CONTRIBUTION TO THE DEFINITION OF CONDITIONS OF USE OF THE MUNICIPAL SOLID WASTE SLAG IN EMBANKMENTS AND IN CAPPING LAYERS

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OBJECTIVES OF THE RESEARCH PROGRAM (LCPC)

1) To elaborate a geotechnical characterization of the MSWS.

2) To define the conditions of use of the MSWS in embankments and in capping layers without treatment

3) To check the interpretation in control compaction with dynamic penetrometer.

Today in France

- GTR classification of MSW Slag : Class F61

This class is characterized with an unburnt rate at 500°C < 5%

- Objectives of density

- **Embankments: q4 objective**	average ρ_d **> 95%** $\rho_{d\ SP}$
	bottom ρ_d **> 92%** $\rho_{d\ SP}$
- **Capping layer: q3 objective**	average ρ_d **> 98.5%** $\rho_{d\ SP}$
	bottom ρ_d **> 96%** $\rho_{d\ SP}$
- **Roadbase: q2 objective**	average ρ_d **> 97%** $\rho_{d\ MP}$
	bottom ρ_d **> 95%** $\rho_{d\ MP}$

GEOTECHNICAL CHARACTERIZATION OF THE MSW SLAG

- **<u>Moisture content</u>**

influence of the oven temperature.

Measures at 35°C, 50°C and 105°C show that a measure of the moisture content in the same conditions than those for the conventional materials **(105°C) is convenient.**

influence of the grain size

The moisture content is deeply **included in the fine size part of the soil (0/10mm)**

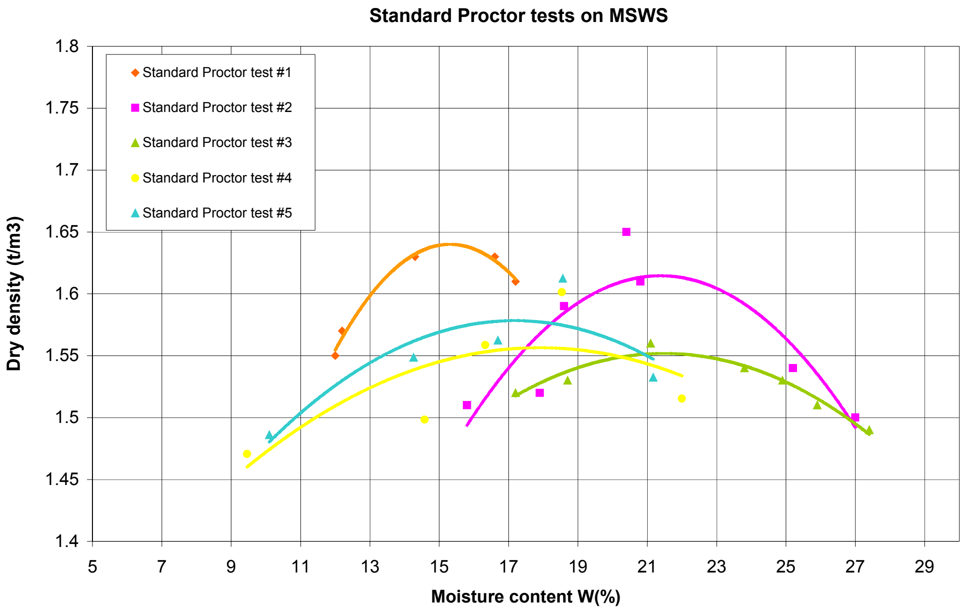
influence of the compaction

Tests made with Standard Proctor energy show that it **doesn't release enough water to generate a change** of hydrous state of the MSWS.

GEOTECHNICAL CHARACTERIZATION OF THE MSW SLAG

•Variations with the production

The Proctor curves obtained from January to August 2002 on different productions of the same site show that the maximal dry density varies **from 1,54 to 1,64 t/m3** and that the optimum moisture content varies **from 15,4 to 21,1 %.**

