Bulletin of the *Transilvania* University of Braşov • Vol. 10 (59) Special Issue No. 1 - 2017
Series I: Engineering Sciences

CONSIDERATIONS ON THE DETERMINATION OF STRATIFICATION BY DYNAMIC PENETRATION IN SOILS

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Abstract: *The dynamic penetration interpretation in soil investigations involves many approximations, being an indirect method. It is widely used for assessing the geotechnical characteristics, especially for uncohesive soil, also for expanding direct investigations. Determination of stratification based on a reference direct method often leads to errors due to the interference between the different properties of the deformation modules of different layers. The article proposes a method of correcting penetration results to reflect with greater accuracy the stratification of the soil*

Key words: *soil investigation, dynamic penetration , lithology, strata limits.*

1. Introduction

Dynamic penetration is an indirect method of soil investigating in geotechnics. The principle of determination consists in driving of a metallic rods with a cone on the effect of multiple shocks and the recording of the number of blows required for penetration at a certain depth.

Based on the device's characteristics, the energy used can be calculated that is proportional to the resistance of the soil. The most used formula for calculating resistance to dynamic penetration, Rpd, is the Dutch formula:

$$Rpd = G^2 \cdot h / [A \cdot e \cdot (G + P)] \quad (1)$$

where:
G – is the weight of the hammer;
h - The height of free fall of the hammer;
e - the penetration depth on a hit;
A - the maximum section of the cone;
P - the weight of the beating system (rods, anvils, etc).

Based on this resistance to dynamic penetration, some geotechnical indices can be evaluated [1] [2], but it is a question of choosing the values that characterize the layer.

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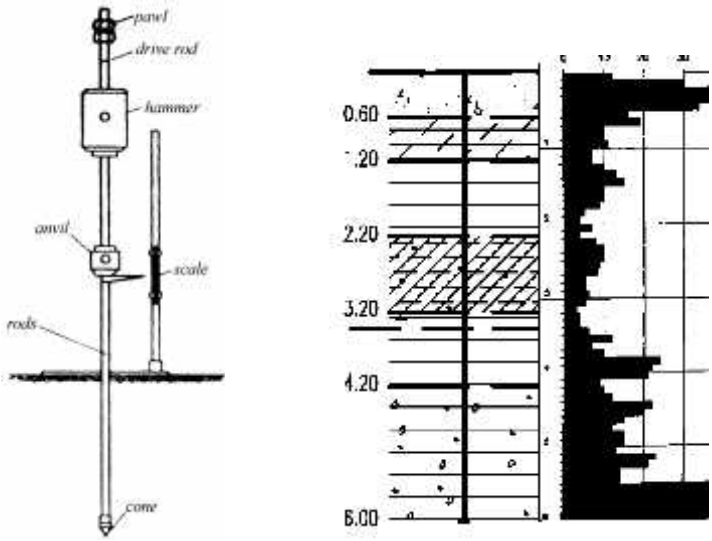

Fig. 1. a) *Dynamic penetrometer (sketch) and b) Example of results of a borehole investigation related to a dynamic penetrations (graph of blow number vs. depth).*

The number of blows is not constant over within a layer for several reasons:

- No layer is perfectly homogeneous. Sediment deposition has a fairly long period, it is hard to assume that the conditions of disaggregation, transport and deposition of sediments are repeated identically in the mid-decades, centuries or millennia. On the other hand, the sediment pile acts by its own weight on older deposits;
- As the penetration advances in depth, the weight of the ensemble that acts on the ground changes, and the friction force on the rods increases;
- In the vicinity of contact between different layers with different deformability the resistance to penetration changes due to the influence of the substrate, from the depth..

