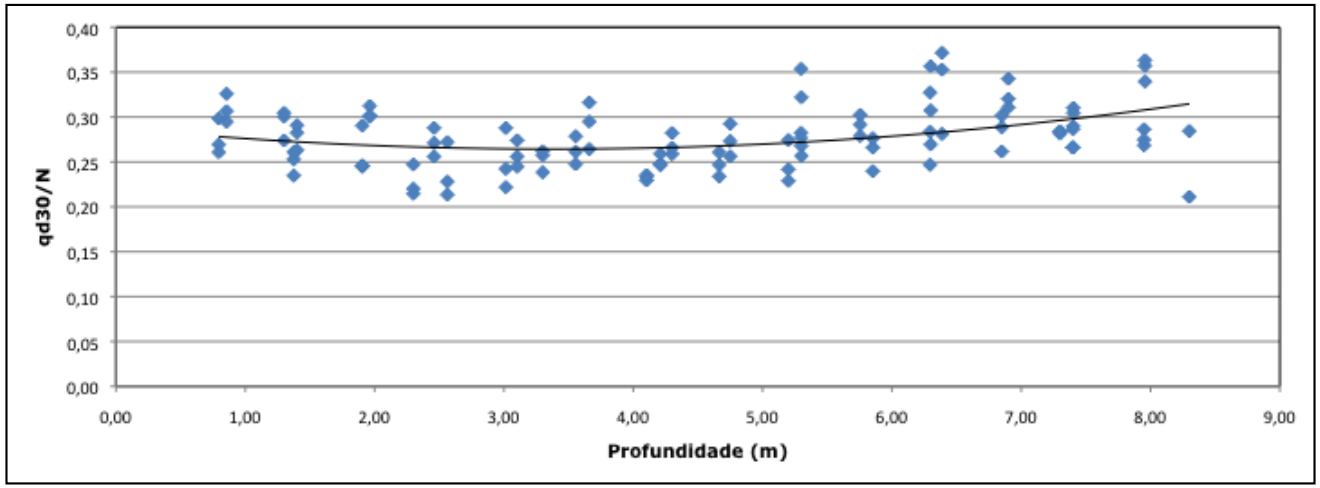
Comparative table and curves between SPT3 and Panda tests group (P1, P2 and P3)

	SPT3	P1		P2		P3	
Profundidade (m)	N	q_{d30} (MPa)	q_{d30}/N	q_{d30} (MPa)	q_{d30}/N	q_{d30} (MPa)	q_{d30}/N
		(d* = 4,25 m)		(d* = 6,70 m)		(d* = 0,50 m)	
1,30	8	2,19	0,27	2,44	0,30	2,40	0,30
2,30	10	2,47	0,25	2,20	0,22	2,15	0,21
3,30	12	3,09	0,26	2,86	0,24	3,14	0,26
4,30	11	2,85	0,26	2,92	0,27	3,10	0,28
5,30	11	3,54	0,32	2,95	0,27	2,82	0,26
6,30	11	3,38	0,31	2,96	0,27	3,92	0,36
7,30	13	3,69	0,28	3,70	0,28	3,66	0,28
8,30	13	2,74	0,21	3,70	0,28	-	-
Média	11	-	0,27	-	0,27	-	0,28
CV(%)**	14,76	-	12,96	-	10,05	-	15,63



CORRELATION PANDA® / SPT (BRAZIL) :

The relation qd30/N change a little and it's not linear with the depth.



qd30 / N = 0,27 or N = 3,7 qd30 (compacted tropical clay soil)
qd30 allow to establish satisfactorily a N SPT value.

1 PANDA® test at 9 m (2 à 4 Mpa) needs around 1 hour
1 SPT test at 9 m (N SPT from 8 to 13 strokes) needs around 1 day

CONTINUOUS CHARACTERIZATION OF THE BALLAST UNDERNEATH RAILTRACKS

To know precisely the condition of the ballast layers with the combination of various technicals investigations (PANDA®, geoendoscopy, GPR).

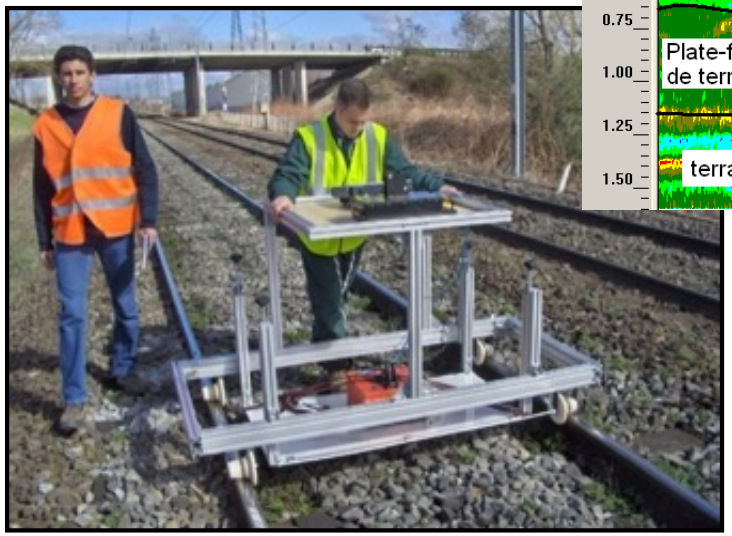
To evaluate its contamination, i.e the level of contamination of voids, which cause modifications in the global structure.

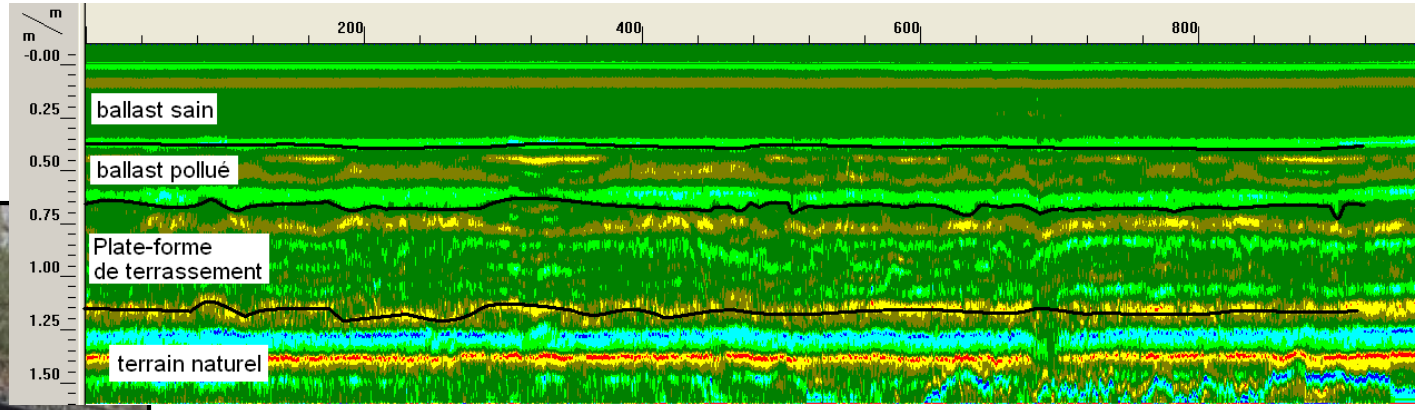
Objectives :

- To determine the thickness of clean and contaminated ballast
- To measure the resistance of ballast
- To identify the various materials investigated
- Detect water in the ground

CONTINUOUS CHARACTERIZATION OF THE BALLAST UNDERNEATH RAILTRACKS :

The GPR allows to do a global and continous mapping of the tracks and spot the clean and contaminated zones of the 25/50 ballast.





