Three-Dimensional Models of Bearing Capacity – Case Study

Modèles tridimensionnels de capacité de portante – Étude de cas.

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ABSTRACT: To mitigate risk in geotechnical constructions by making borings and pile load tests that enable the elaboration of bi and three-dimensional models, which assure the correct analysis and evaluation of the associated risks to design and to the construction execution should be one of the targets of a Geotechnical Engineering. Generally, the analyses done in terms of design level are conducted under some uncertainties, especially concerning geological-geotechnical formation which has a great influence on the soil-foundation system, however, it has been looking for techniques that assure a good evaluation of such constructions, by the elaboration and usage of three-dimensional models, based on data from geotechnical and geological survey. The organization, treatment and specialization of soil data furnish models that help in the decision and mitigating process of risks involved in those constructions. The obtained results by the usage of the referred methodology show that data interpolation during the three-dimensional modeling process decrease uncertainties that come from the natural variability of the soil.

RÉSUMÉ : Pour atténuer les risques dans les constructions géotechniques en faisant des essais de chargement sur pieux et des tests de forages qui permettent l'élaboration de modèles bi et tridimensionnels, qui assurent la bonne analyse et la bonne évaluation des risques associés à la conception et à l'exécution de la construction devraient être l'un des objectifs de l'ingénierie géotechnique. En général, les analyses effectuées en terme de niveau de conception sont menés malgré certaines incertitudes, notamment en ce qui concerne la formation géologique-géotechnique qui a une grande influence sur le système sol-fondation, cependant, on a effectué des recherches de techniques qui assurent une bonne évaluation de ces constructions, par l'élaboration et l'utilisation des modèles en trois dimensions, à partir des données de l'enquête géotechnique et géologique. L'organisation, le traitement et la spécialisation des données du sol fournissent des modèles qui aident dans le processus de décision et d'atténuation des risques liés à ces constructions. Les résultats obtenus par l'utilisation de cette méthode montrent que l'interpolation des données pendant le processus de modélisation tridimensionnelles diminue les incertitudes qui proviennent de la variabilité naturelle du sol.

KEYWORDS: bearing capacity, three-dimensional model, geotechnical risk.

MOTS CLES : capacité de portant, model tridimentionnel, risque géotechnique.

1 INTRODUCTION

The estimation of the bearing capacity, the definition of the resistant surface, the tip elevation of the bases and the execution control of the foundations are in many times defined under uncertain conditions which are caused by nature and by the intrinsic characteristics of the soil and by the deficiencies and limitations of the preliminary studies which are the support for the elaboration of a design.

The ideal would be that the foundation could offer a minimum risk concerning the safety and the maximum economy about the costs. The satisfy such dual idea it is necessary to have wide range and consistent preliminary studies for the understanding of the geological-geotechnical behavior of the soil and its interaction with the foundation and the superstructure Silva (2011).

To handle such problem, the elaboration and the usage of three-dimensional models, based on data from geotechnical, geological and geo-physical surveys start to gain a space in civil engineering constructions, especially in foundation and excavation constructions. Based on such philosophy, firstly the design forces (loads) were defined; secondly, the sub-surface model (resistant surface) (soil layers) that would be used in the foundation solution was set.

It is known that to solve the referred problem there are many dimensioning methods which result in many possible foundation solutions. However not even the best method , that is, the one that best adapts itself to the local soil and to the construction's expectations can skip from the natural variability of the soil. Therefore, to understand such variability is the great task of the geotechnical engineering, which is the key point of this article, which proposes a way, for not saying a new one, but efficient to organize, treat and specify in a bi or tridimensional way the soil data, to furnish information that help in the decision making process and in the mitigation of the risks which take part in the foundation constructions.

To validate and measure the quality of the three-dimensional methods, results from load testes were used which decreased in a good way the uncertainties concerning the real execution condition and the foundations' behaviors, in terms of bearing capacity and deformability.

