Universitatea Tehnică de Construcţii Bucureşti

SOCIETATEA ROMANA DE GEOTEHNICĂ ŞI FUNDAŢII

Norme technique roumaine sur les sols affaissables NP 125-2010: Principes d'identification et de conception des ouvrages

Romanian technical norm for collapsible soils NP 125-2010: Principles of identification and design

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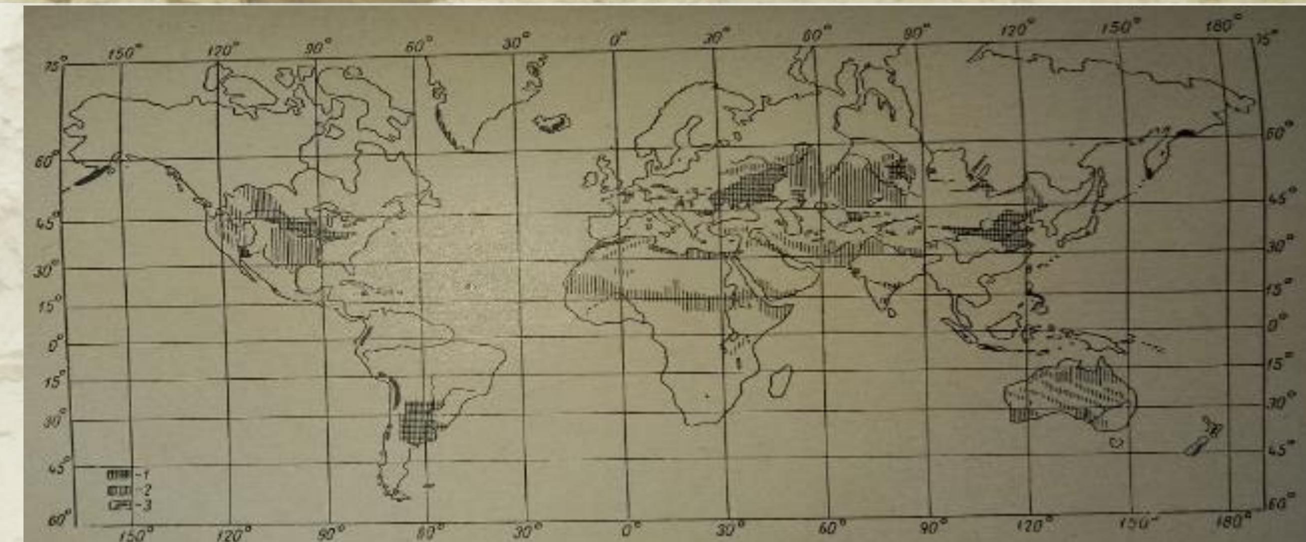
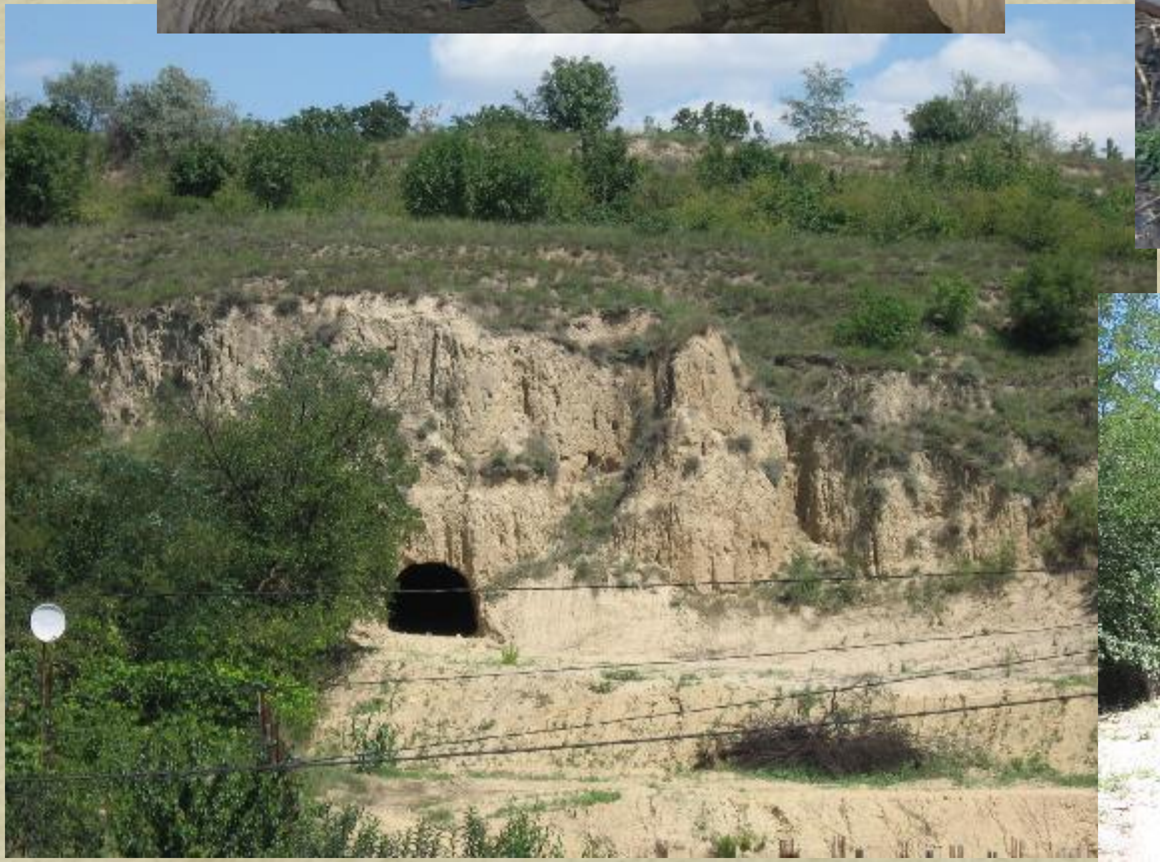
Distribution of loess and loessoid soils in world and in Romania



In Romania the loessoid soils covers significant areas – about 17 % of the territory.

What is LOESS? Existing tunnel in Dobrogea area and site investigation



Definition of loessoid soils

The soils sensitive to wetting (collapsible soils) are defined as unsaturated macroporic cohesive soils, which on contact with water undergo sudden and irreversible changes of internal structure, as reflected by additional settlements nature of collapse and decreases in behavioral parameters geotechnical engineer.

In this category are loessoid soils and other soils mainly silty with high porosity, marked uneven.

Additional settlements defined as the vertical deformation of sensitive to water soils manifested with increasing humidity, with values greater than those of the soil in its natural state at the same state efforts.

Additional settlement may occur under the own weight of wetted layer (Img) and under the action of compressive loads transmitted by the foundations (Imp).

In terms of how the settlement occurs, the loess is classified in two groups:
- Group A: loess having additional Img less than 5 cm;
- Group B: loess having additional Img equal to or greater than 5 cm.

In accordance with national rules (NP074:2022 and NP125:2010) and EUROCODE
- collapsible soils are defined like *difficult soils;*
- generally the sites where the foundation soil is sensitive to wetting the *geotechnical risk is moderately or major, resulting the requirements for geotechnical investigations.*

The influence of wetting in the behavior of LOESS

The evolution of technical norms regarding collapsible soils in Romania

- 1964: D-7-64 Instructiuni tehnice pentru proiectarea si executarea constructiilor hidroameliorative pe *pamanturi macroporice sensibile la inmuiere*; ***macroporic soils sensitive to wetting***
- 1967: C7-67 Normativ pentru proiectarea si executarea constructiilor fundate pe *pamanturi macroporice sensibile la inmuiere*; ***macroporic soils sensitive to wetting***
- 1962: C29-62 Normativ pentru proiectarea si executarea consolidarii terenurilor din *pamanturi macroporice* cu piloti din pamant batut; ***macroporic soils***
- 1973: C7-73 Normativ pentru proiectarea, executatrea si exploatarea constructiilor fundate pe *pamanturi sensibile la umezire*; ***sensitive to wetting soils***
- 1978: P7-77 Normativ privind proiectarea si executarea constructiilor fundate pe *terenuri slabe*; ***difficult soils***
- 1978: C29-77 Normativ privind consolidarea *terenurilor de fundare slabe* prin procedee mecanice; ***difficult soils***
- 1992: P7-92 Normativ privind fundarea, executarea si exploatarea constructiilor pe *pamanturi sensibile la umezire;* ***sensitive to wetting soils***
- 2000: P7-2000 Normativ privind fundarea constructiilor pe *pamanturi sensibile la umezire* (proiectare, executie, exploatare); ***sensitive to wetting soils***
- 2010: NP125:2010 Normativ privind fundarea constructiilor pe *pamanturi sensibile la umezire*. ***sensitive to wetting soils***

Characterization of loessoid soils

To characterize a soil as sensitive to wetting should have at least one criteria related to physical properties and one criteria related to mechanical behavior.

In this connection were imposed physical identification (I) and mechanical (II) criteria as follows:

I.1. cohesive soil with silt 50 ÷ 80% in unsaturated state (Sr <0.8) and the natural porosity n> 40%.