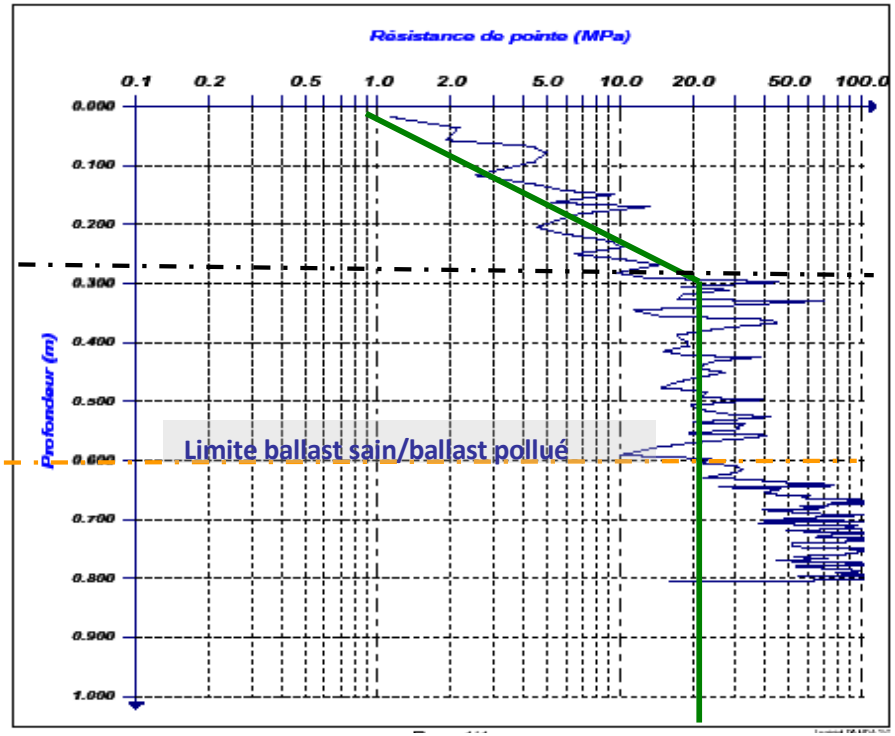
Continuous layer mapping with GPR

CONTINUOUS CHARACTERIZATION OF THE BALLAST UNDERNEATH RAILTRACKS :

PANDA® tests

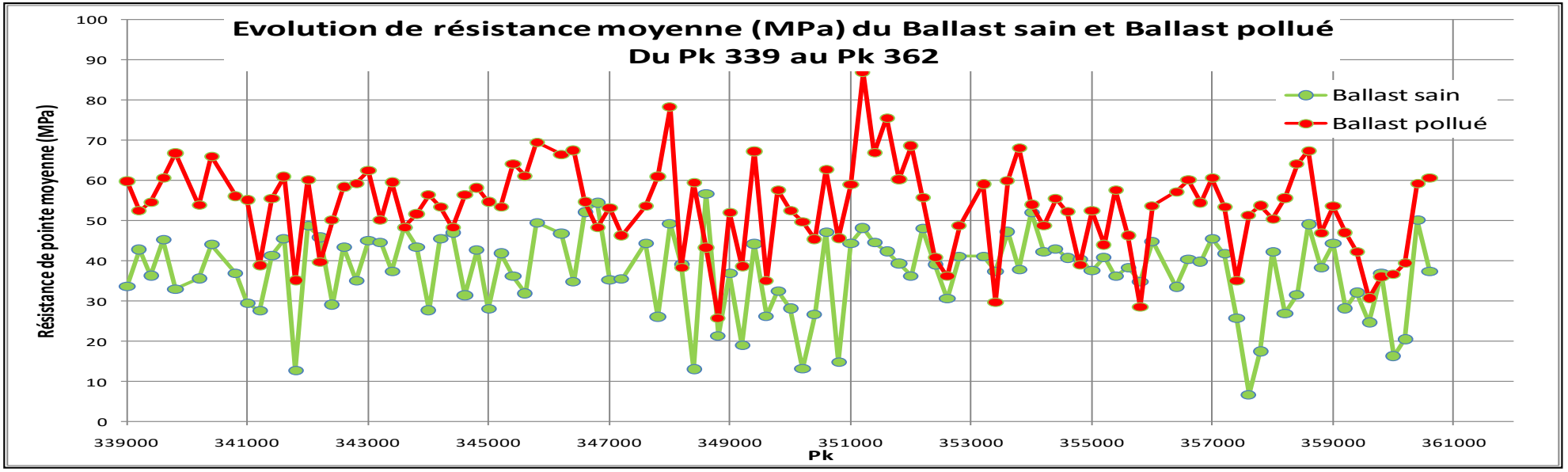
Test done to measure the mechanical resistances of clean and contaminated ballast and resistances in problem areas





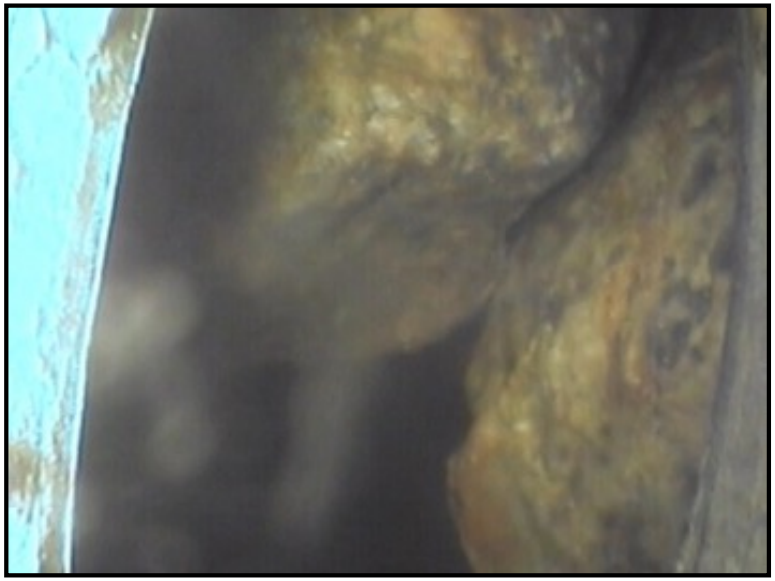
CONTINUOUS CHARACTERIZATION OF THE BALLAST UNDERNEATH RAILTRACKS :

We get a continuous profile of sound and contaminated ballasts and a mechanical characterization of the investigated zones (chaineage 339 to 362 : 23 km).



CONTINUOUS CHARACTERIZATION OF THE BALLAST UNDERNEATH RAILTRACKS :

Geoendoscopy based investigation
To spot heterogeneous areas : Contaminated ballast, altered materials,…



Clean ballast



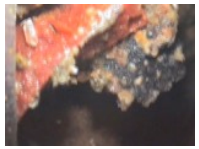
Contaminated ballast

5 mm

CONTINUOUS CHARACTERIZATION OF THE BALLAST UNDERNEATH RAILTRACKS :