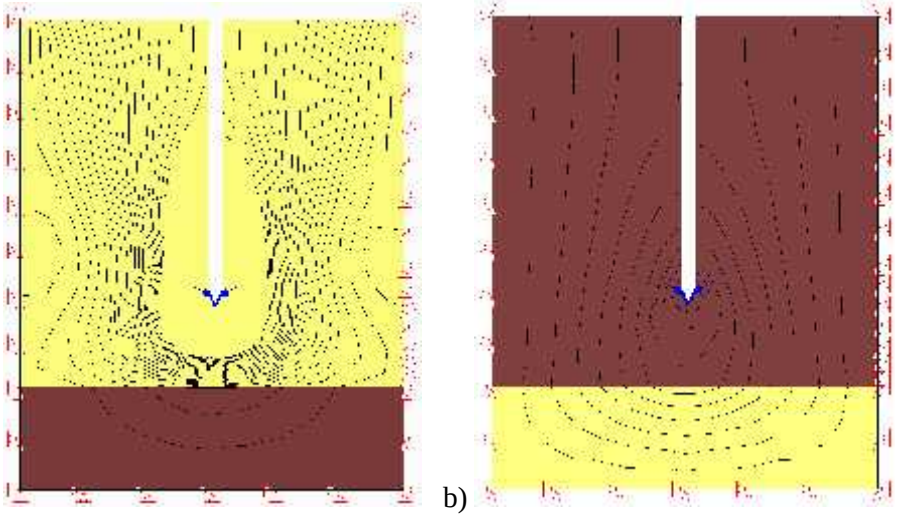

Fig. 2 *The distribution of vertical deformations in dynamic penetration in the case of two layers of which a) the one above is softer and b) the one above is stiffer*

On this last alteration of the results we want to make some considerations especially that the method is used for this purpose - the determination of the stratification of a field. Direct investigations, drills are frequently extended on a larger surface with this method, cheaper and faster. First is running a reference drilling or ditch near which a dynamic penetration is performed. The correlation between drilling results and penetration is essential because it extrapolates over the whole field. There are currently algorithms for determining stratification, but for static penetration [3].

2. Compressibility Influence of Two Different Layers on the State of Tension in the Soil

Tension in a system consisting of two layers is calculated on the basis of empirical approaches by tables or graphs prepared by Biot (1935) Burnmeister (1943, 1956), Fox (1948), Veshita and Meyerhof (1968) [4]. The most widespread current solution is given by Egorov expressing the effort transmitted in the field as fractions of the *p* load on the surface of the bilayer system:

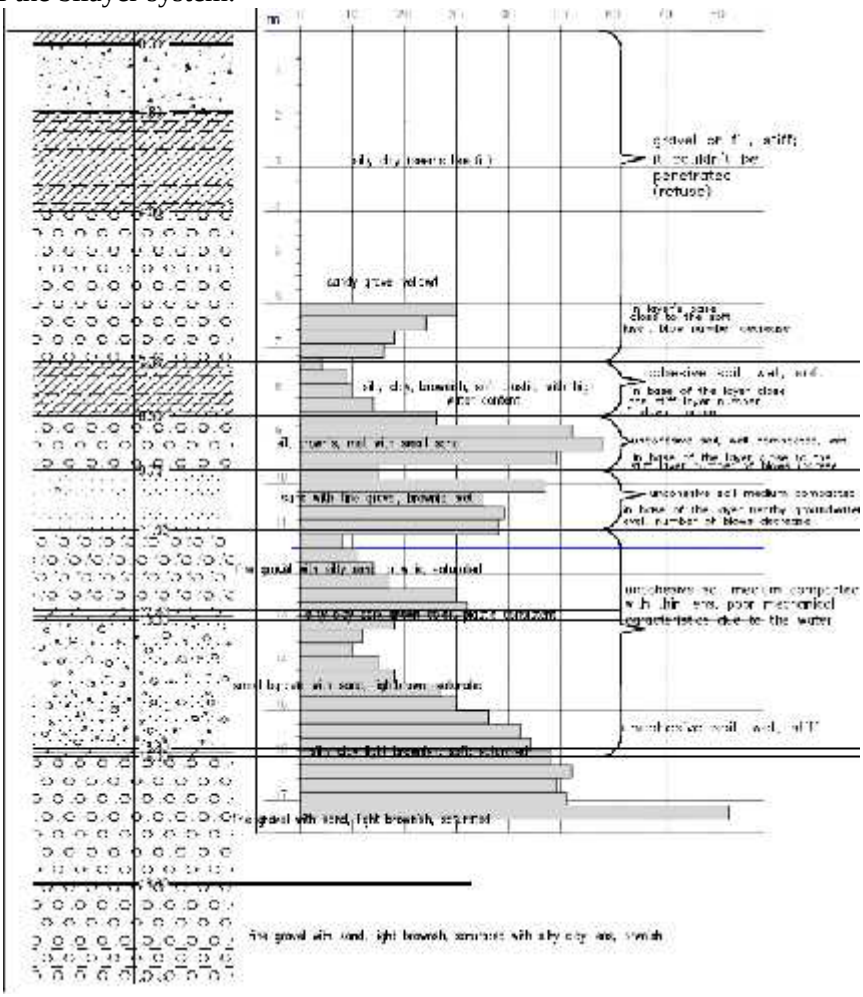

Fig. 3. *Detailed correlation beetwin borehole log and dynamic penetration results*

$$I = \frac{E_1}{E_2} \cdot \frac{1-\neg_2^2}{1-\neg_1^2} \quad (2)$$

where:
- E is the linear deformation module;
- ν is the lateral deformation coefficient.

Next, the approximate solution consists in modifying the thickness h_1 of the top layer by an equivalent height, such that the bilayer system is considered to be a single homogeneous layer.

$$h_{eq} = \sqrt{\frac{E_1}{E_2} \cdot \frac{¥_2}{¥_1}} \cdot \sim \cdot h_1 \quad (3)$$

where:
- E_1, E_2 is the linear deformation modulus of the upper and second, of the lower layer;
- γ_1 is the bulk density of the upper layer;
- γ_2 is the bulk density of the lower layer;
- α is a coefficient equal to 0.90 for earth and 0.83 for concrete.

If the top layer is softer, additional stresses accumulate at its base, near the stiffer layer. As a result, the resistance to dynamic penetration increases. Taken into account only the number of blows the thickness of the upper layer is apparently smaller than the reality.

On the contrary, when the upper layer is softer, the penetration energy dissipates at the base of the layer, and the number of blows decreases. As result based strict on the number of blows, the delimitation must be corrected according to the succession of the strata.

For the interpretation of penetration results, Rpd turns into N_{SPT}, meaning the number of equivalent strikes for the standard penetration test. Based on N_{SPT}, it can be evaluated linear deformation modules either as a dynamic or static.

Near the cone that is causing shocks the soil deformation occurs in the plastic domain. At a certain distance, where the waves are relatively large damped, deformation enters the elastic domain. The amplification factor for switching from dynamic to static, in case of shocks can be assumed as being equal to 3 [5] [6]. Even if this value is overlapping, given the relatively small dimension of the cone surface, the error does not essentially affect the depth that shock is amortized. The effort at which a piece of earth comes out of the elastic domain and enters into the plastic one, depends on the nature of the soil, the granularity, the saturation ratio and so on. The depth at which shocks propagate only in the considered layer and does not interfere with other strata can be considered the depth at which 0.2 equivalent static load is felt.

Second, the area chosen as significant must be homogeneous. The homogeneity criterion may be a variation of up to 15% of the number of blows for a minimum of three intervals for determining the number of blows (10 cm for DPL, 20 cm for DPM, 30 cm for DPSH).

3. Description of the Method of Delimitation of Lithological Strata

The method we propose can not completely replace the interpretation that the

geotechnician will finally make. In addition to interpreting data on the algorithm we propose, a certain empiricism based on experience and intuition should be added.

The first step is the delimitation of significant sequences of the penetration that can be clearly correlated with the drilling stratification. The significant sequence will be located somewhere in the middle of the layer. The median area must not interfere with other adjacent strata in terms of shock transmission

The wave shocks propagation at a certain distance depends on their magnitude, by the density of the soil and the depth at which it occurs [7].

The raw boundary delimitation can be based on the average of the blows that are having a mean square deviation below a required limit, which we consider to be optimal at the value of 3.0. These thicknesses shall be corrected and replaced with an equivalent thickness starting from the top to the lower ranges.