At the end, the obtained results from the three-dimensioning spacialization are shown throughout the proposed methodology. The results obtained from the application of the methodology show that on the contrary of the traditional methods, the data interpolation during the three-dimensional modeling process reduced the uncertainties of the natural variability of the soil.

2 MATERIALS AND METHODS

2.1 *Localization of the Study Area*

The refferred construction is located in an adjacent city called Guará II, Brasília, DF. The design consists of two residential towers with an underpark garage excavated in such a way that the three-dimensional spacialization of soil data was justified because of the great soil variability and because of that the difficulty in executing the foundations. In such construction, 33 SPT borings were made in a piece of land with 60 m by 150 m and lately load tests were also made which results were added to the three-dimensional models. The differential of that construction is that a three-dimensional model of bearing capacity was proposed for it, which was calibrated by the field load tests.

The UTM coordinates which limit the area are: Xmin = 180.941 m, Xmax=181.001 m, Ymin= 8.246.782 m, Ymax=8.246.932 m, Zone 23, datum Astro-Chuá with central meridian of 45º WGr. Figure 1 shows the study area location.

2.2 *Geological Context of the Study Area*

With the topographical ellevations around 1090-1108 m that area presents a plan topography. The river basin of Riacho Fundo is the fundamental factor of the local landscape evolution. The original rock, with a low degree of metamorphism shows an ordinary bright probably due to the sericita presence. The lithological characteristics and the geographycal situation of such occurance suggests its posisioning in the Fácies Ardósia (MNPpa), according to the statigraphical sequence proposed by Faria (1995).

2.3 *Three-dimensional Modeling of the Geotechnical Data*

The data modeling in a three-dimensional environment requires some methodological procedures (Silva & Souza, 2009). The more used parameters for three-dimensioning modeling are the lithological ones in the case of rock descriptions; statigraphical ones to describe soil layers or excavating material; Nspt values or any numerical measurement (geophysical data, geochemical data, strength parameters among others) which can be described in a local manner or between pre-defined intervals; water table; among other parameters that can be adapted to the RockWorks 15 software

I this case, the adopted calculating method for the foundations, continuous flight auger piles, was proposed by Decourt & Quaresma (1978). By the access to the geotechnical dimensioning and results of the load tests, load test models were generated for 50 and 60 centimeter diameter piles.

It is important to mention that the target of the load test was to calibrate the results obtained from the foundations' calculations, once the adjustment parameters for the shaft and tip calculation bearing capacity were initially assumed by the designer, and letting the model to spacialize the results to make possible a proper ajustment for the dimensioning adopted method. That is, it was not the objective of the work to review any foundation calculating method, but to show that it is possible to manage other types of three-dimensioning models and their applications on the field in the most direct way.

2.3.1 *Data Log*

The first step for the three-dimensional modeling is the data log in a data bank of the computer software which will be responsible for the modeling. The data log of the borings in the RockWorks 15 software is done in a sequence as follows:

1. Location of the borings. A simple procedure which requires the name of the boring, The East and North coordinates (x,y) and the elevation of the top of the boring (coordinate z), besides the total depth achieved by the drilling. If it is necessary, a symbol can be added represent the borings in the generated bi-dimensional charts.

2. After the location of the borings, the soil profile or the statigraphic log can be done. However, it is very important to evaluate all borings and to establish which will be the soil profile to be used by the model, which procedure can be a complex one because of the soil variability, and in some cases it will be impossible to elaborate the statigraphic model due to such variability.

3. Description of the punctual numerical values. That concerns to insert the numerical values described in the borings, normally the Nspt values.

3 RESULTS

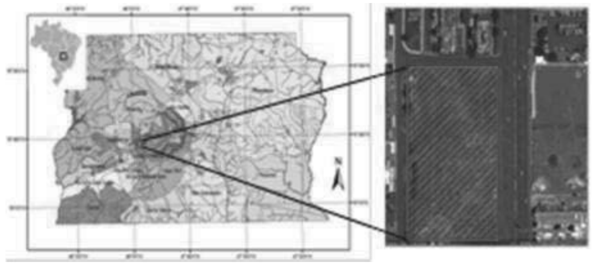

Figure 1. Location of the study area.