I.2. Index

$$I = \frac{e_L - e}{1 + e}$$

with values between 0.10 ÷ 0.30 depending on the plasticity index Ip = 10 ÷ 22%, where e is the void ratio in natural state and e_L is the void ratio at the liquid limit of plasticity, w_L of the soil.

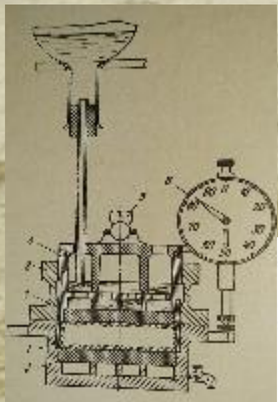
II.1. the index of additional settlement to wetting under the load of 300 kPa (in oedometric test i_{m300} > 2%).

II.2. the indexes η and δ related to soil settlement in natural and flooded state (in plate load test) have values:

$$\eta = \frac{s_i}{s_n} \geq 5 \qquad \delta = s_i - s_n \geq 3 \text{ cm},$$

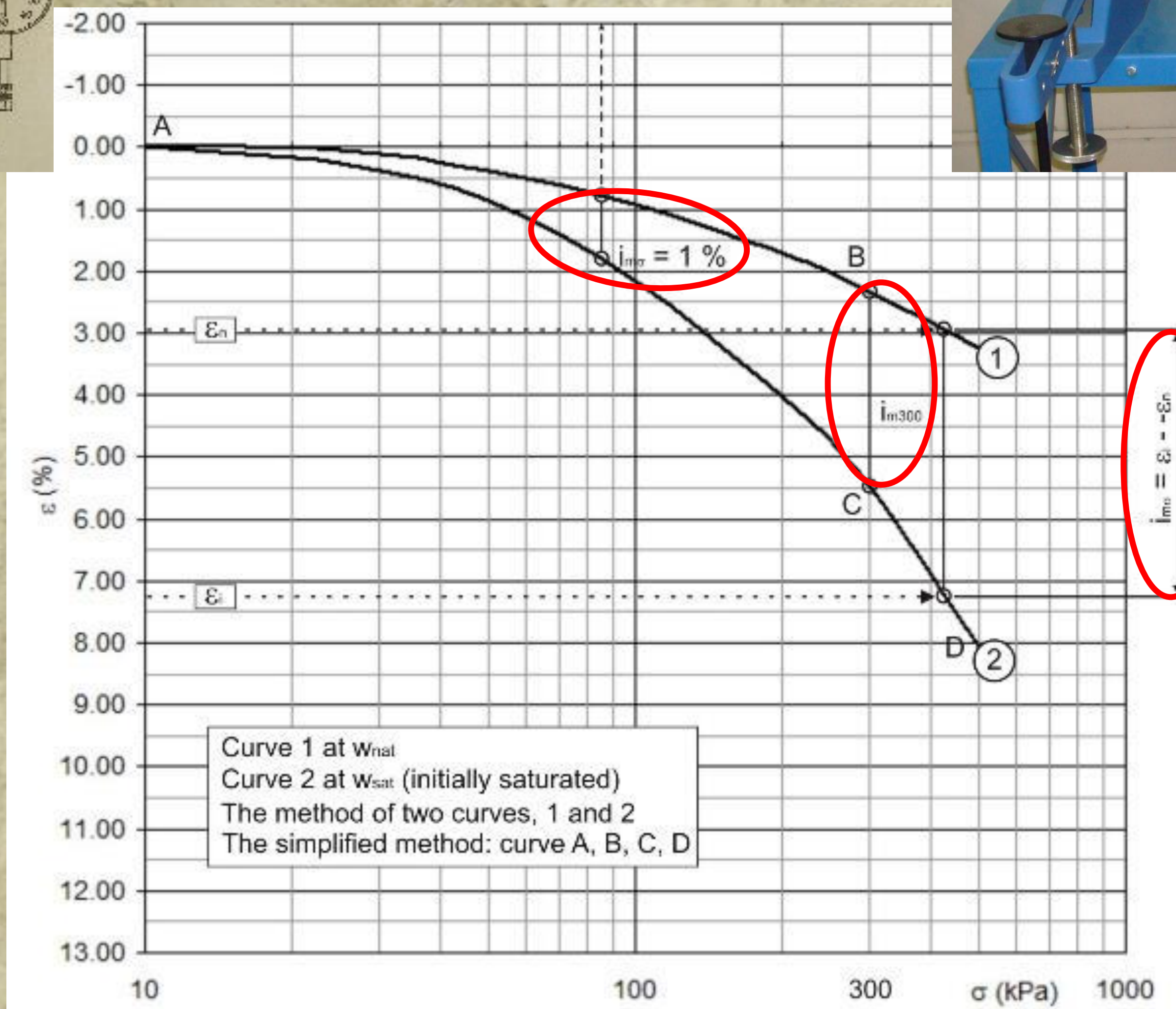
where s_i is submerged soil settlement and s_n is the settlement at natural moisture content as determined by plate load test under the pressure of 300 kPa.

Specific oedometric tests on loess

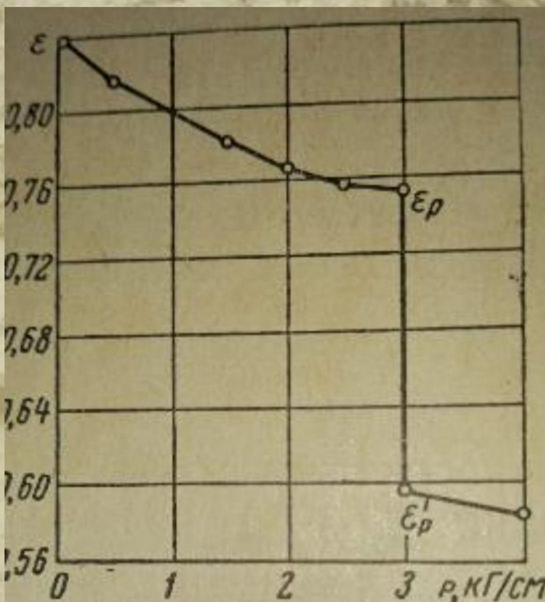


1968- ABELEV

UTCB LABORATORY



Specific oedometric tests on loess



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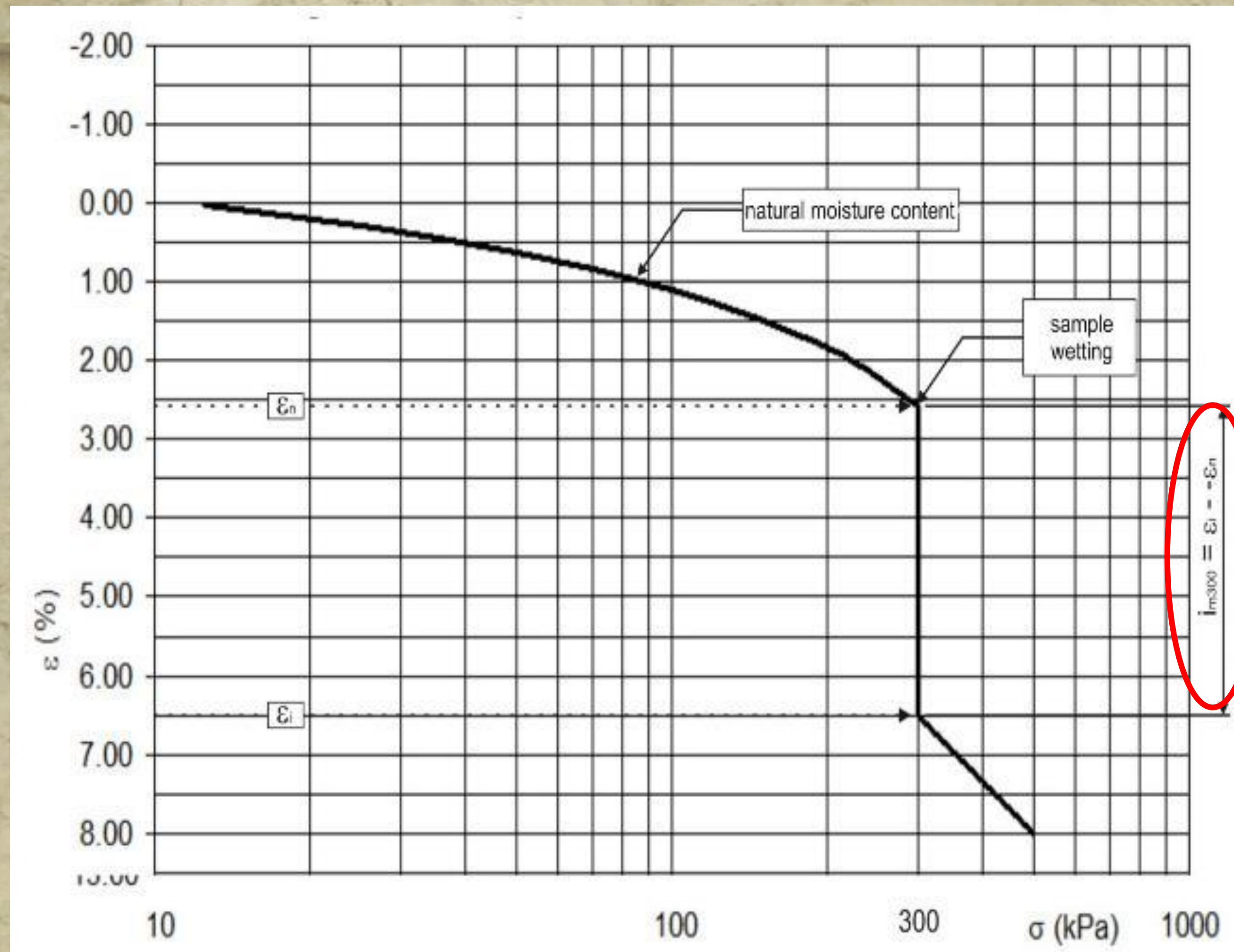