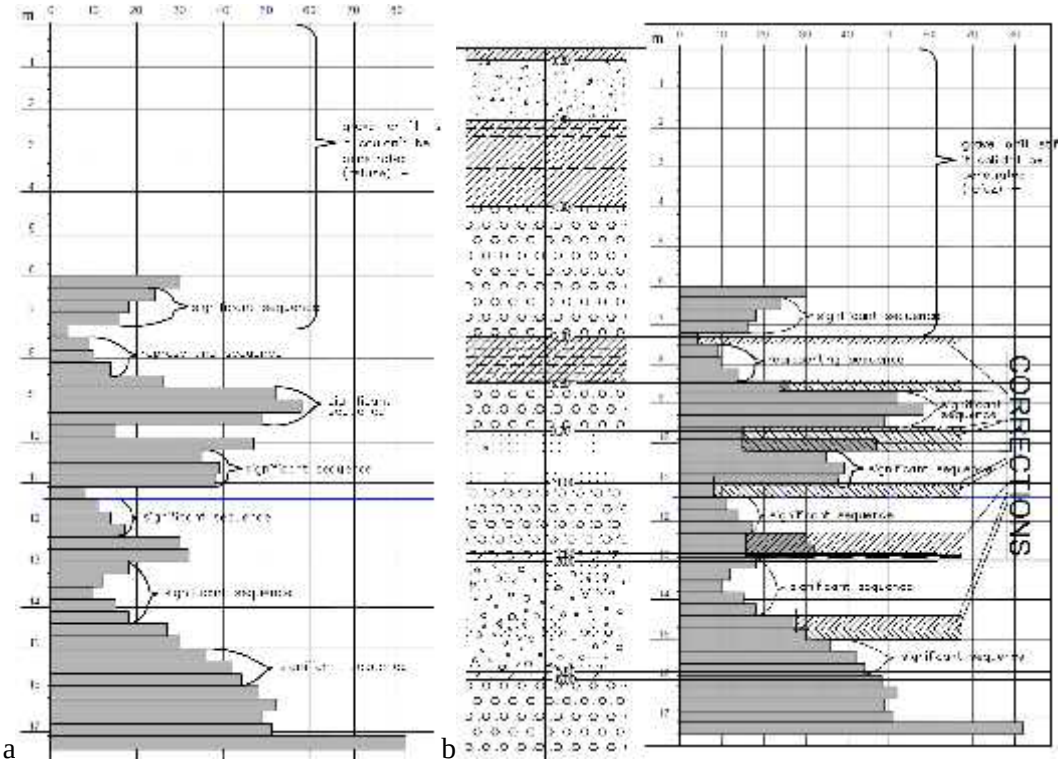

Fig. 4. *a - Example of choosing significant sequences on penetration results, b - corrected stratification on the same example*

The equivalent thickness of a layer will be calculate by the formula:

$$h_{eq} = \sqrt{\frac{N_{SPT1}}{N_{SPT2}}} \cdot \sim \cdot h_1 \tag{4}$$

where:

N_{SPT1} and N_{SPT2} - are the equivalent number of blows for the upper and for the lower layer in standard penetration test, SPT;

~ - is a coefficient equal to 5 cm for the light dynamic penetration DPL and 25 cm for the heavy dynamic penetration, DPH.

4. Conclusions

Expanding direct investigations through dynamic penetration offers much faster and cheaper results than other methods. However, claiming that penetration has led directly to correct stratification of the soil it can not be accepted. Those results must be corrected by appling different depths to the limits of the different strata. In this manner the calculated geotechnical indices will be much more closer to the reality.

In those that were above described, a correction formula has been proposed in which the limit between the two strata is offset from the one indicated by the number of blows.

Because of the difference of the layer stiffness, the number of blows in a layer is distorted nearby another layer due to the concentration or dissipation of the efforts at the limit. A simple method was proposed based on the ratio of the number of blows.

The same ratio would result between E - deformation modules of the two layers or other determinated characteristics based on penetration. The proposed method does not replace the geotechnician's interpretation for several reasons:

Significant sequences of penetration must be chosen in each layer, and the subjective human factor remains determinant

On the other hand, thin layers with thickness below the coefficient value will be neglected.

The method should be certified by a large number or correlation beetwin boreholes log and dynamic penetrations results. As well it can appear significant factors (as saturation ratio, difference beetwin cohesive and noncohesive soil and so on) that can be included in corrections.

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