The first result obtained for the case study was the basic chart with the information concerning the borings' location, the "Verano" and "Blanc" constructions which gave the name of the case study, and the hipsometria values for the piece of land. In the case of this construction there was no compatibility of datum and the construction was not geologically referred, that is, the modeling was done based on the local reference, because the construction made its choice based on such reference.

It can be observed in Figure 2 the basic chart with the information geologically referred. It is important to mention that ground is general plan and later it was excavated 4 meters below because of the execution of the construction undergrounds.

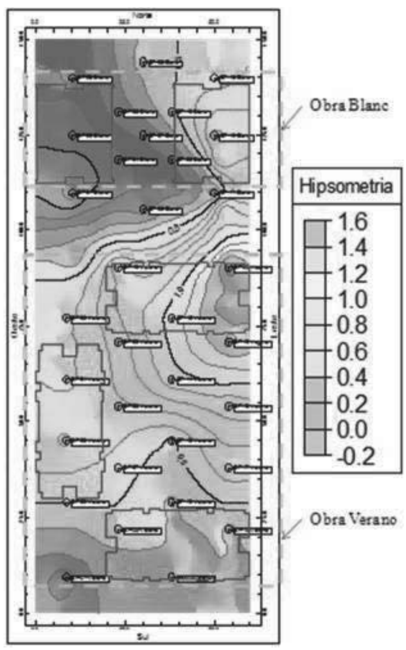

Figure 2. Hipsométrica chart with the SPT borings' location and the constructions' location.

Besides the wide red clay layer, observed in the SPT borings, the soil presented a great variability in the Nspt resistance values what justified the development of the modeling for such construction.

3.1 *Horizontal Slicing of Nspt Values*

To detect with more preciseness the places with soft soil many horizontal slicings were done where the values in grey color represent Nspt values below 30 blows (which do not represent trouble for the continuous flight auger equipments), the other values follow with the presented colors showed sequentially in Figures 3 to 5.

The slicing was done taking into account that the foundation would start 4 meters below the original ground level and that the foundation with continuous flight auger has a minimum execution depth, which in the case was considered 8 meters from the excavation, that is, 12 meters below the ground level (4 meters of excavation + 8 meters of minimum length for continuous flight auger piles).

It can be observed by such sequence of slicings that some places of the construction had soil areas with low Nspt resistance (values in grey color) which were in course and that the design should consider such fact. By taking the analysis of such problem that the idea of elaborating a bearing capacity model for the construction came up, which was done. By observing the great variability of the geological profile it was evident that the resistant surface was variable forcing the definition of different depths for each region of the construction by the detailed analysis of the three-dimensional model. However for the model to be convincing the over-position of the calculate piles in the design was done in the bearing capacity model

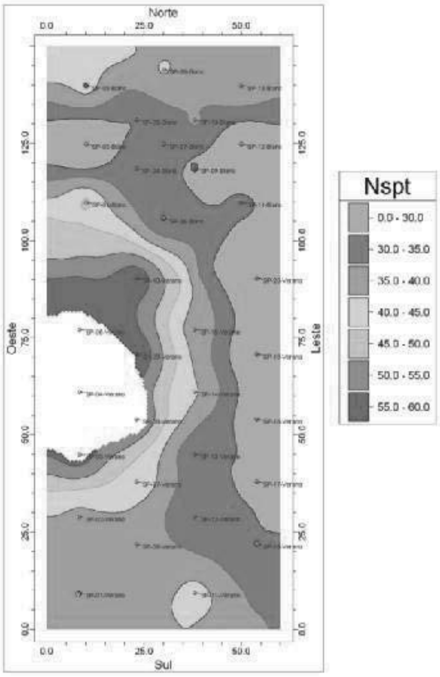

Figure 3. Horizontal Slicing Sequence of the Nspt Model – Decision Taking for the Execution of the continuous flight auger piles – 18 m depth.