Typical values for geotechnical parameters of loess and loessoid soils

Geotechnical parameter	Symbol	U.M.	Characteristic value
Skeleton density	ρ_s	g/cm³	2,52 - 2,67
Unit weight of the soil	γ	kN/m³	12,0 - 18,0
Dry unit weight of the soil	γ_d	kN/m³	11,0 - 16,0
Porosity	n	%	40 - 55
Plasticity index	I_P	%	5 – 22
Index of additional settlement to wetting at σ = 300 kPa	i_{m300}	%	2 – 14
Oedomertic modulus	$E_{\text{oed 200-300}}$	kPa	5000 - 15000
Internal friction angle	φ	grade	5 – 25
Cohesion	c	kPa	10 - 30

Geotechnical design in the case of loess

Starting from the EUROCODE definitions, the following rules have been established with respect to the geotechnical design in the case of loess:

- it is accepted the use of “geotechnical design based on prescriptive methods” only for preliminary calculations, by the use of accepted pressures established based on an experience of about 50 years in Romania.

- the use of “in situ tests” by wetting is accepted only in experimental plots outside the constructed area, without affecting it.

- “observational method” is applied when it is considered that the forecast of the construction and foundation system behaviour is not realised with enough precision in the design stage or for the consolidation of an existing structure.

Geotechnical design by calculation

For the design of the foundation solutions on collapsible soils, the following will be taken into account:

- for the verification at normal exploitation limit state, differential settlements of the foundations will be limited in order to avoid appearance of any limit state in the structure;

- the compatibility of the deformations reached in ultimate limit state will be taken into account, by analyzing the relative rigidity of the structure and soil;

- the choice of the geotechnical actions, based on the destination and lifetime of the construction, will be considered those resulted from wetting (saturation) of the soil taking into account:

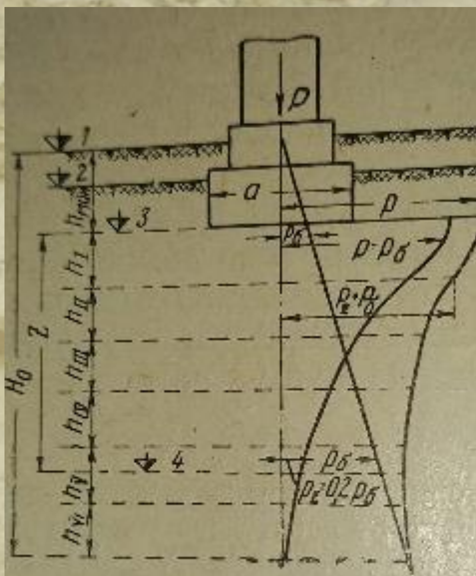
  • the source and the type of the wetting (local, general);

  • the direction of wetting, which can be gravitational or generated by the rising of the groundwater table;

  • speed and direction of the groundwater flow, that can have alternately different directions (irrigational canal, shore);

- in the case of pile foundations embedded in a layer non-sensitive to water, beneath a loess layer, if the wetting is possible and the settlement under the weight of the soil can occur, if will be considered the negative skin friction on the piles.

Calculation of the foundation soil



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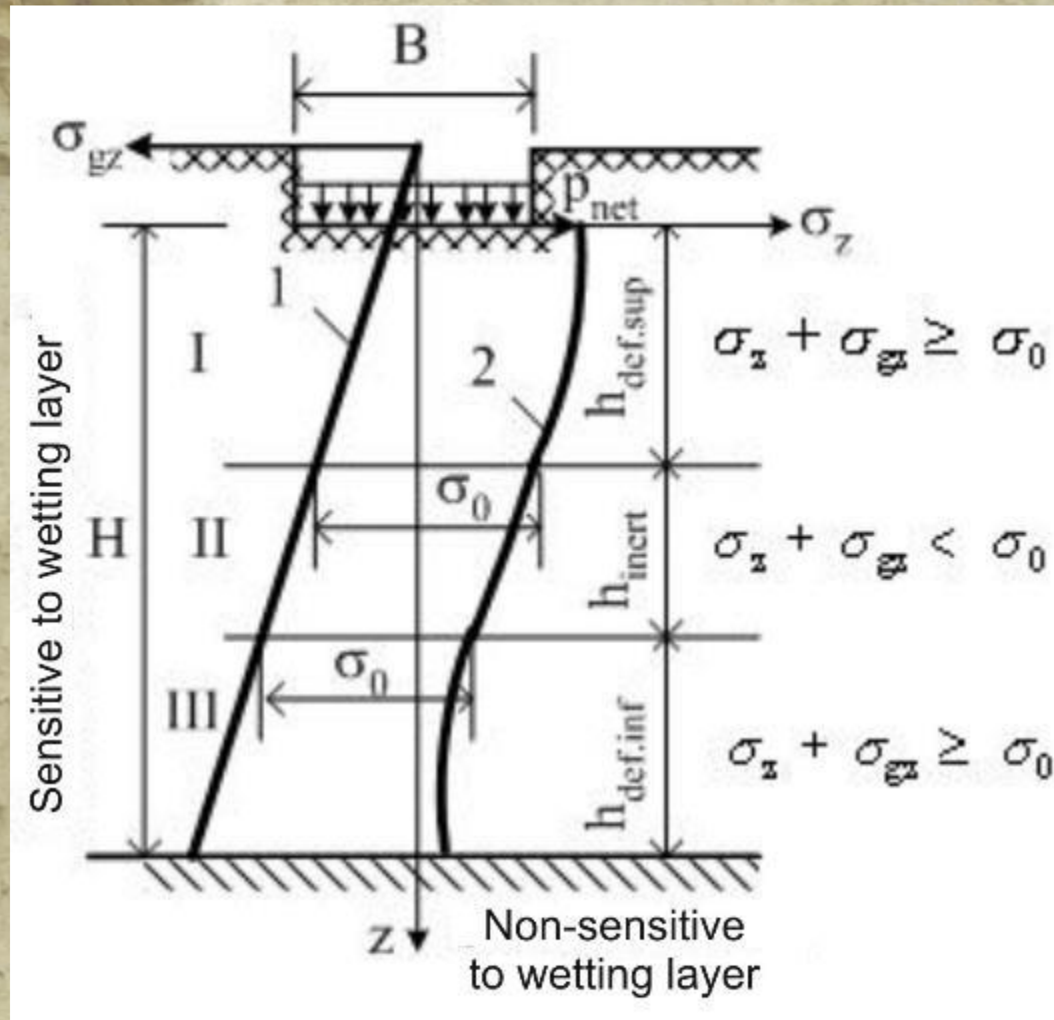
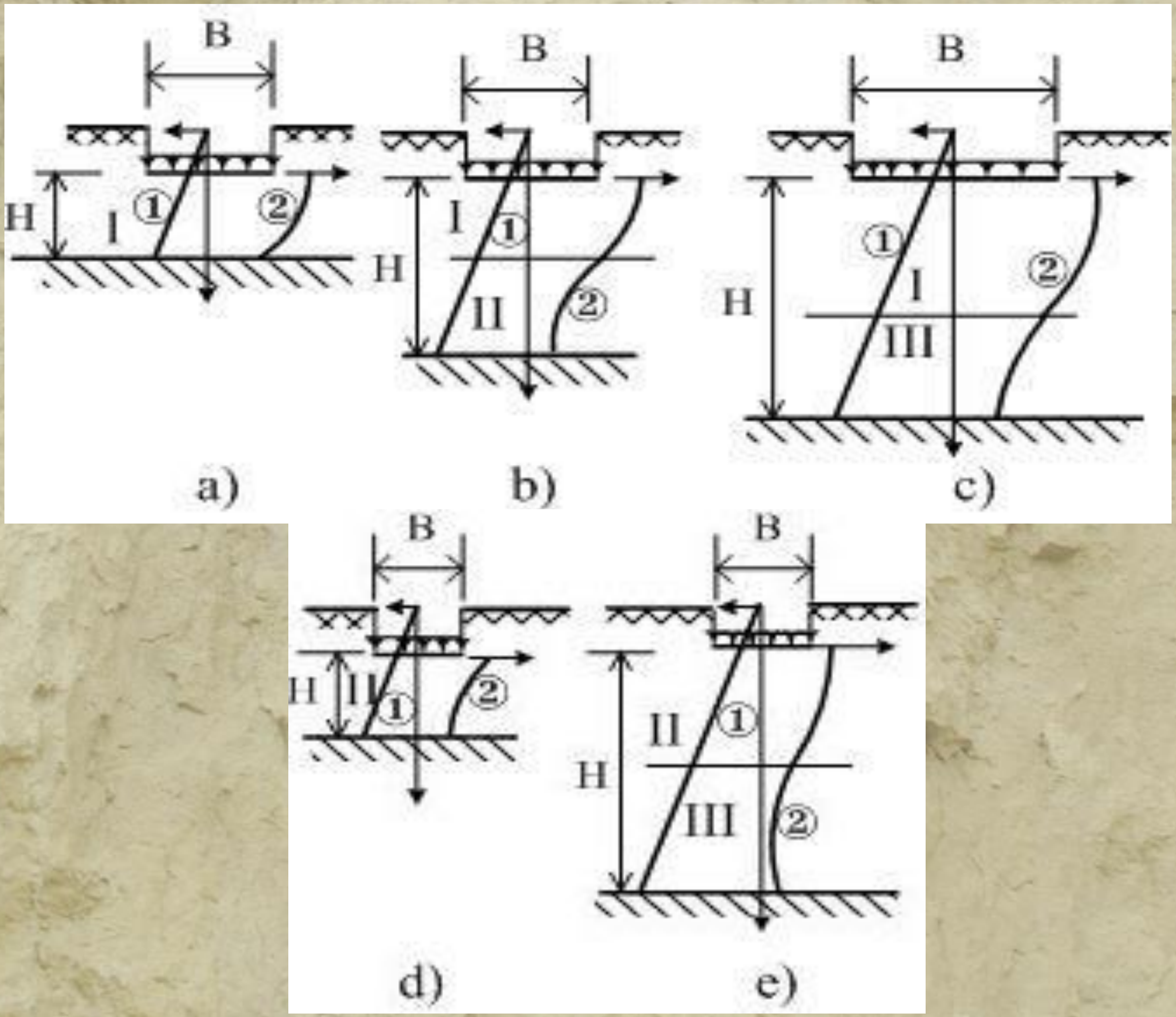


