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CORRELATION BETWEEN MWD DATA AND LITHOLOGY IN THE PARISIAN BASIN

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ABSTRACT

The use of Measurement While Drilling (MWD) technology during geotechnical investigations provides a large amount of data to engineers in a quick and efficient manner. This method of drilling can be deployed in any kind of soil, from soft clays to soft rocks, and the data acquired is more detailed than what could be acquired through SPT or pressuremeter tests. The machine parameters are systematically collected during the drilling operation and these logs are known to correlate well with local lithology as large variations are usually seen in the data at the transition point between two soil layers. However, interpreting these data in isolation can be challenging as there can be a large difference in performance depending on the machine configuration, drill bit and stabilizing fluid chosen for a given project. For this reason, case studies typically analyse a few drillings in a small area, and there are no widespread correlations that can be used as a basis for interpretation. In this paper, a series of 91 MWD drillings of up to 75 m in depth along a linear path about 11 km long in the suburbs of Paris have been statistically analysed to determine a correlation between the various geological formations encountered and the data collected.

Keywords: Measurement while drilling, statistical analysis, Parisian basin, soil classification.

INTRODUCTION

To safely design the foundations of any new construction project, it is necessary to have information about the subsoil. This information can be gathered through an investigation campaign that can use multiple methods to determine the local lithology and the properties of the soils found there.

The Measurement While Drilling (MWD) technique is a rapid method that can be employed in a large variety of terrains as a complement to other more time-consuming methods (Kreziak and Pioline, 2005). In this method, the machine parameters of a drill rig are recorded as it drills through the terrain, creating a log of the drilling as a function of depth. The parameters most commonly measured are the advance rate, downthrust, holdback pressure, torque and rotation speed, as well as the injection rate and pressure of the drilling fluid responsible for stabilizing, cooling and removing debris (Reiffsteck, 2010).

MWD is a technique meant to be used alongside destructive drilling, as soil samples cannot be recovered for later laboratory testing, but the information gathered in the drilling logs can inform on the soil's properties even though the parameters recorded don't directly measure them. There are correlations between a parameter's behaviour and the soil's characteristics, allowing for a better understanding of the subsoil (Reiffsteck et al., 2018).

Figure 1 *Geotechnical drill rig*

However, due to the limited number of investigations made in a given project and to the

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large variability in rig architecture, drill bit design and drilling techniques, the correlations found tend to be project-specific and only qualitative in nature (Moussouteguy, 2002; Reiffsteck, 2010).

This paper aims to evaluate a large number of MWD investigations in the northwest of Paris to determine a correlation between these parameters and the various geological formations of the Parisian Basin. These drillings were made with similar rigs but various types of drill bit, they'll be grouped by drill bit type for this analysis.

GEOLOGY OF THE PARISIAN BASIN

The Parisian Basin is one of the three great sedimentary basins in France, covering approximately one third of the territory of Metropolitan France (Delmas et al., 2002).

It encompasses a vast region, with rocks and soils of marine, lacustrine, lagoon and fluvial origin and reaches a maximum depth of 3000 m, resting on a crystalline basement of Neoproterozoic origin (Mottet, 1999; Delmas et al., 2002).

The sediments that formed the various rocks in the basin began to be deposited in the Cambrian period, when the entire region was covered by a shallow sea. Tectonic movements then elevated the area, turning it into a plateau, and later lowered it again in the Triassic period, triggering a new sedimentation cycle (Mottet, 1999; Lasseur, 2007).

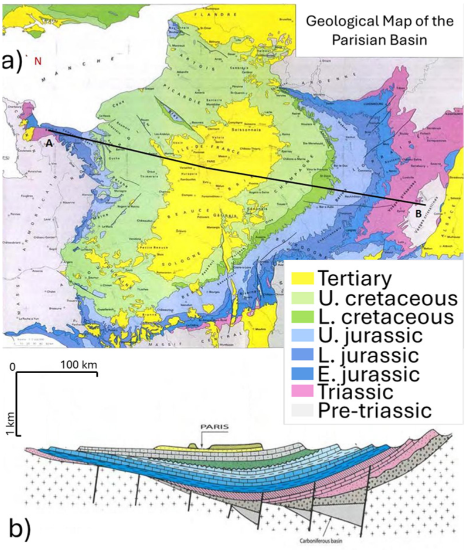

Figure 2 *(a) Geological map and (b) cross-section of the Parisian Basin (BRGM, 2025*

The entire basin has passed through various other cycles of rising above and sinking below sea level throughout the eons, leading to the formation of numerous overconsolidated sedimentary layers of diverse origins. Glaciation cycles in the Pleistocene and early Holocene also fold and recompress these layers, and the river Seine establishes its current course in this later period and starts depositing silty and sandy layers along its banks (Delmas et al., 2002; Lasseur, 2007).