Geoendoscopy based investigation

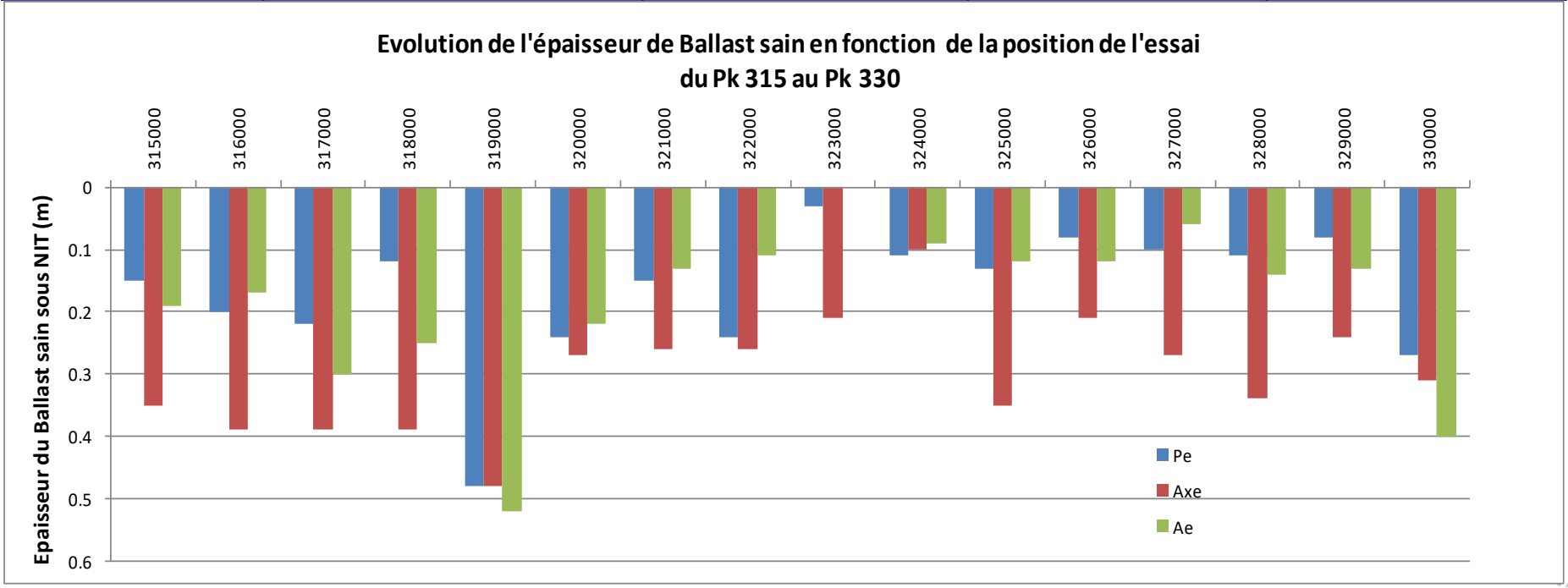
To measure the thickness of ballast, intermediary layers, of earthwork….

Couche	images	
Clean ballast		
Less contaminated ballast		
Contaminated ballast		
Intermediate layer		

CONTINUOUS CHARACTERIZATION OF THE BALLAST UNDERNEATH RAILTRACKS :

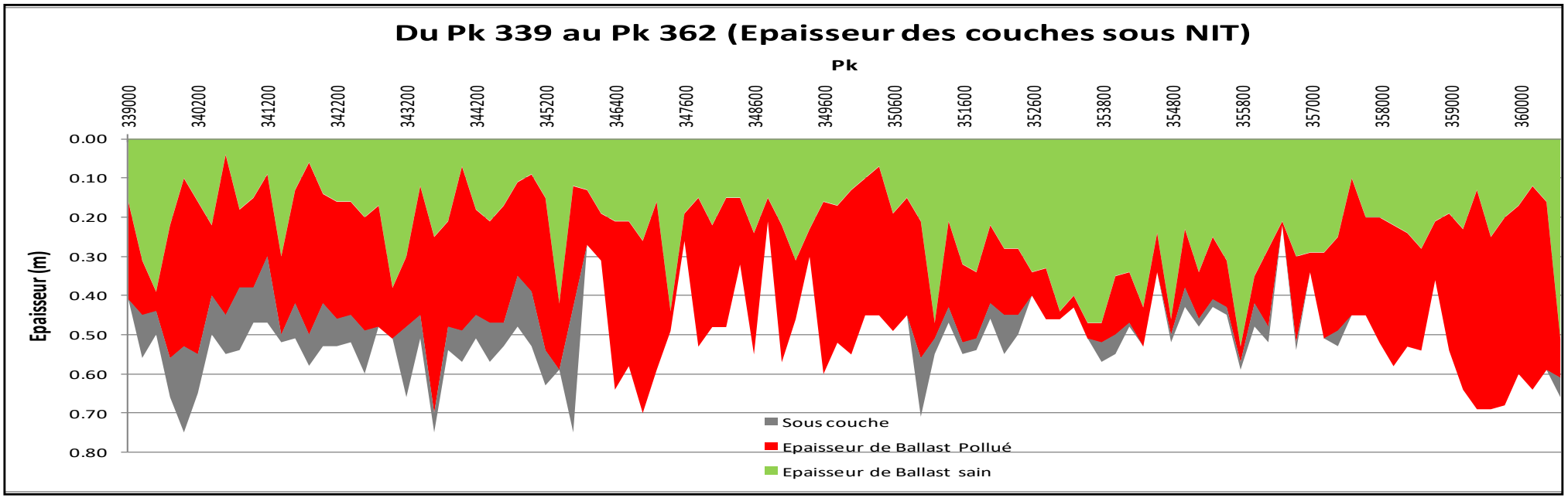
Continuous survey of sound ballasts following the axis of the track (chaineage 315 to chaineage 330 : 15 km).

	Sound ballast		Contaminated ballast	
	Depth under lower sleeper level (cm)	Cone Restistance (MPa)	Thickness (cm)	Cone Restistance (MPa)
Right side	17	31	39	58
Axis of the track	30	32	24	61
Left side	18	34	32	58



CONTINUOUS CHARACTERIZATION OF THE BALLAST UNDERNEATH RAILTRACKS :

Continuous survey of sound ballasts following the axis of the track (chaineage 339 to chaineage 362 : 23 km).



BALLAST EXPLORATION AND DIAGNOSIS OF THE SNIM RAILWAY TRACKS IN MAURITANIA :

Aim of the study : characterize the stiffness of the platform and ballast





Trains of the SNIM (iron ore transportation) are amongst the heaviest (22000 t), the slowest and the longest trains in the world (2,5 km long)
With 26 tons per axle load (16 to 20 t for a regular train), they transmit heavy constraints and stresses to the track and the ballast (causing premature wear)

BALLAST EXPLORATION AND DIAGNOSIS OF THE SNIM RAILWAY TRACKS IN MAURITANIA :

To characterize the contamination of the ballast and its silting level (acceptable if < 25%) and evaluate its stiffness and/or elasticity