3.2 *2D Sections of Bearing Capacity (tf)*

Because of the application of the new technique, in the beginning there was a resistance by the piling contractors concerning the usage of the obtained results from the bearing capacity models. Forcing the specialization of the majority of

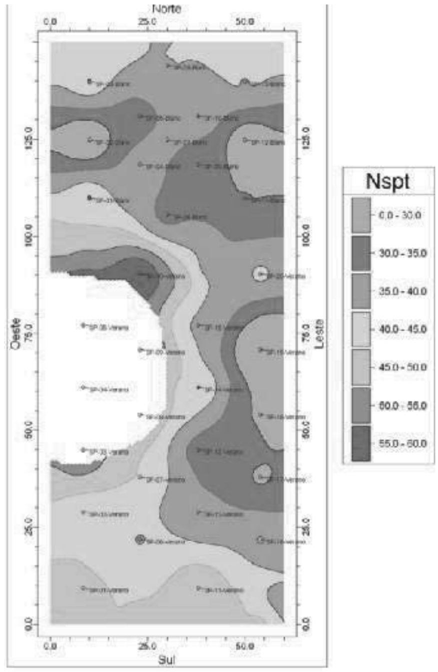

Figure 4. Horizontal Slicing Sequence for the Nspt Model – Decision Taking for the Execution of continuous flight auger piles – 19 m depth.

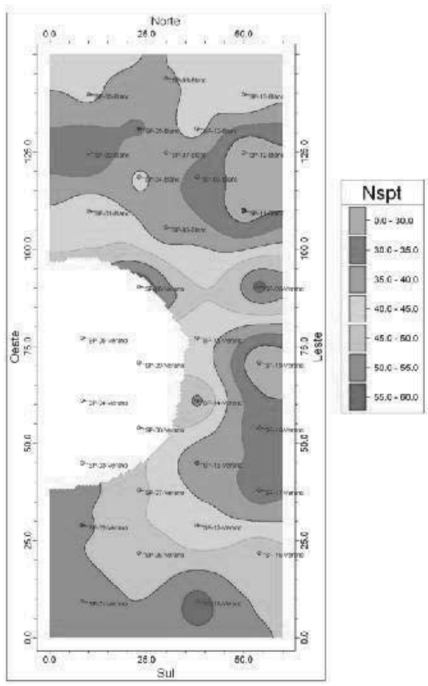

Figure 5. Horizontal Slicing Sequence for the Nspt Model – Decision Taking for the Execution of continuous flight auger piles – 20 m depth.

the piles to make it easier to understand the decision taking in terms of design level that were subsided by the bi and three-dimensional models.

Most of the piles of interest which were to be executed in the construction had a depth of 20 m (length) with a prevailing diameter of 50 cm for 100 tf of bearing capacity, had their execution in terms of depth defined by the elaborated models.

The objective of the 2D sections of bearing capacity, which in the beginning was just to do the depth control reached by the execution, took new destinations when many piles start to present problems during the excavation. Figure 6 shows a section of interest for the construction in which some piles presented execution problems.