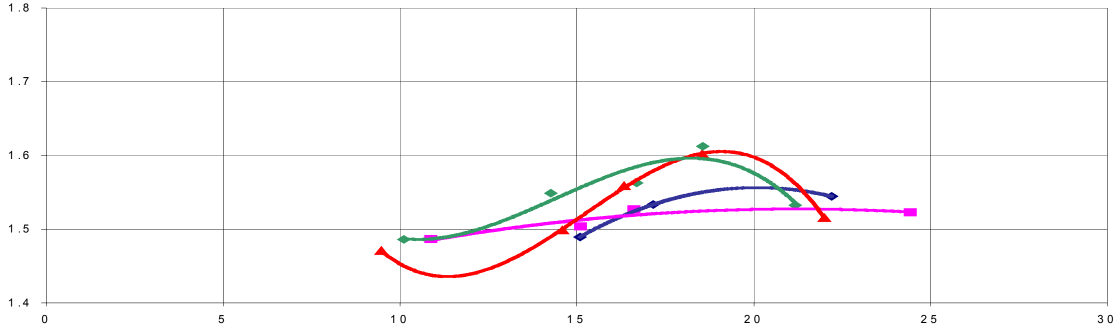


GEOTECHNICAL CHARACTERIZATION OF THE MSW SLAG

- **Homogeneity of the material**

4 standard Proctor tests have been made on the same sample from the same stock.

	Test 1		Test 2		Test 3		Test 4	
	W(%)	ρ_d(t/m^3)	W(%)	ρ_d(t/m^3)	W(%)	ρ_d(t/m^3)	W(%)	ρ_d(t/m^3)
Optimum Dry Density	19.8	1.54	21	1.53	19.0	1.61	18.3	1.60



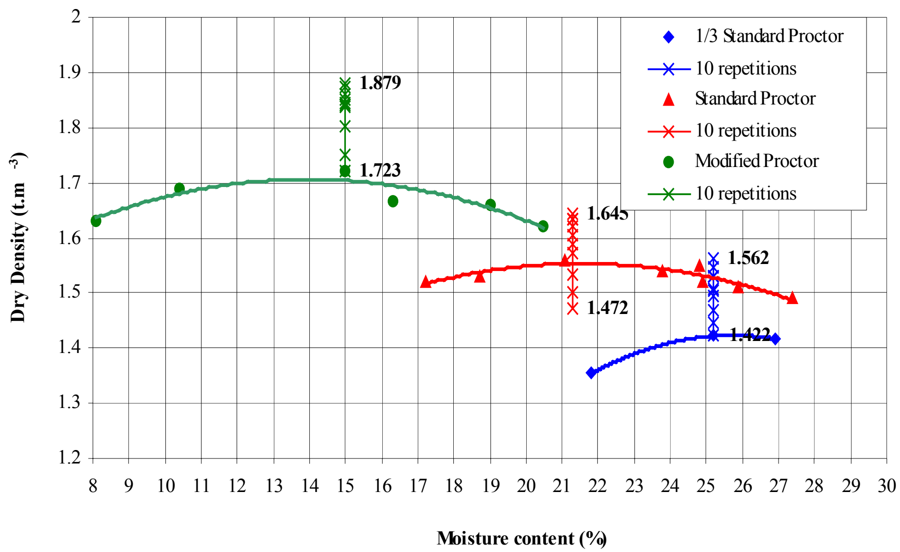
The variations of the Standard Proctor test on the same stock, are alike those of the whole production