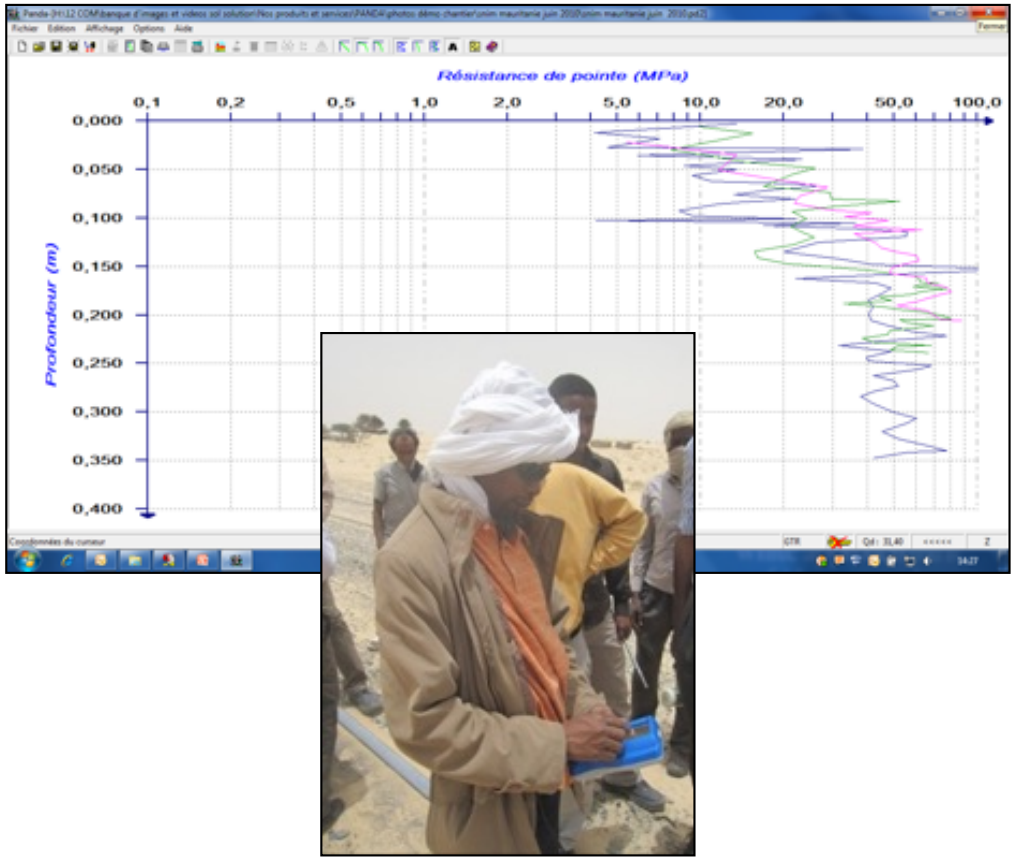


The presence of Aeolian sand is unavoidable on most of the track (no friction area).
The original ballast is not a genuine d/D but already a 0/D ballast (with no voids) when it is put on the track.

BALLAST EXPLORATION AND DIAGNOSIS OF THE SNIM RAILWAY TRACKS IN MAURITANIA :

PK 236 : tests on the track and on the right and left sides of it.

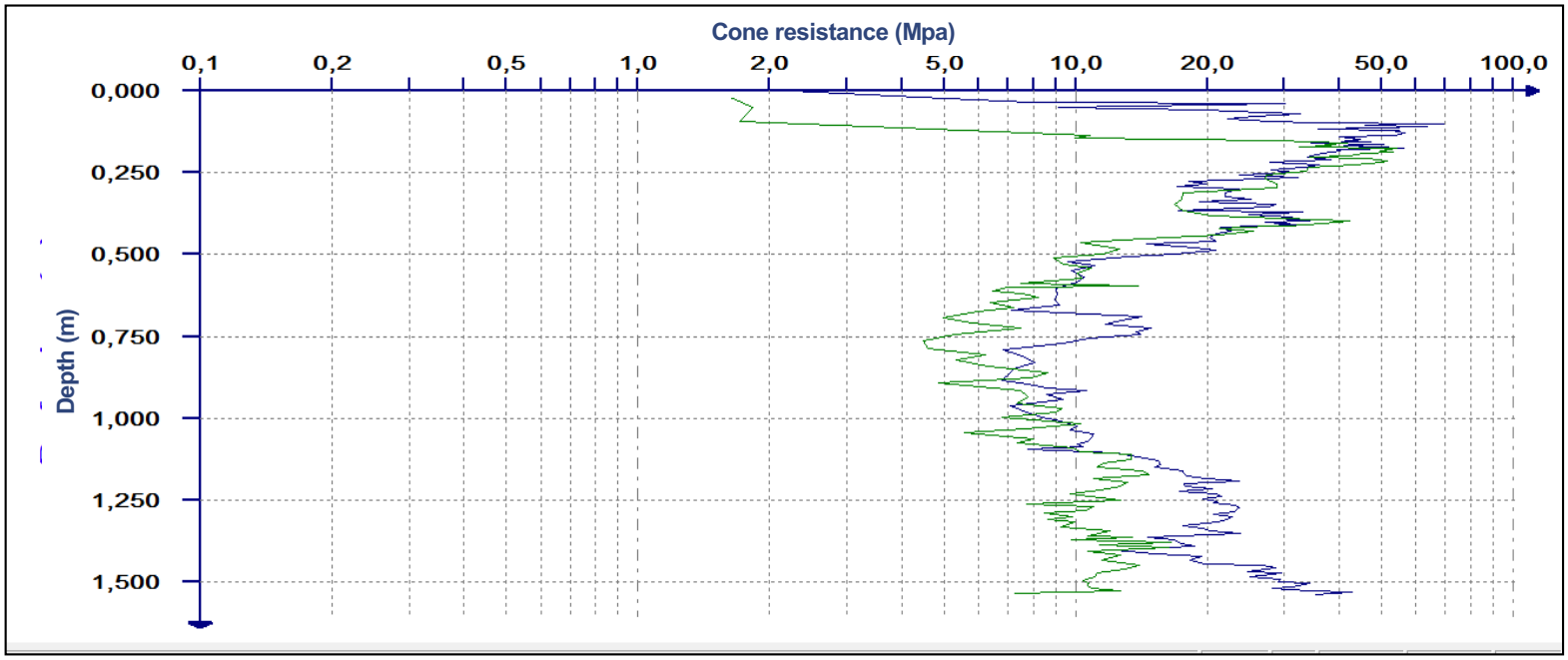




BALLAST EXPLORATION AND DIAGNOSIS OF THE SNIM RAILWAY TRACKS IN MAURITANIA :

Frequency and depth of Panda® tests for representative diagnosis of the track :

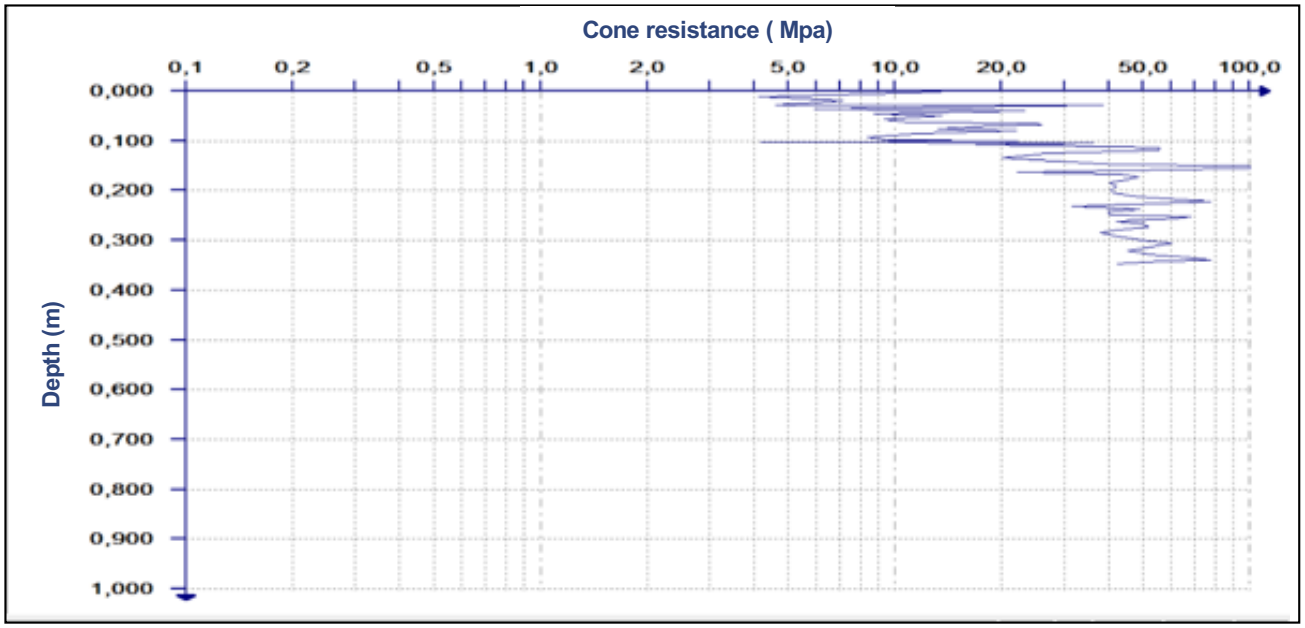
- 3 tests : center line, right side and left side off of the track
- Every 200 linear meters- every 50m if tests in contaminated areas or risk zones
- Total height of ballast (sound and contaminated) and upper part of the platform to ensure its bearing capacity