1969- BOTEA, STANCULESCU, BALLY, ANTONESCU, MANOLIU

Characteristic zones in the foundation soil composed of collapsible soils:
I – deformable upper zone; II – inert zone; III – deformable lower zone;
1 – the variation of σ_{gz} versus depth; 2 – the variation of σ_z versus depth

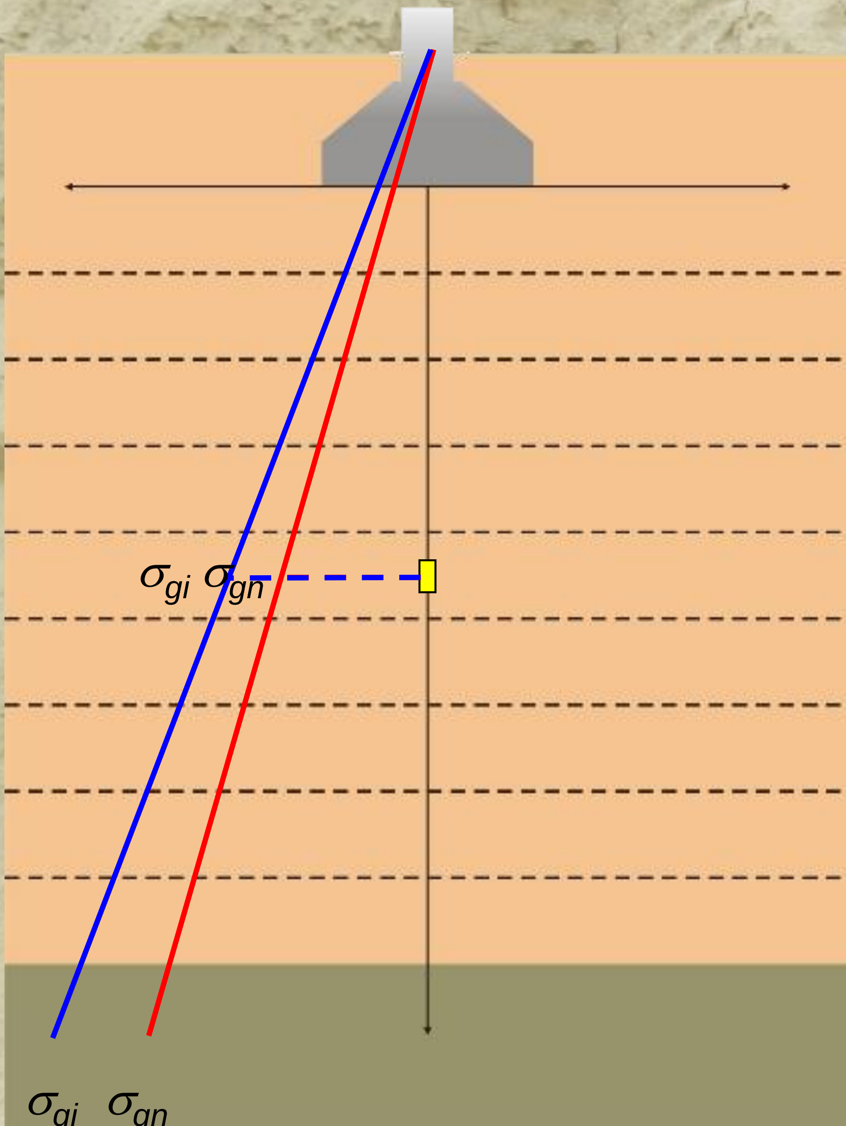
Characteristic situations for the foundation soil composed of a layer sensitive to water

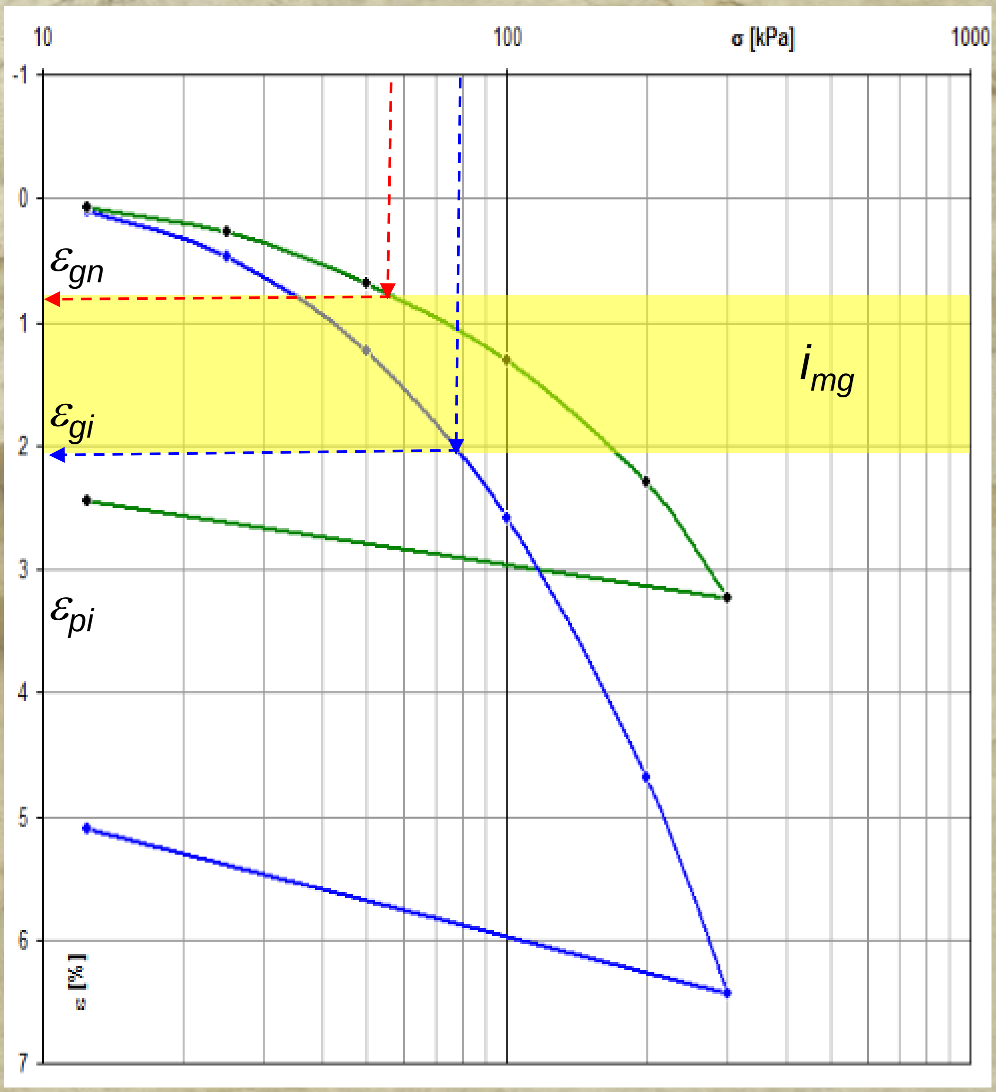


I – deformable upper zone; II – inert zone; III – deformable lower zone;
1 – the variation of σ_{gz} versus depth; 2 – the variation of σ_z versus depth

Calculation of additional settlement calculation by wetting (Img) under the own weight for all thickness of the soil layer ($i_{m300} \geq 2$ %)