GEOTECHNICAL CHARACTERIZATION OF THE MSW SLAG

- **An evolutionary material**

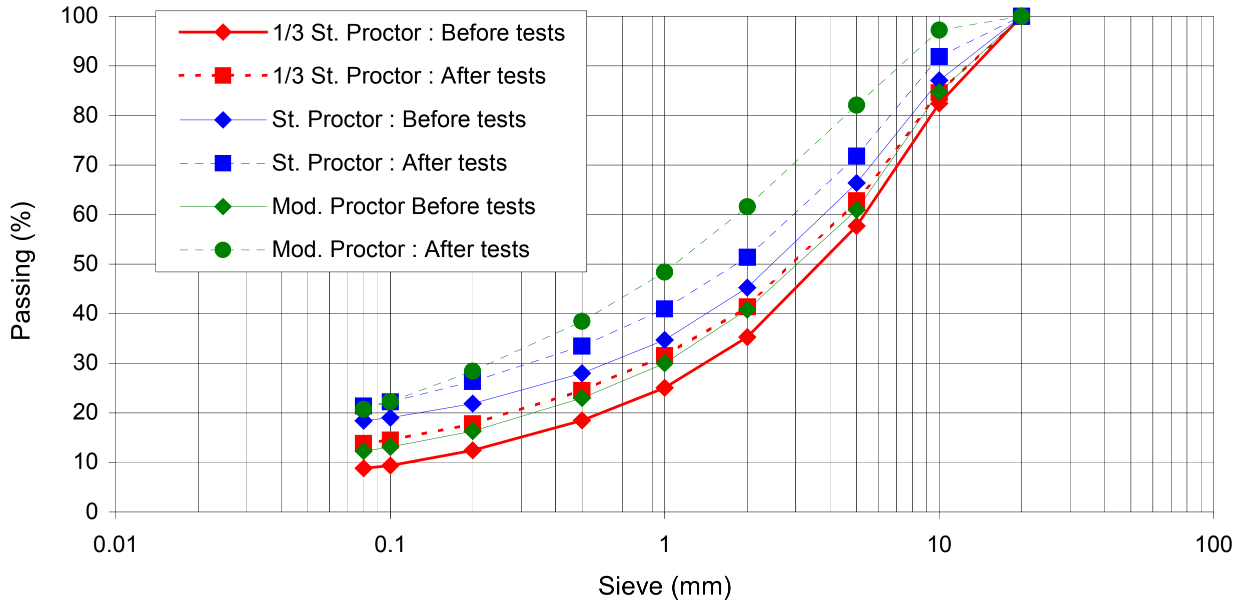
I-Evolutivity of the material

3 curves are obtained: one with **Standard Proctor energy**, one with **Modified Proctor energy** and one with **1/3 of the Standard Proctor energy**. Then, at the optimum moisture content value of every curve, 10 tests are repeated in the mold with the same sample put back every time, to check the evolution of the dry density



The 10 repetitions show the strong evolution of densities at the optimum point, whatever are the energies of compaction. **The asymptote of evolution is not yet obtained after the 10th test.**

GEOTECHNICAL CHARACTERIZATION OF THE MSW SLAG



Grain size curves made before the first test and after the tenth test show that the relative material passing increase to 5mm is 33 %, and the one to 2mm is 50 %, with the Modified Proctor energy.

This evolution is checking the use of MSWS for the higher compaction objectives (>=q2).

CONDITIONS OF USE OF THE MSW SLAG

Characterization of the MSWS used (Rouen)

Tests have been made with a MSWS having 3 months of maturation from a homogeneous stock. The MSWS comes from the MSWS plant of ROUEN. The Standard Proctor values are: $\boldsymbol{\rho_{dMAX}}$ **= 1,57 t/m3 and $\boldsymbol{W_{OMC}}$ = 19,5%.**

CONDITIONS OF USE OF THE MSW SLAG

Experimentation scheme

The studied parameters are:

- **The moisture content of the material,**
- **The energy of compaction (number of roller passes),**
- **The thickness of layers.**

3 Test sections have been made at CER.

Sections 1 and 2 concern the influence of the layer thickness, and sections 2, 3 and 5 are devoted to the influence of the moisture content.

PHASE A

test section # 3 Hydrous state: **dry** thickness=30cm
test section # 2 Hydrous state: **dry** thickness=30cm
test section # 1 Hydrous state: **medium** thickness=60cm

PHASE B

test section # 5 Hydrous state: **wet** thickness=30cm
test section # 4 Hydrous state: **wet** thickness=30cm
test section # 1 Hydrous state: **medium** thickness=60cm

The experiment progress had two phases (A and B). Sections 1, 2 and 3 have been first placed. After dismantling of sections 2 and 3, sections 4 and 5 have been placed on section 1. Sections n°4 and 5 are identical (same thickness and moisture content); the section 4 is incorporated to provide section 5 with a similar foundation.

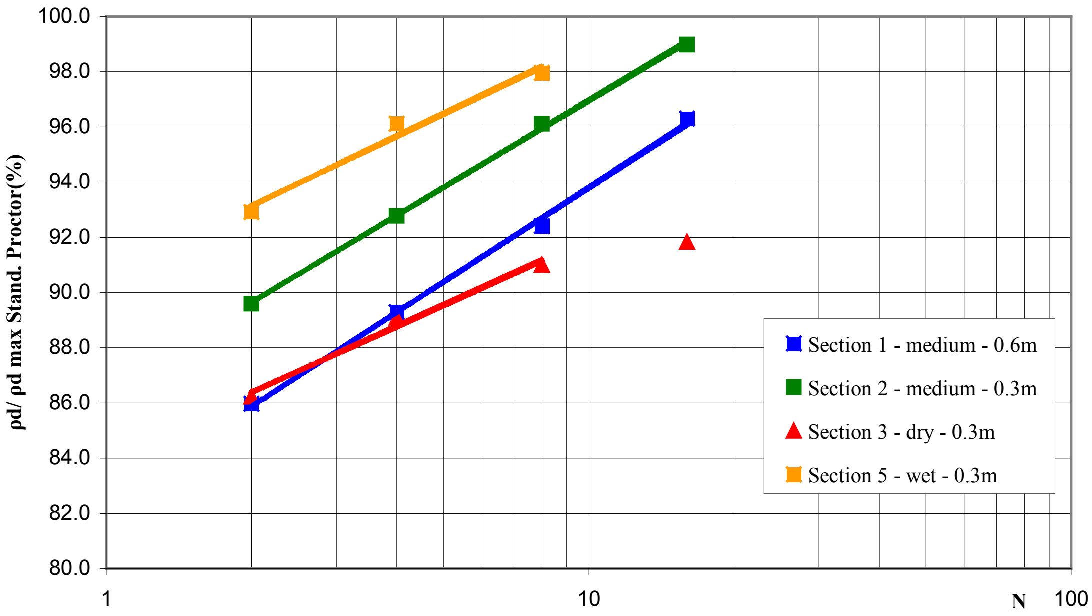
For every section, the compaction is realized with a 28 kg/cm vibratory roller (V2 class).
The size of every test section is about 2,5m x 25m.