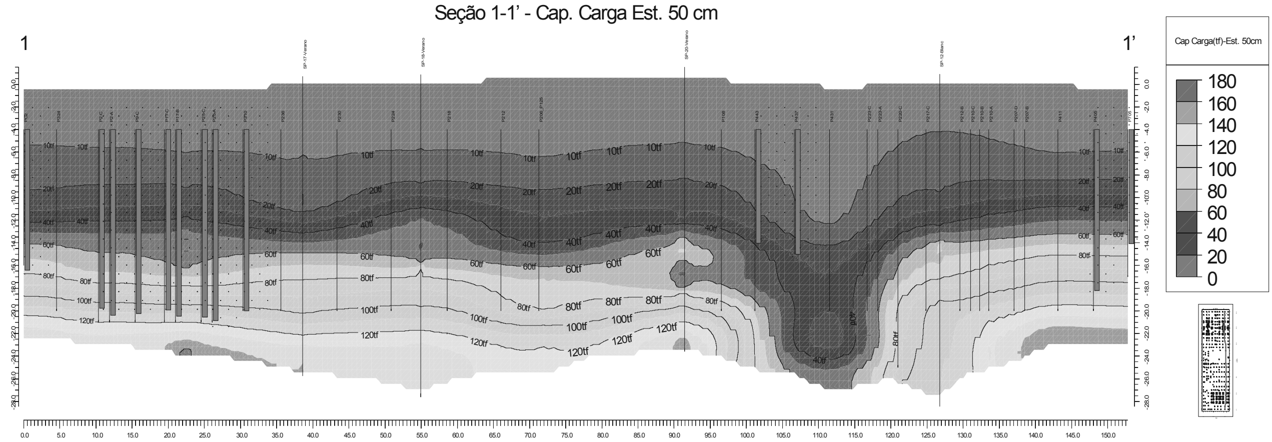

Figure 6. Section 1-1 of bearing capacity of the case study

3.3 *Horizontal Sections (2D) of Bearing Capacity*

The horizontal sections 2D of bearing capacity are very useful to see the results in a general way. Figure 7 shows the bearing capacity (tf), for 50 cm diameter and 16 meters depth and Figure 24 shows the bearing capacity surface for 20 meters depth, and those are in reality what can be called as 2,5D surfaces.

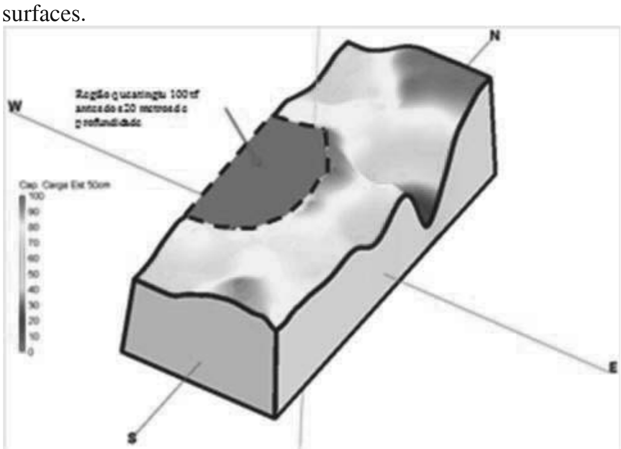

Figure 7. Horizontal Section of Bearing Capacity for 20meters depth of the case study.

The choice of the 20 meters depth was due to the fact to achieve most of piles in terms of bearing capacity and because many piles did not reach longer depths, once they were getting close to the maximum excavation limit of the equipment.

Finally it can be observed how often the resistant surface can vary in the construction and how can the models help in the problem analysis and in the search of more efficient solutions for the construction.

4 CONCLUSIONS

The three-dimensional mapping of the soil has the target to obtain the maximum knowledge of the geotechnical conditions of the construction location to make the engineers' analyses easier. On the contrary of traditional methods, the data interpolation during the 3D modeling process decrease the uncertainties of the natural variability of the soil.

The propose to produce a bearing capacity model was extremely satisfactory and with a practical value, however we must be careful in taking into account the traditional methods and the field tests, as the static load tests, with the objective to calibrate the bearing capacity model. Besides, the construction control with the spacialization of the design foundations and the executed ones, in the bearing capacity model, diminish a great deal the uncertainties in the construction and promote a greater economy for the foundation execution..

The process of post-evaluation of the models produced by the computer softwares must always be done with criterion. That is, the whole process of three-dimensional modeling of sub-surfaces or underground space requires geological/geotechnical experience of the region and knowledge of limitations and potential advantages of the computer softwares as the quantity of input attributes, working grid limit, interpolating devices and their limitations.

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