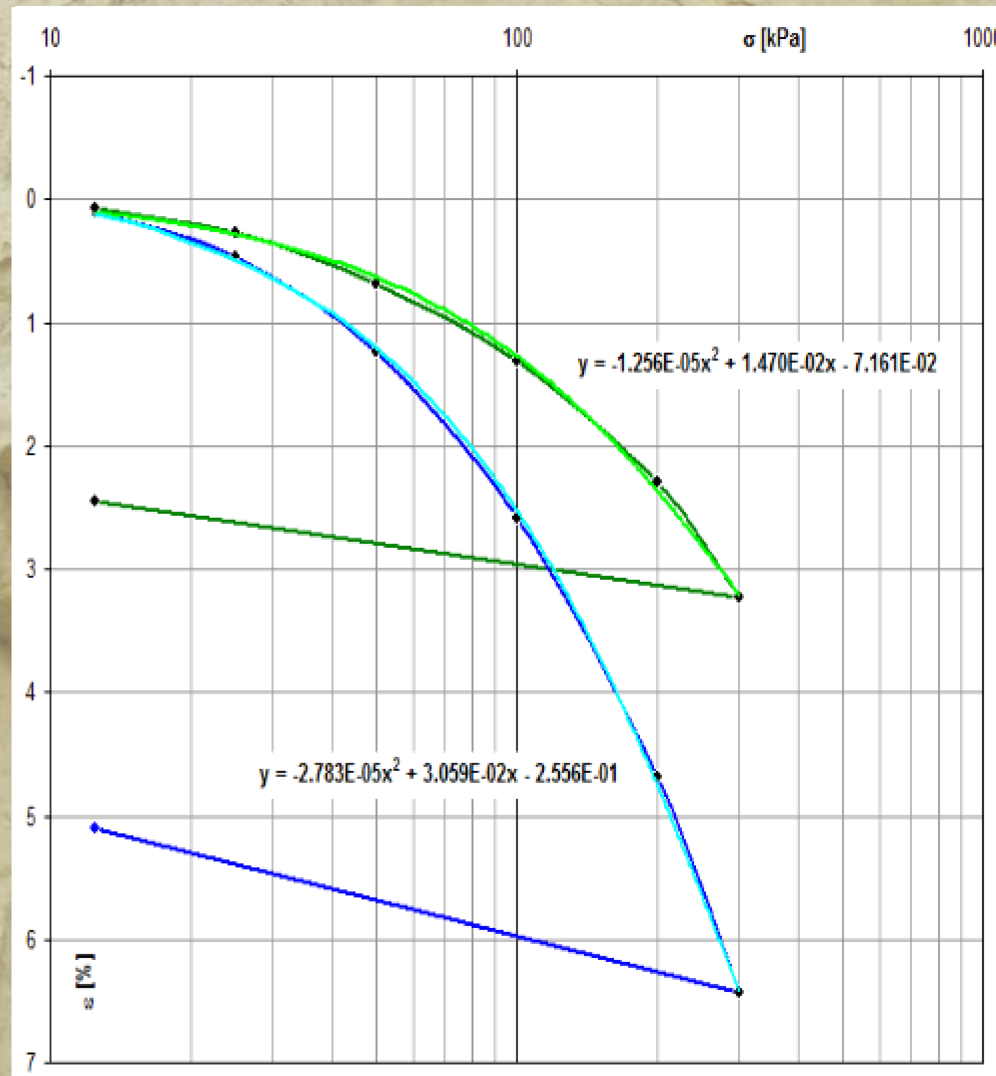
$$I_{mg} = \sum_{1}^{N} i_{mg} \cdot h_i$$





Calculation of additional settlement calculation by wetting under the action of compressive loads transmitted by the foundations (Imp) for deformable zone

$$I_{mp} = \sum_{1(D_f)}^{N'} i_{mp} \cdot h_i$$



Measurements for the choice of the foundation solutions

The following measures should be taken into account for the choice of the foundation solution on a foundation soil consisting of loessoid soils:

- *prevention of soil wetting*;

- *soil improvement* by different technologies following the formation of a new internal structure for the entire layer (desensitization to wetting). Can be considered:

  • intensive compaction;
  • injection by silication
  • thermic treatment;
  • compacted columns of concrete or local materials; **it is forbidden to use only granular permeable materials**.

- *construction of a compacted cushion above* the layer of collapsible soil; **it is forbidden to use only granular permeable materials**;

- *replacement* of the collapsible soil layer by excavation and controlled soil fill with adequate materials.;

- *consuming of the additional settlements* by wetting through:

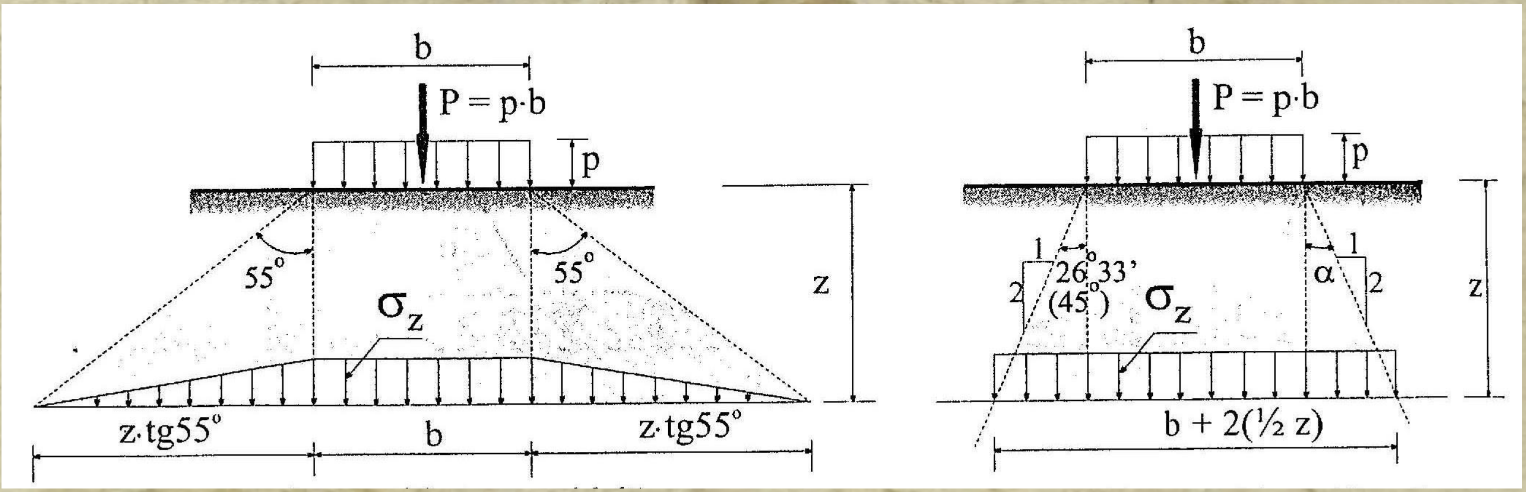
  • controlled wetting;
  • saturation under supplementary load;
  • deep explosions.

- selection of *indirect foundation system* (piles, barrets, etc…) embedded in a non-sensitive to water layer.