CONDITIONS OF USE OF THE MSW SLAG

Measure of average density with the Gammadensimeter (GPV)

Measures of density (ρ_d) in current soils are plotted in a law of the type T(%) = a.log(N)+b with N= Number of roller passes.

The results show the important role of the moisture content, and particularly the difficulty of compaction in the dry conditions.



$$T(\%) = \frac{\rho_d}{\rho_{d\ max}}$$

Standard Proctor

Evolution of the compaction versus the roller passes N

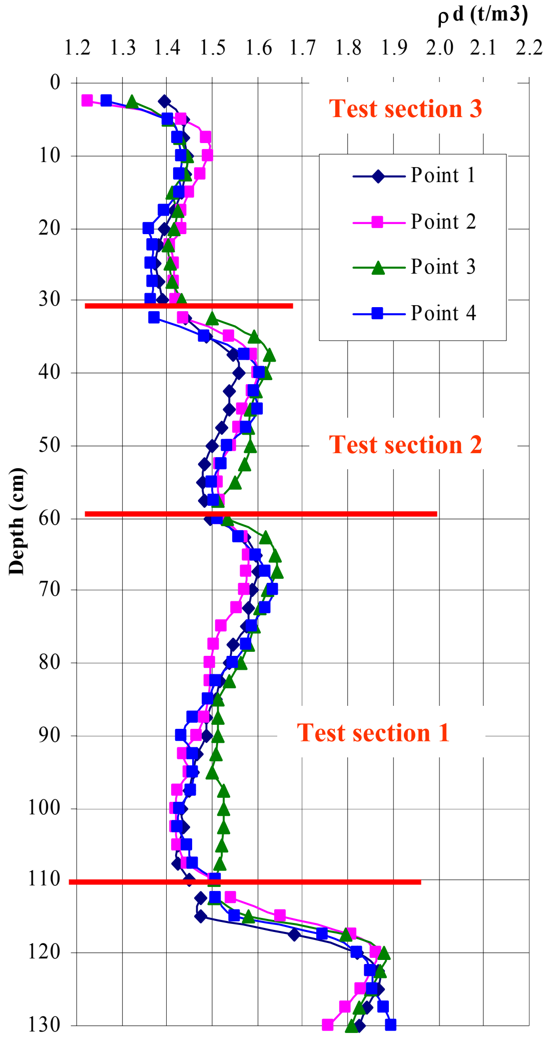
CONDITIONS OF USE OF THE MSW SLAG

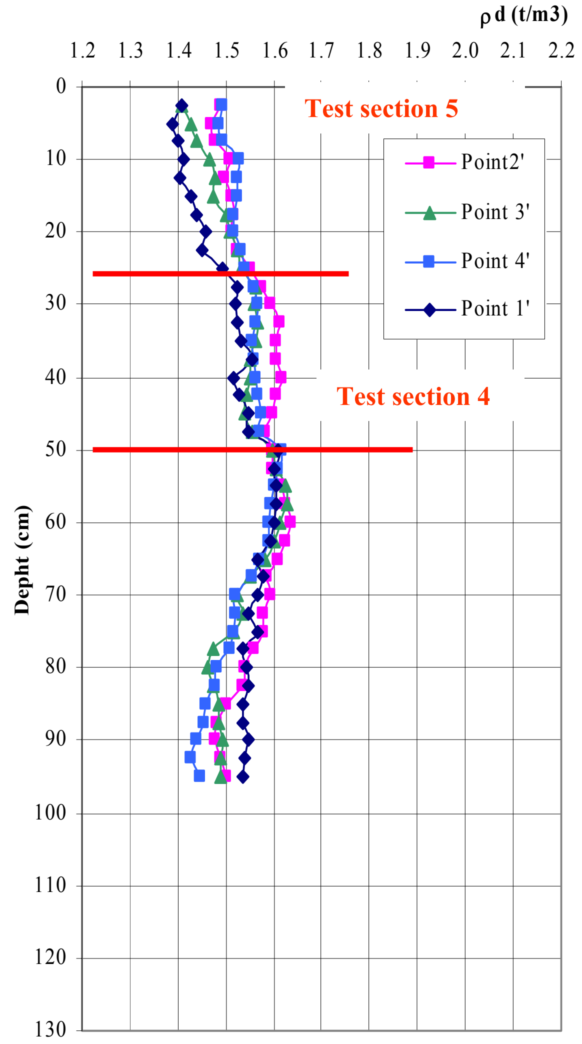
Measure of the density gradient with the "Gamma Double Probe " GDS200.