BALLAST EXPLORATION AND DIAGNOSIS OF THE SNIM RAILWAY TRACKS IN MAURITANIA :

Ballast SNIM (qd > 50 to 100 MPa) is stiff to super stiff

- SNCF platform with fines soils considererd stiff if Qd > 5 MPa
- SNCF platform with coarse soils considererd stiff if Qd > 15 MPa
- Clean ballast (underneath sleeper) SNCF : 20 to 30 MPa.
- Contaminated ballast (underneath sleeper) SNCF : 50 to 100 MPa



LATERITICS GRAVEL CALIBRATION – BURKINA FASO

Lateritics gravels compaction control 0/30 (B6 – Ip of 15 and 18) :

- Identify the PANDA® reference and refusal lines in calibrated mould
- Confirm the values by in-situ tests sections



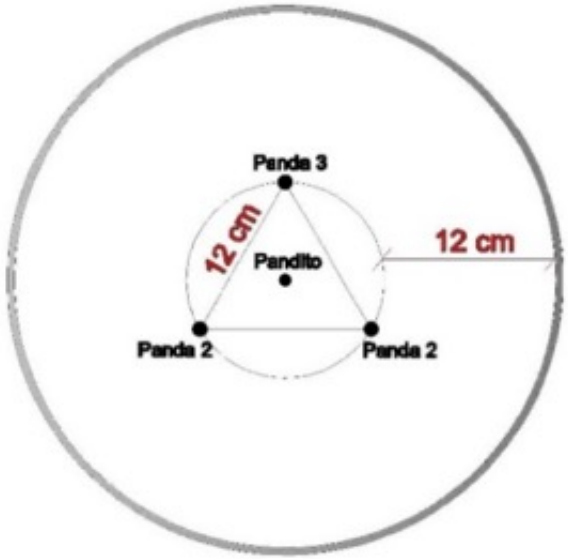


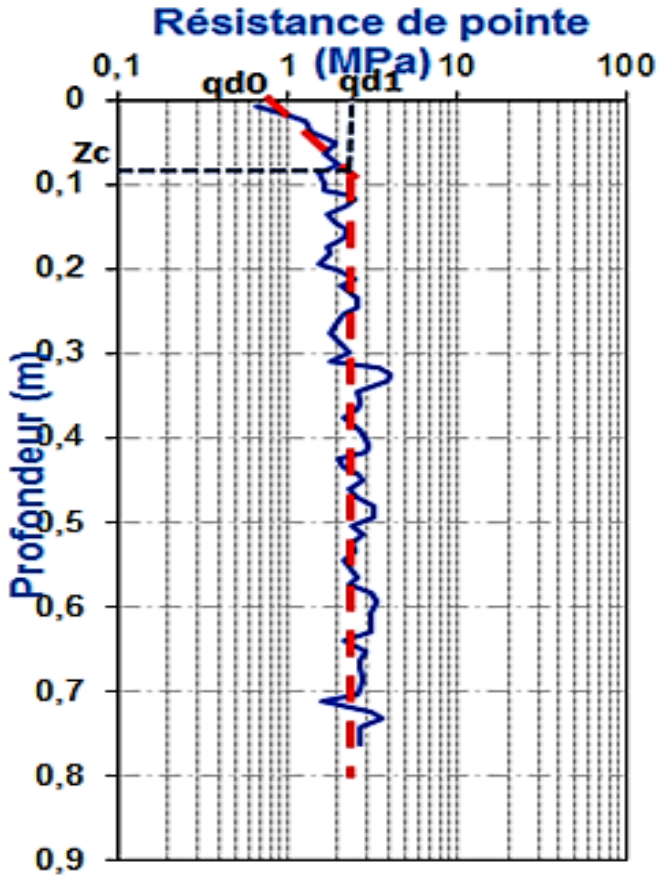


LATERITICS GRAVEL CALIBRATION – BURKINA FASO

Calibration in mould : 3 level of water content (dry, medium, wet) and 5 level of density by hydrous state

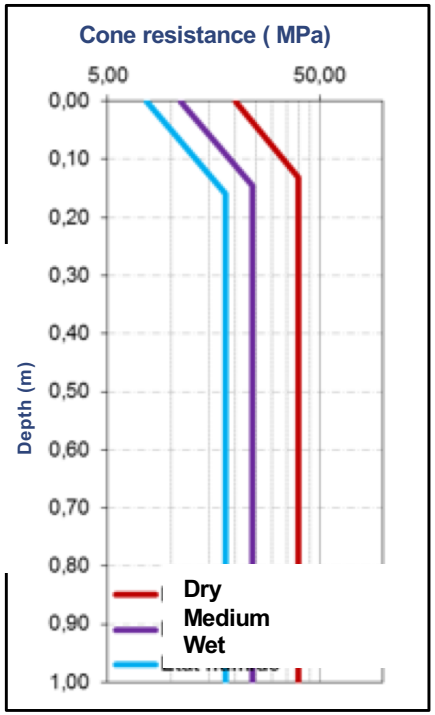




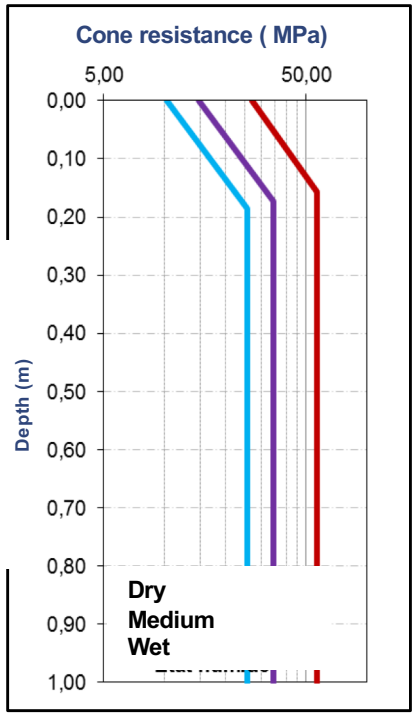


LATERITICS GRAVEL CALIBRATION – BURKINA FASO

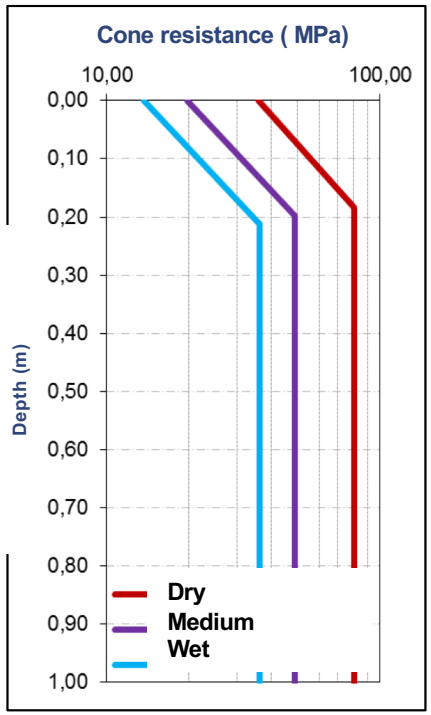
Determination of PANDA® reference and refusal curves



92% OPM



95% OPM



98% OPM

LATERITICS GRAVEL CALIBRATION – BURKINA FASO

Test section of 120 meters with 3 level of hydrous state (wet, medium, dry)

Calibration in-situ : sand cone, gamma-densimeter, static load testing, Panda®





LATERITICS GRAVEL CALIBRATION – BURKINA FASO

PANDOSCOPE® view : 5 mm wide window

Evolution of the grain structure before and after compaction
Plenty of grains are compressed and reorganized