Applied solutions

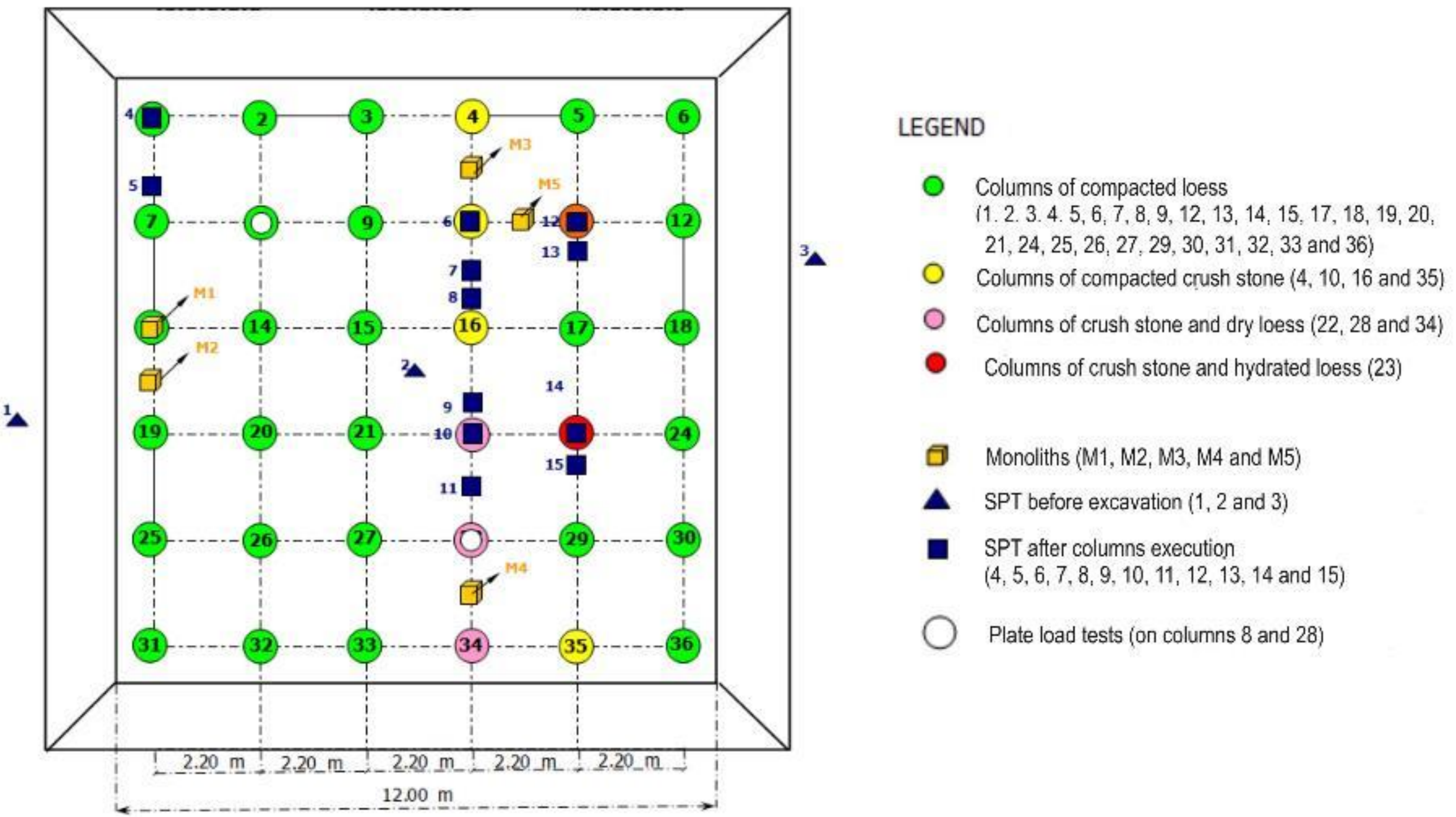
The solution most commonly used for constructions with fell height regime such as platforms, parking lots, access roads, etc..., is the "cushion of compacted loess”. It has proven its effectiveness and applicability to depths of about 3 to 3.5 m, being designed by the allowable pressures of the soil.

In the figure below an overview of a site for a landfill for low radioactive residues in Cernavoda area, where because the thickness of about 10 to 12 m of dry loess layer sensitive to wetting and operating loads, compacted cushion needs are beyond the normal depths (more than 4 m) resulting in the choice of alternatives.



Distribution of load pressure under the cushion in different theories

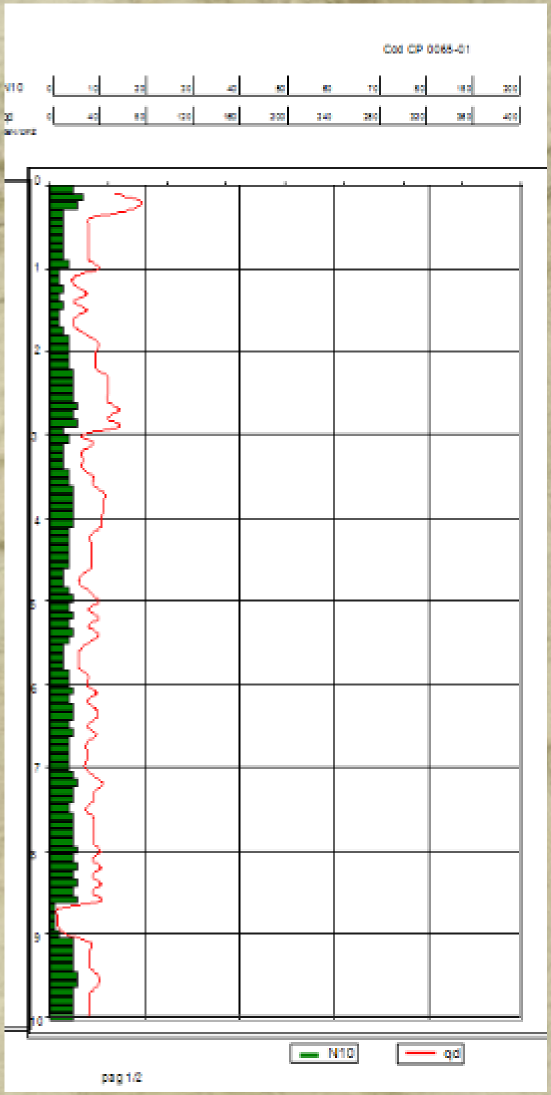
Layout of test pad in Cernavoda site



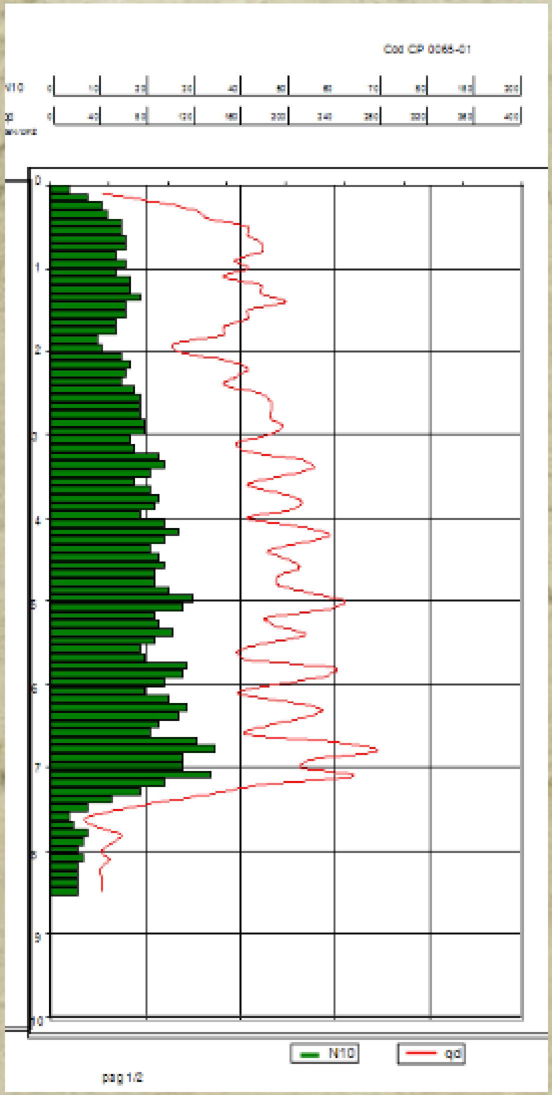
If this site has proposed improving the depths of 10 to 12 m by making inclusions - columns of natural material to desensitizing the layer (compacting between columns) and also to provide and taking the required loads.

Heavy dynamic penetration diagrams

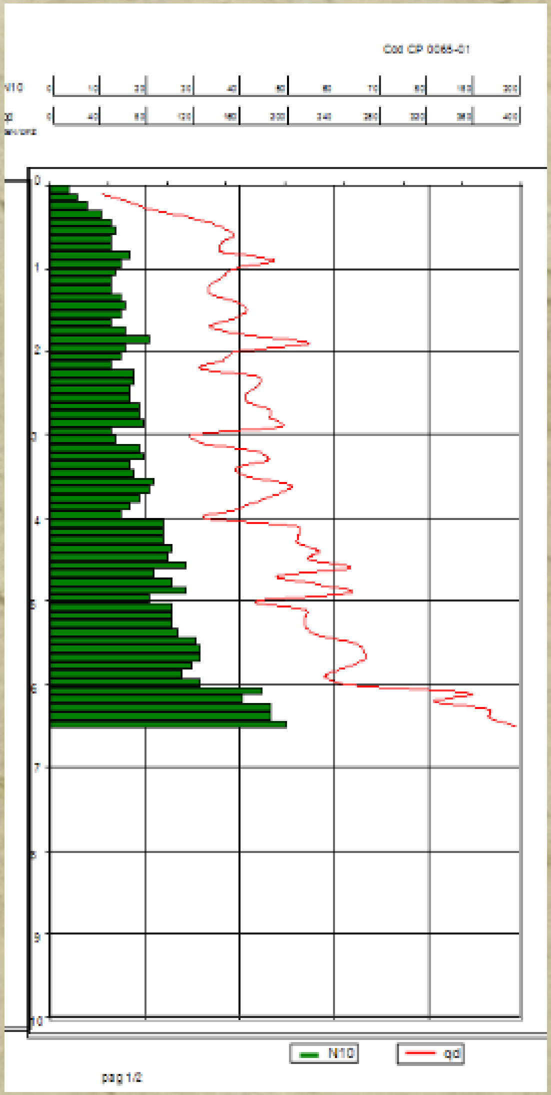
In a polygon test was intended for an available technology (GEOPIER) the efficiency columns made by drilling and filling controlled mixture of loess and stone, based on dynamic penetration testing.