Gradients of density are measured with the «Gamma Double Probe GDS200 » used for the compaction studies.

This apparatus allows to measure gradient density up to 2,00m of depth.

CONDITIONS OF USE OF THE MSW SLAG





Measures of $\rho_d = f(z)$ in 4 points, to the final roller pass number, show low gradients in wet conditions (4 and 5), compared to medium (1) and dry (2 and 3).

CONDITIONS OF USE OF THE MSW SLAG

Conditions of compaction for the tested MSW Slag in quality q4 and q3

Embankment quality q4

Moisture	Parameters	V1	V2	V3		V4		V5	
wet	Q/S	0.040	0.070	0.115		0.150		0.185	
	e	0.25	0.35	0.30	0.45	0.30	0.60	0.30	0.75
	V	2.0	2.0	3.0	2.0	4.0	2.0	5.0	2.0
	N	6	5	3	4	0.02	4	2	4
	Q/L	80	140	345	230	600	300	925	370
medium	Q/S	0.025	0.045	0.065		0.09		0.115	
	e	0.20	0.30	0.30	0.40	0.30	0.55	0.30	0.70
	V	2.0	2.0	2.5	2.0	3.5	2.0	4.5	2.0
	N	8	7	5	6	4	6	3	6
	Q/L	50	90	162.5	130	315	180	517.5	230
dry	Q/S				0.02		0.03		0.035
	e				0.20		030		0.35
	V				2.0		2.0		2.0
	N				10		10		10
	Q/L				40		60		70

Capping layer quality q3

Moisture	Parameters	V1	V2	V3		V4		V5	
medium	Q/S		0.020	0.030		0.040		0.050	
	e		0.20		0.30	0.30	0.40	0.30	0.50
	V		2.0		2.0	2.5	2.0	3.5	2.0
	N		10		10	8	10	0.06	10
	Q/L		40		60	100	80	175	100

V1, V2, …, V5: vibratory roller class

Q/S (m^3/m^2) : Ratio compacted volume / compacted surface.

e (m) : Compacted thickness

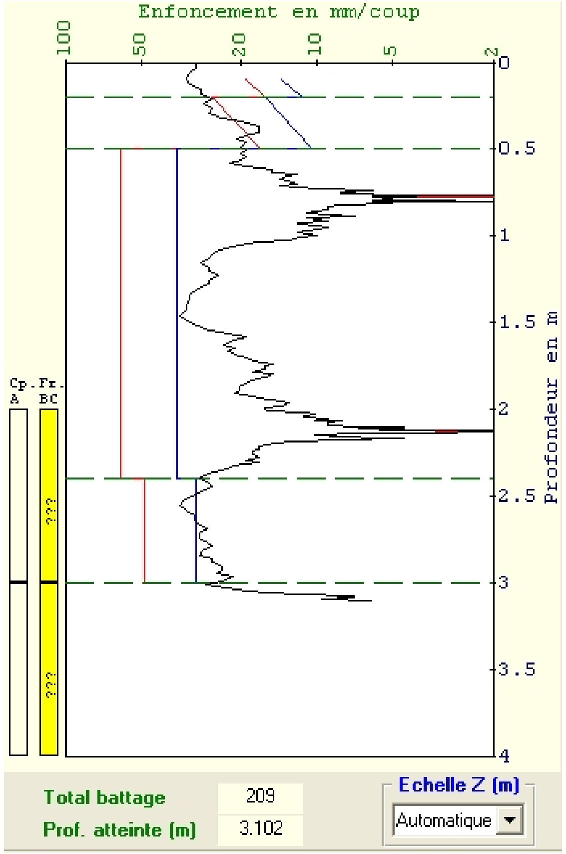
V (km/h) : Travel speed

N (km/h) : Number of passes (1 drum)

Q/L (m^3/h per m) : Theoretical output per meter width

CONTROL OF COMPACTION BY DYNAMIC PENETROMETER

The aim of these measures is to determine limit values and reference values for the interpretation of controls in MSWS.