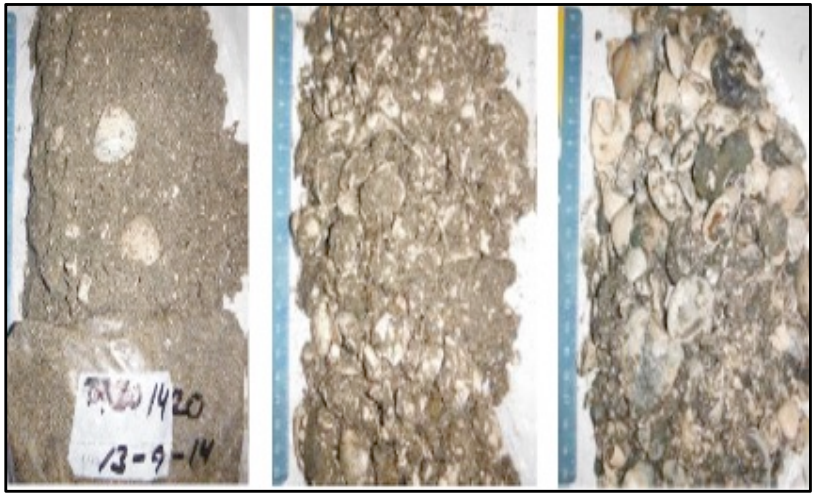




SHELLS SAND VIBROCOMPACTION CALIBRATION (URUGUAY)

- The foundation of an offshore breakwater (LNG-terminal construction) consists of very soft soil top layer (high plasticity clay with N SPT = 0) which should be removed and replaced with fill material with good mechanical properties, to get the appropriate bearing capacity.
- The available sand for the soil replacement underneath the breakwater is mixed with shells. The substituted sand in the foundation has to be compacted by vibrocompaction.

For practical convenience and mobility, the PANDA® is used instead of CPT measurements.

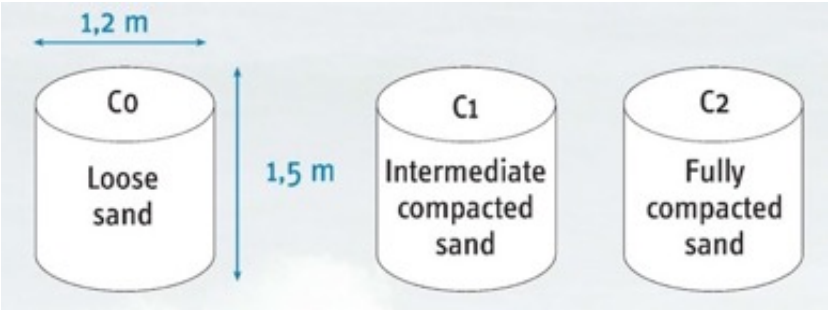


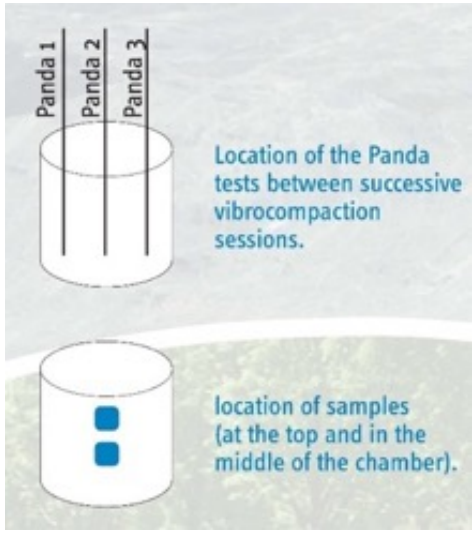


Fine to medium silica sand with shell contents ranging up to 50%, taken from trailing suction hopper dredger

SHELLS SAND VIBROCOMPACTION CALIBRATION (URUGUAY)

- 3 degrees of pre-compaction (C0, C1, C2) : loose, intermediate and fully compacted sand (compacted once or twice by layers of 15 cm with a stamper)
- 3 degrees of vibrocompaction (V0, V1, V2) : not vibrated (state of the soil), vibrated for half of the time to reach full compaction, and vibrated till maximum settlement is reached.





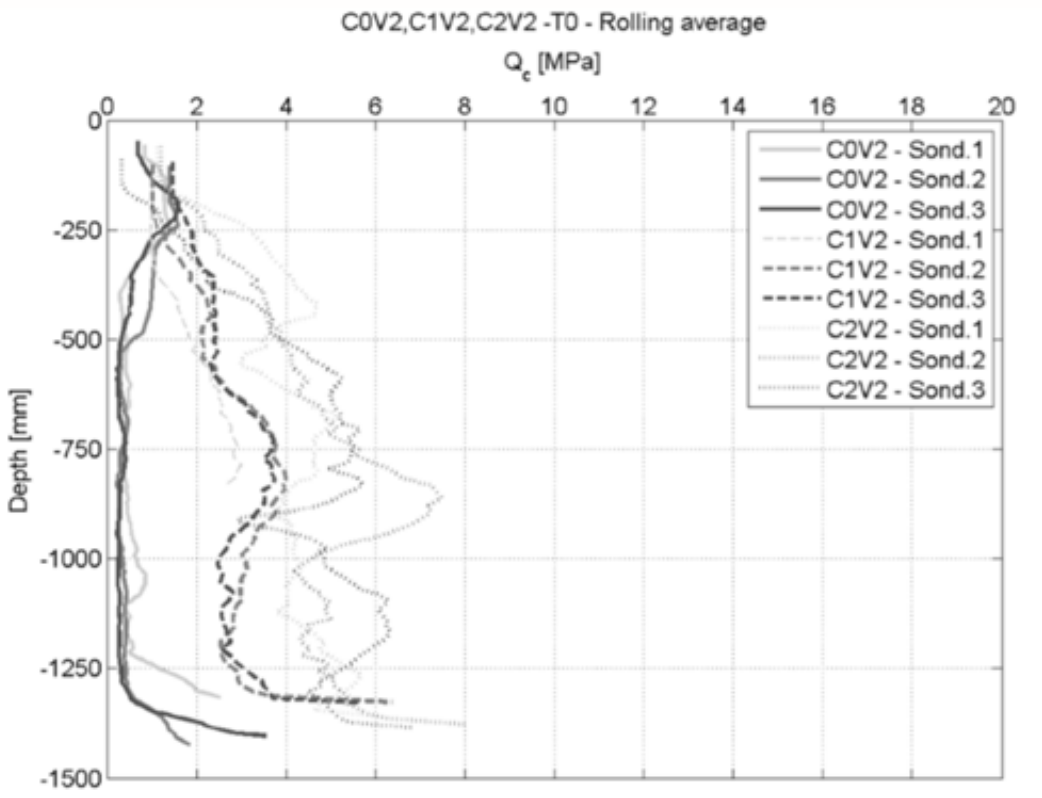


3 PANDA® between successive vibrocompaction sessions.
Settlement after each vibrocompation session is measured.
After the PANDA® test, soil samples are taken, to determine the density of the material.