a) natural terrain



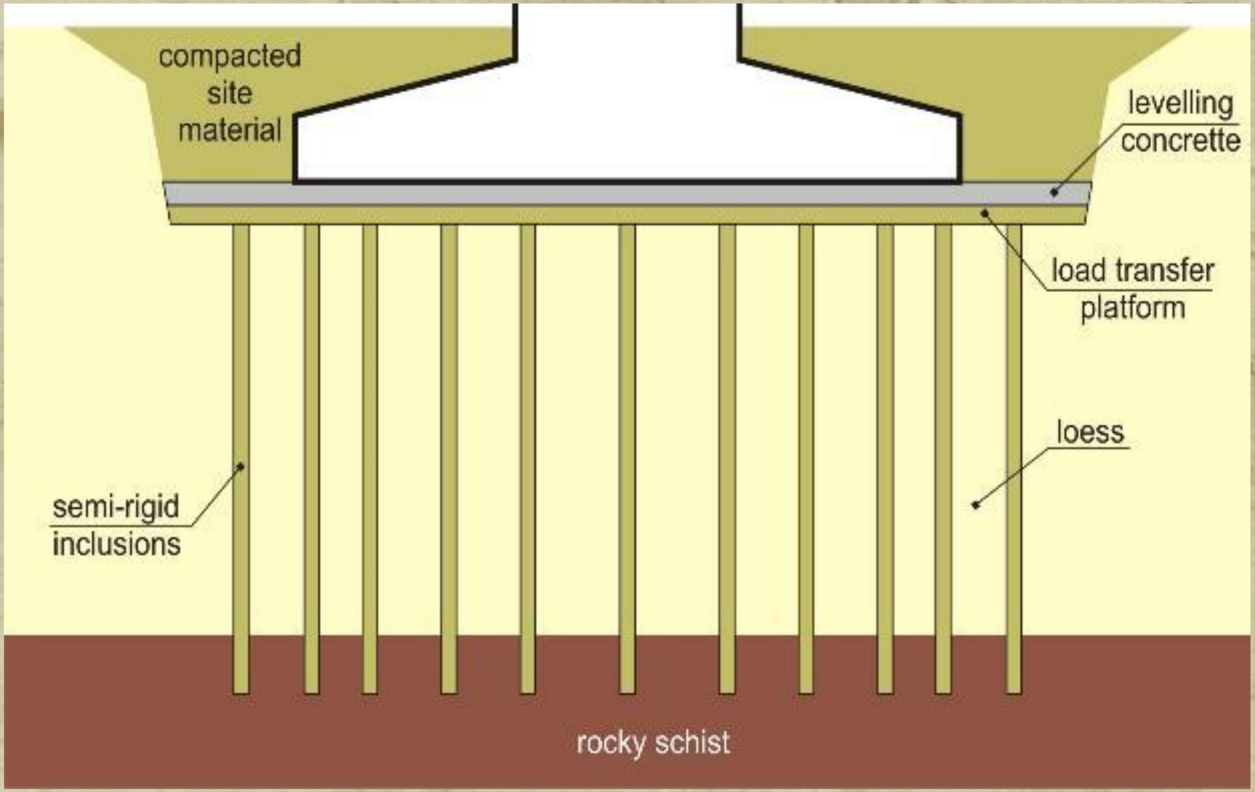
b) stone columns

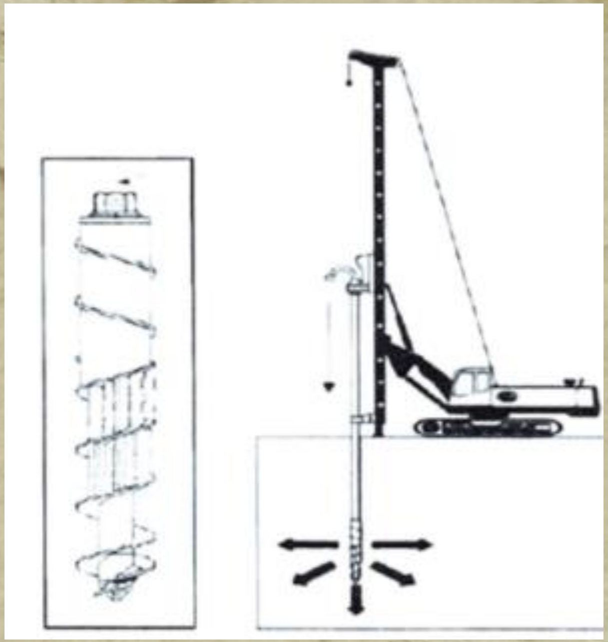


c) columns made of mixture of loess and rock

Foundation solution applied for windmill turbines in Dobrogea

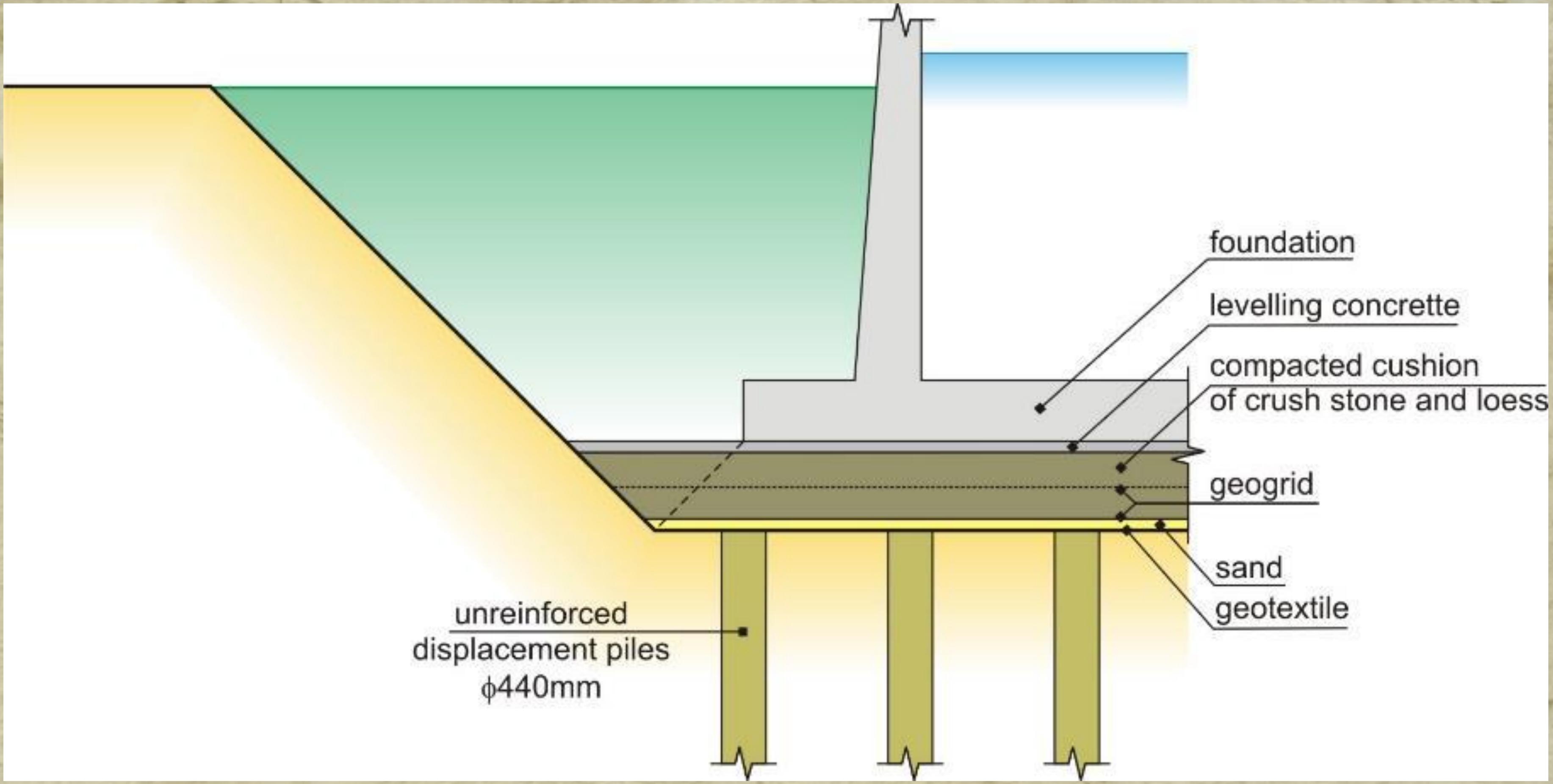
For a windmill farm (about 130 turbines) located in Dobrogea region, variable thickness of the layer of dry loess rests on a rocky foundation - system has led to the solution to improving the soil by simple concrete inclusions – piles with a diameter of 40 cm and lengths up to 25 m. Direct foundation has done on this field using an improved load transfer platform about 55 cm thickness composed of loess treated with cement.