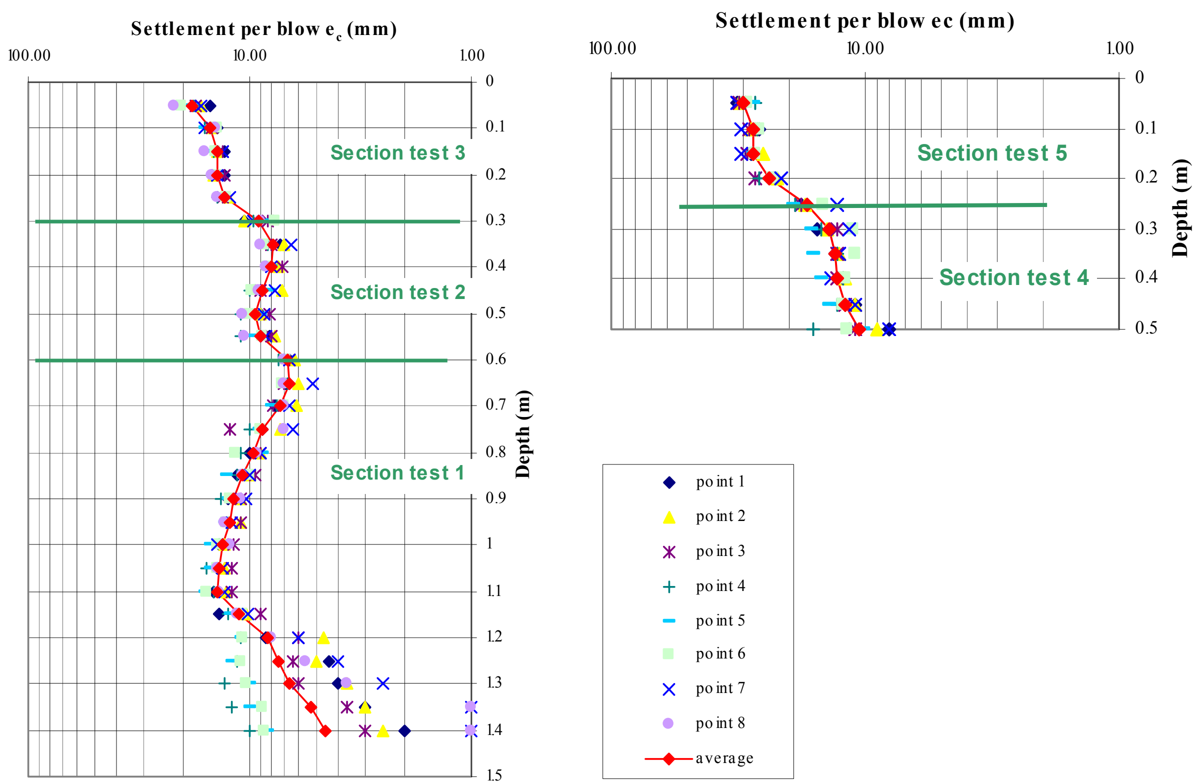


Dynamic penetrometer with constant energy PDG1000.