SHELLS SAND VIBROCOMPACTION CALIBRATION (URUGUAY)

5 MPa qc is quite easily obtained for all the initial sand conditions (loose, medium and dense).

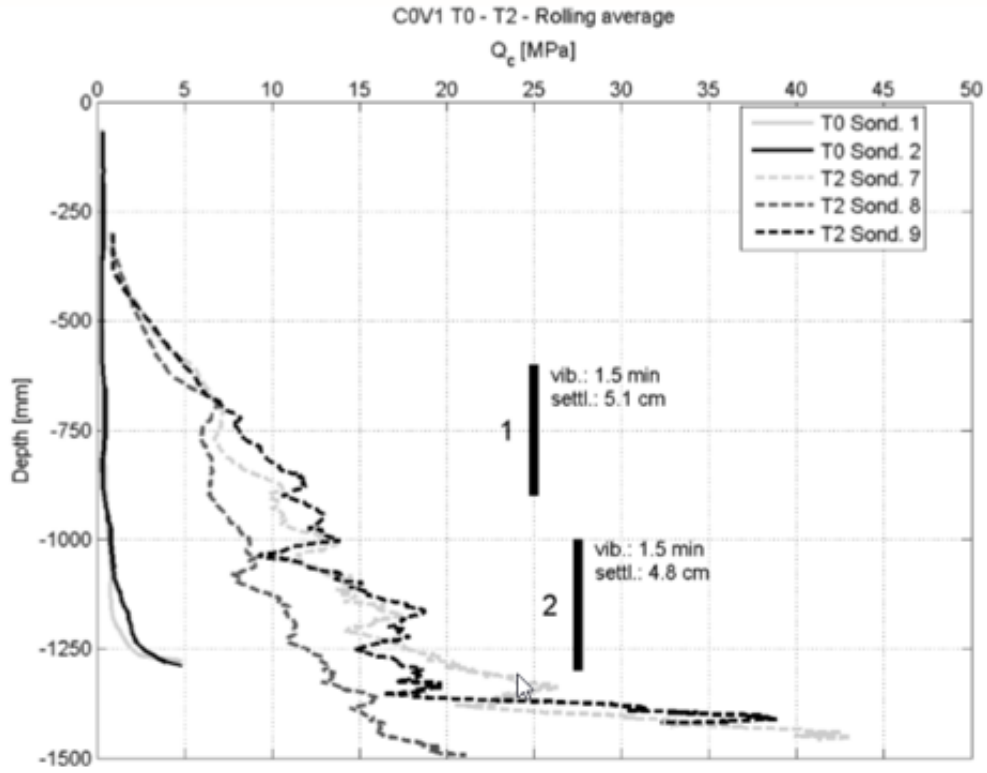
PANDA® tests of the initial condition (T0) of the chambers with loose (C0V2), medium dense (C1V2) and dense sand (C2V2) prior to any vibrocompaction.



SHELLS SAND VIBROCOMPACTION CALIBRATION (URUGUAY)

PANDA® tests with loose sand (C0V1) before (T0) and after two sets of vibrocompaction (T2).

Duration and location of the performed vibrocompactions and the measured settlement after each vibrocompaction are indicated with the thick black lines.





SHELLS SAND VIBROCOMPACTION CALIBRATION (URUGUAY)

Test are repeatable. For the same degree of pre-compaction, the measured settlements after the same vibration time are very similar.

There is no perfect correlation between the settlements and the PANDA® increase value.

Longer vibration times have an influence on q_c value, although further settlements are limited.

One should be careful when using the settlements as an acceptance criterion for the required strength during the vibrocompaction campaign.

Location of the applied vibration energy has an influence on the increase of PANDA® value.

Very high q_c values (15 to 20 Mpa) are obtainable with sand-shell mixture vibrocompaction.

CONTROLLING THE USE OF EXPANDED CLAY BALLS :

Filling of a full scale model (8 m diameter) of the future sealing of storage tunnels using a clayish material (bentonite clay) made of a mix of dry pellets balls of 32 mm in diameter and a 0/4 mm crushed material.

Measuring the density of the material and controlling the homogeneity and the filling quality of the model thanks to Panda® 2 tests.

Model : L 36 x l 11 x H 10 m

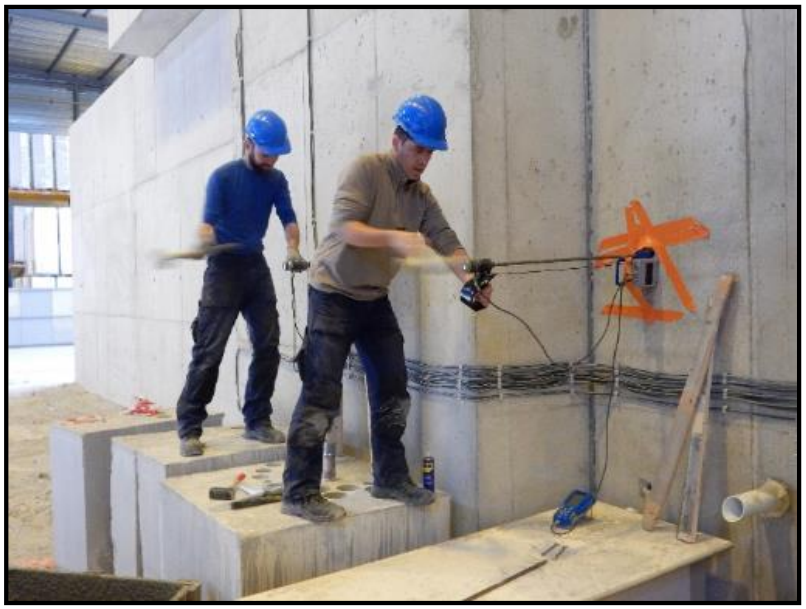


Determining % pellets / crushed material:
100/0, 85/15, 70/30 (optimal), 55/45, 0/100

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CONTROLLING THE USE OF EXPANDED CLAY BALLS :

Horizontal, vertical and sloppy soundings done with the Panda® 2 penetrometer

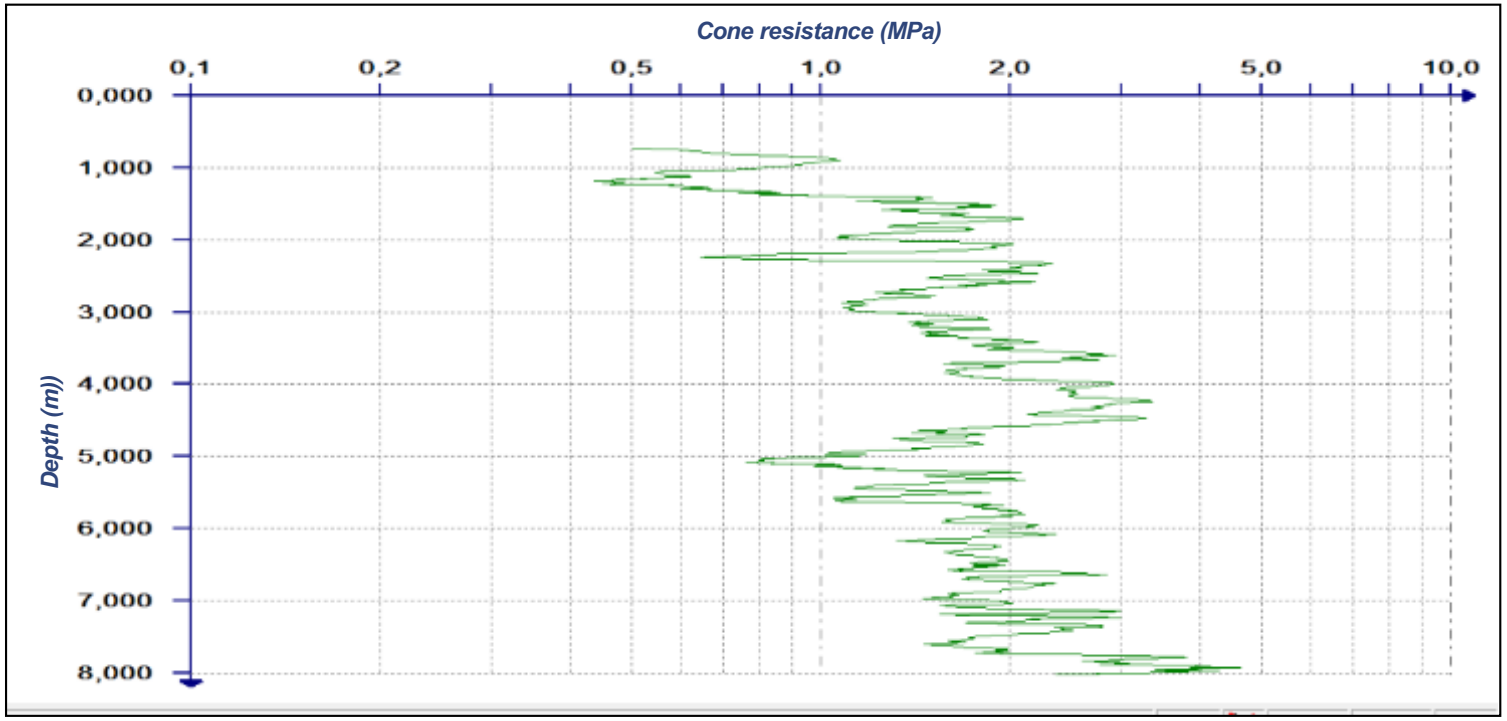






CONTROLLING THE USE OF EXPANDED CLAY BALLS :