Foundation solution applied for WWTP tanks in Braila and Galati

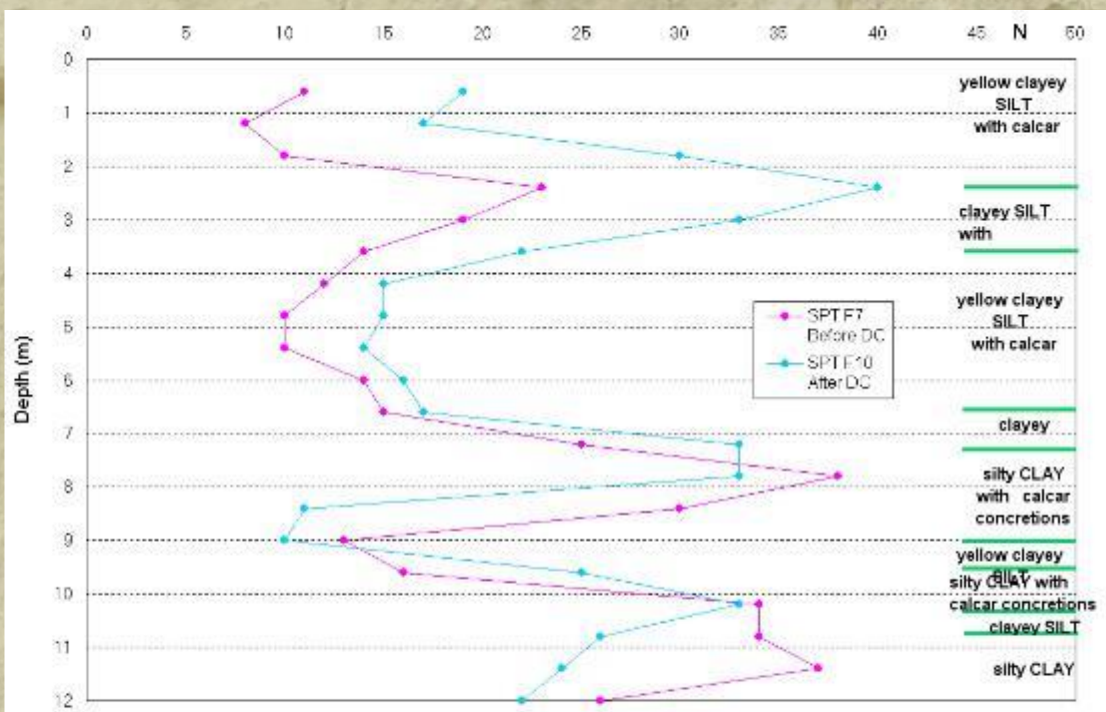
The same principle of soil consolidation to allow direct foundation solution was applied for waste water treatment plants from Braila and Galati where loess layer placed on a layer of sand and gravel located at depths of up to 32 m is partially flooded presenting tend to saturate the entire thickness by raising groundwater. In Braila WWTP have been used simple concrete piles (C16/20) with a diameter of 40 cm and lengths 23.5 m. Platform transfer in this case was taken from the granular material reinforced with geogrids.



Improvement of the foundation soil by dynamic compaction on a national road in the neighborhood of Constanta, for a depth of 2 to 8 m loess layer under an embankment of about 6 m.

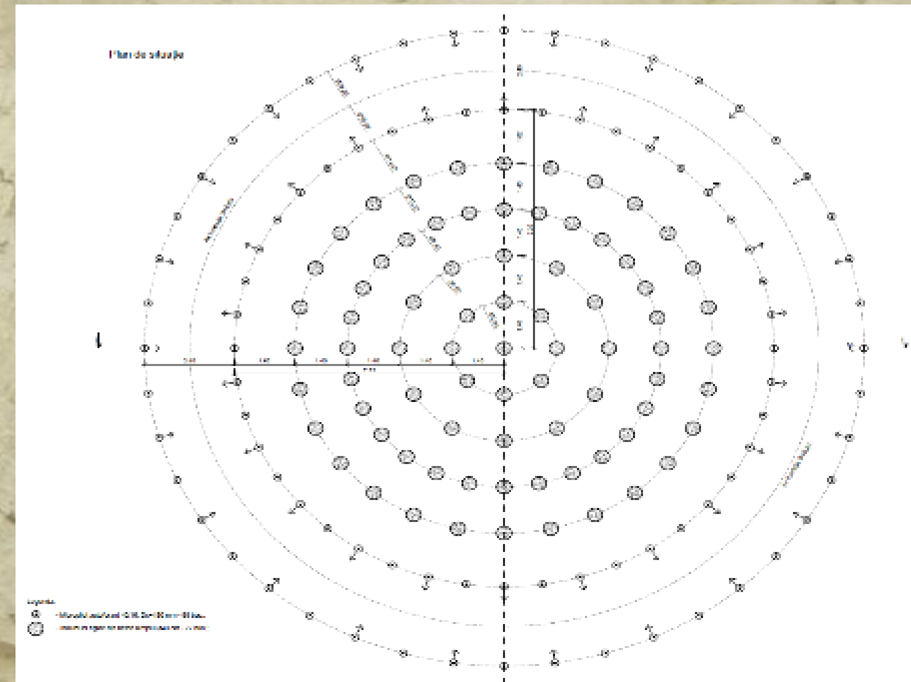
DC technique was applied to improve soil bearing capacity, under the proposed embankments, to reduce differential settlements and mitigate the collapse potential of loess.

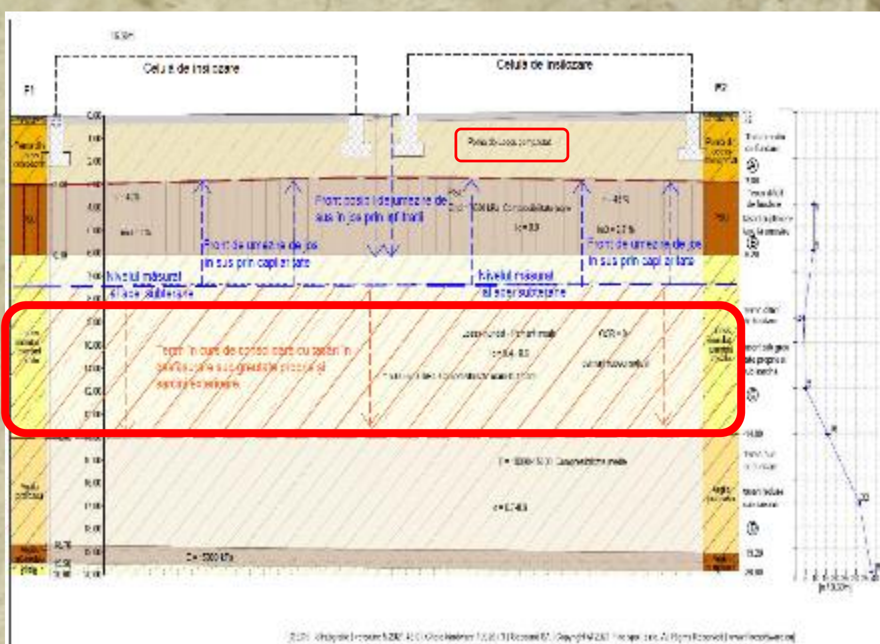
After compaction the soil will not suffer additional settlements under its own weight or under external loads. Prior to compaction, the ground could have suffered additional non-uniform settlements with values between 15 - 40cm.

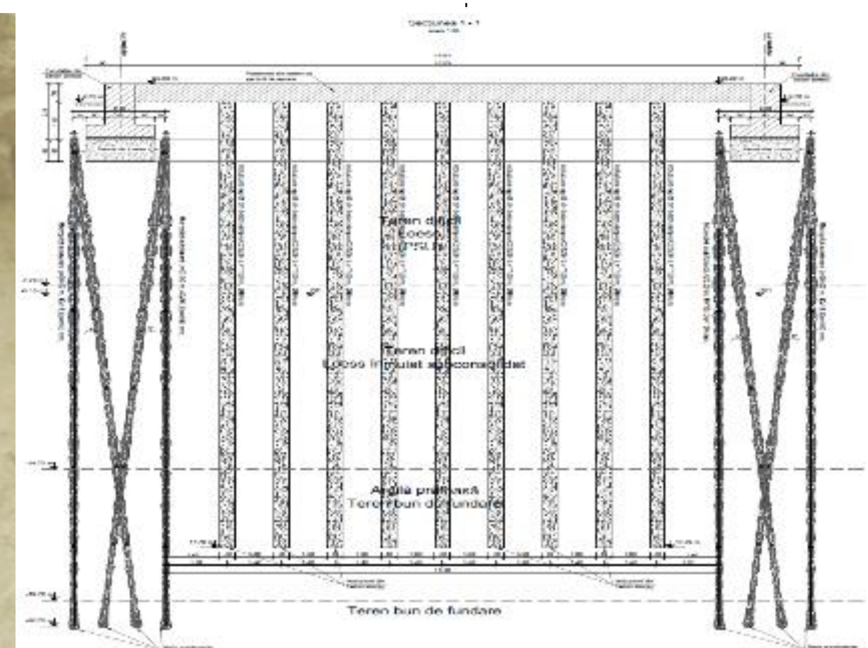


SPT values before and after dynamic compaction

Consolidation of existing silos affected by additional settlements by wetting in South Romania







Conclusions

The existence of areas in Romania with the foundation soil consists of loess and loessoid soils required to develop specific design norms, which have been connected to the principles EUROCODE.

The primary requirements relate first to investigate this soil and set values for calculating the specific geotechnical features, showing the behavior in relation to water.

Geotechnical design calculations for the ultimate limit state is the GEO limit state, assuming wetting of the soil.

Foundation design solutions must take into account the specific behavior of these soils and provide special constructive measures. These measures refer primarily to prevent wetting of the soil and its desensitization. Improved land foundation solutions applied in recent years in Romania show a number of advantages over indirect foundation solutions.

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