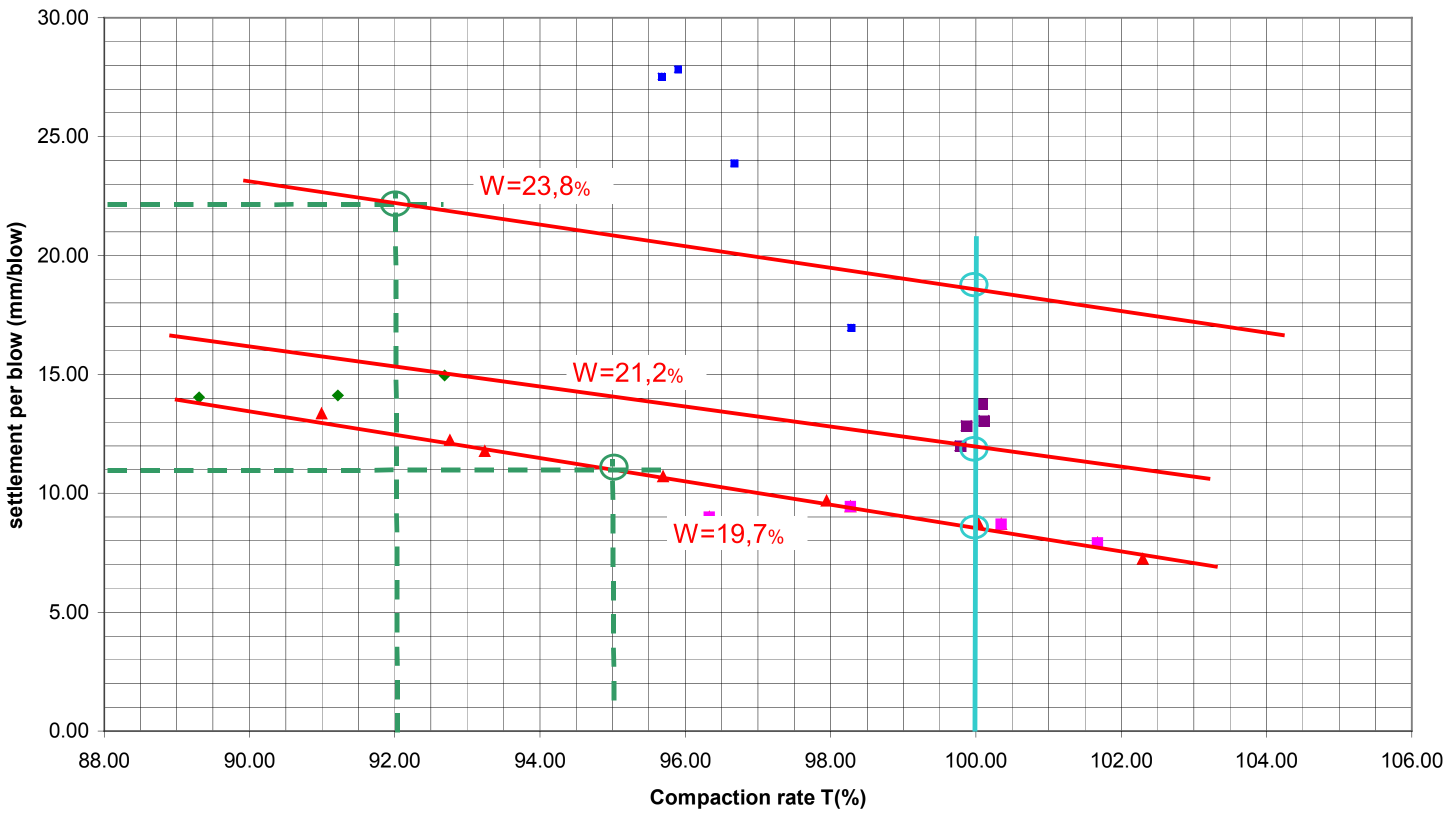
CONTROL OF COMPACTION BY DYNAMIC PENETROMETER

Average profiles from penetrometer

To make the **relationship between settlements per blow ec and compaction values T** the average of the 8 profiles of penetration made are calculated by step of 5 cm in depth.