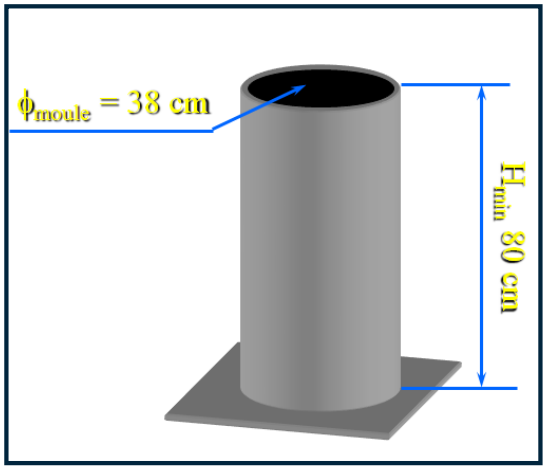
Panda® 2 test done on an average depth of 8 meters



CALIBRATING PHASE OF THE CLAY PELLETS BALLS :

Use of a calibrated mold and compaction of the 70/30 mix (pellets/crushed material)







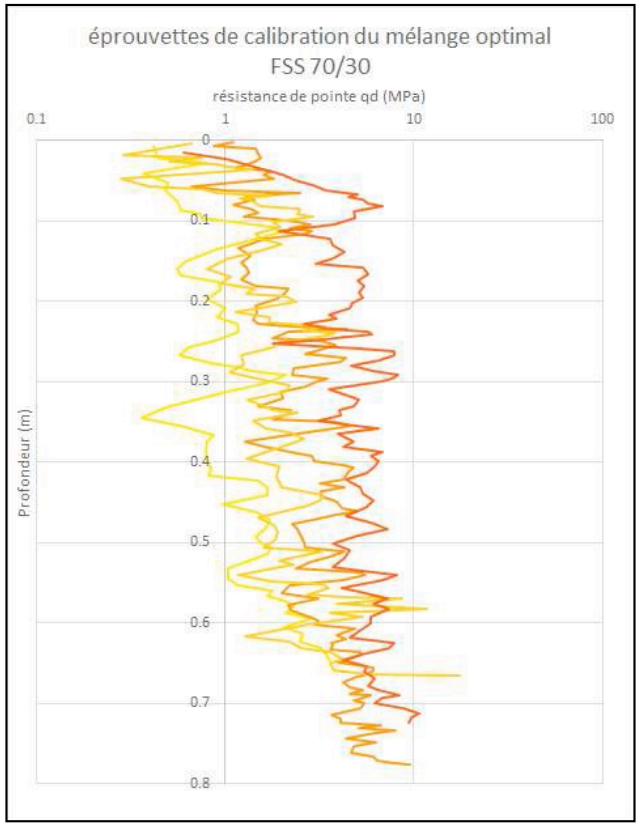


CALIBRATING PHASE OF THE CLAY PELLETS BALLS :

Panda® 2 penetration tests are done for each mix of materials.

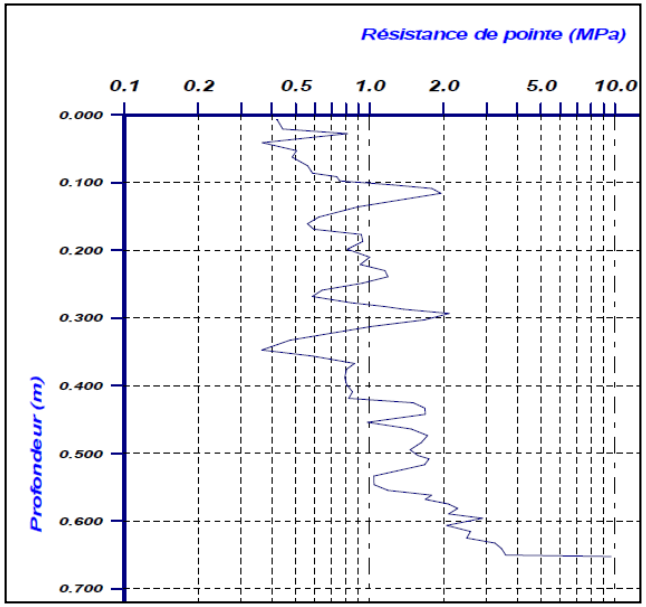


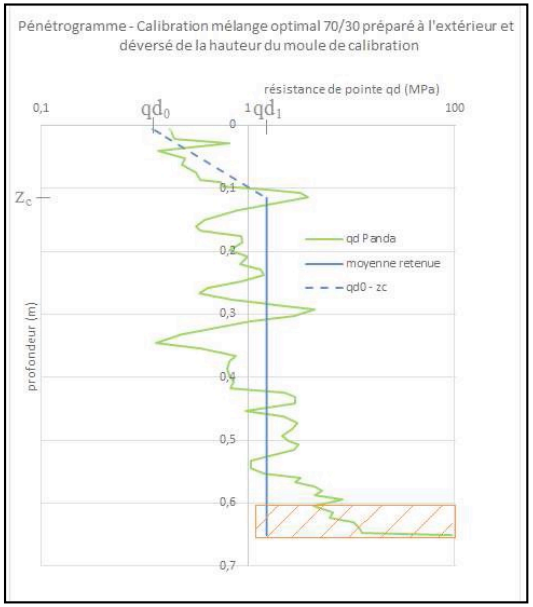


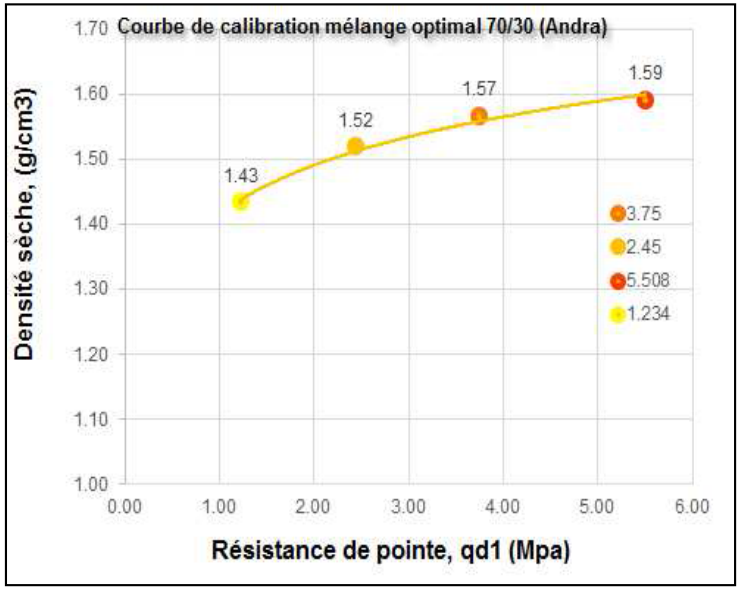


CALIBRATING PHASE OF THE CLAY PELLETS BALLS :

The model of the relation between density and resistance of the Panda® 2 is defined by a logarithmic function







Determination of qd0 / Zc / qd1 parameters