CONTROL OF COMPACTION BY DYNAMIC PENETROMETER

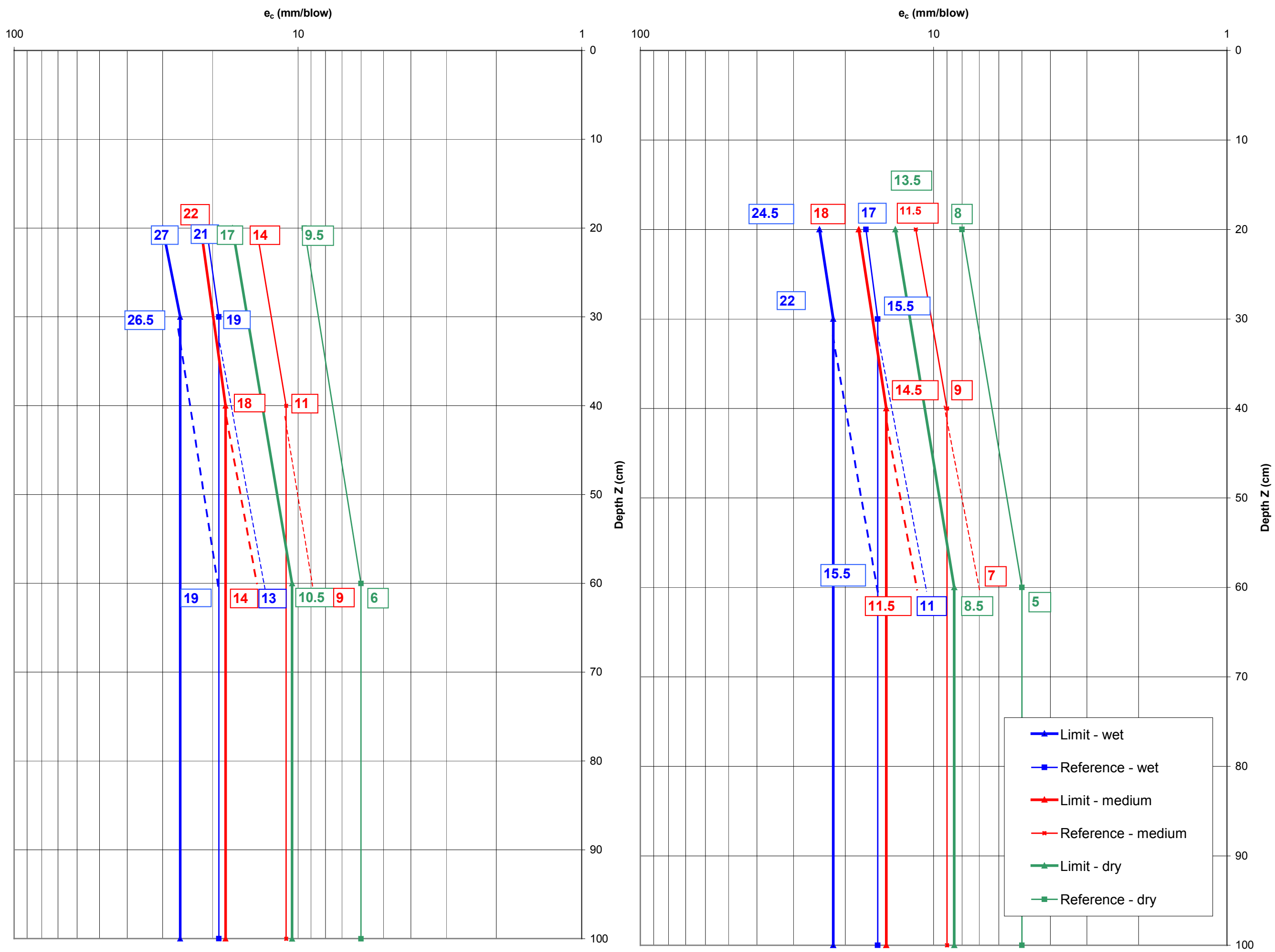


The final relation for the tested MSW slag is

$\log(e_c) = a.W + b.T + c.Z$

CONTROL OF COMPACTION BY DYNAMIC PENETROMETER

After a control, the penetrometer must not overflow on the left of the limit line corresponding to the moisture class of the material, to conclude to a compliant quality to the one that would result from the application of conditions of compaction.



Limit and reference lines in objective q4 embankment (on the left) and in objective q3 capping layer (on the right) for the tested MSW Slag

CLASSIFICATION OF MSW SLAG WITH MOISTURE CAPACITY

The whole tests realized had for conclusion to suggest to modify the bounds of moisture classes wet and medium and to place the new borders for the MSW Slag like this:

Limit wet/medium = 1,10xW_{OMC} instead of 1.20xW_{OMC}

Limit wet/very wet = 1,20 x W_{OMC} instead of 1,30 x W_{OMC}

ASSESSMENTS OF SITU BEARING CAPACITY

Measurements of modulus made with static plate Ø 600 mm or with the Dynaplaque 2 have been done on the whole of the test sections. The values are around 20 MPa in the wet moisture, and near of 50 MPa to the medium and dry moisture conditions, however without passing this value.

The use of the MSW Slag confirms the observations made during the laboratory tests on the atypical behaviour of the material. Whereas the sensivity with water exists (rubber cushion when wet), the MSW Slag has a greatly draining behaviour: it changes on one day from a wet, to a medium state near the optimum moisture content.

CONCLUSIONS

The experiment defines the possibilities to use the tested MSW Slag without treatment in embankments and in capping layers.

The marginal character of this material is confirmed: in one hand, the conditions of compaction are close to a natural soil between a very silty and an argilous ones but, in other hand, its porosity, its important friction, its strong evolution under stresses, and its draining properties do not permit to deduce its mechanical behaviour from the natural soils above. For these reasons, specific tables of compaction conditions have been determined.

These experiment are going on with similar tests, realized on another nature of MSW Slag from Paris area, to widen the conclusions