METHODOLOGY

Five investigation campaigns for a great infrastructure project in the cities of Nanterre, Courbevoie, Bois-Colombes, Gennevilliers and Asnières-sur-Seine in the northwest of Paris were statistically analysed for this paper. The 91 investigations reached between 35 and 75 m in depth for a total of 4010 m of drillings and 323662 data points for each parameter, traversing multiple layers.

All the MWD data from these investigations were then smoothed with a moving median filter to remove any anomalous values that may arise due to drilling stoppages. The window used for this filter had a 30 cm radius. To reduce the influence of the driller's technique, the Somerton index S_d was then calculated. This parameter, shown in Equation 1, considers the effective thrust F_e and the advance rate u and indicates the materials resistance to the drilling process.

$$S_d = \frac{F_c}{\sqrt{u}} \tag{1}$$

Other parameters were also considered, but as these drilling logs lacked the rotation speed data, Somerton's index was the only one that could be used without making major assumptions.

To account for the variability in drill bits, the investigations were grouped by type of drill bit used, of which there were 12: cutter bits of 64 mm in diameter, cross-shaped of 64 mm in diameter, and tricones of various diameters between 64 and 500 mm. The various drill bits and their usage is shown in Figure 4. This isolated the influence of the drill bit on the data recorded, as only the drilling logs made with the same type and size of drill bit were compared.

Each data point was then classified according to its depth and the stratigraphy established by the project's geotechnical lead. The statistical distributions of all base parameters and Somerton index were analysed, at first separated by campaign and then all investigations were analysed together to determine possible correlations between each geological layer and the MWD data.

RESULTS AND DISCUSSION

Analysing the stratigraphy reported in all investigations, most logs traversed the same layers, while the drillings in Nanterre encountered different geological formations. Layers composed primarily of sands, clays and soft rocks were present, with the investigations in Nanterre encountering the layers, from top to bottom: a layer of marl with limestone elements (MC), coarse limestone (CG), gravely sand (SS), sandy clays (FG), clayey sand (SA), plastic clay (AP), marl (MM), limestone (CM) and white chalk (CB).

Meanwhile, the formations encountered by the investigations in the other cities were, starting at the surface: a layer of silty sands called Modern Alluvium (Am), followed by gravely sand (Ancient Alluvium - Aa), soft limestone (Saint-Ouen Limestone - SO), clayey sand (Beauchamps Sands - SB), a layer of marl with limestone elements (Marl and Gravels - MC), Coarse Limestone (CG) and finally a clayey sand layer called Superior Sands (SS). Superficial layers identified to be of human origin (i.e. infill) were ignored during the analysis. An example of soil profile is shown in Figure 3

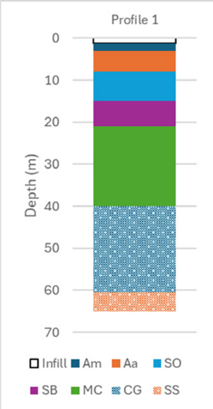

Figure 3 *Example of soil profile encountered*

Of all the drill bits used, the cross-shaped bit with a 64 mm diameter was by far the most used, as seen in Figure 4. It was employed in 38 different investigations in all 5 campaigns, so these are the results that will be shown in this paper.

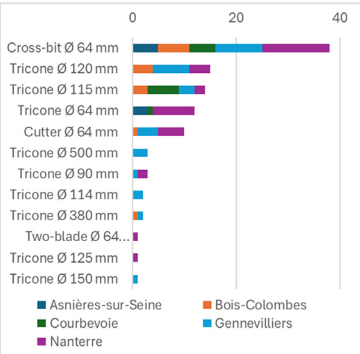

Figure 4 *Drill bit usage in the analysed drillings*

As the lithology encountered in the Nanterre investigations was different from the others, they will also be analysed separately. Regarding the probability distributions for the advance rate (Figure 5) for the remaining investigations, the recorded values tended to be higher in the Modern Alluvium while it was considerably lower when drilling through the Superior Sands or Coarse Limestone. The distributions for the other layers are all somewhere between these two extremes but without much separation.

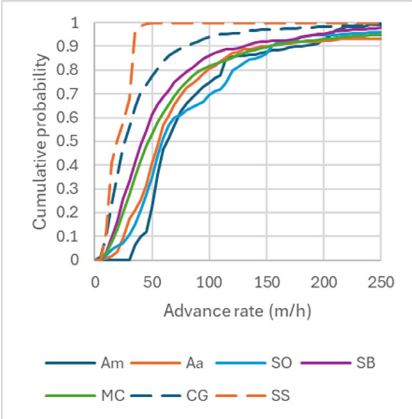

Figure 5 *Distribution probabilities for advance rate (cross-bit 64 mm)*

The inverse is seen in the distributions of injection pressure in Figure 6: lower pressures were used in both alluvium layers and much higher pressures were needed in the Superior Sand layer. This could be explained by the different amounts of fines in each layer, indicating how permeable each of the soils are. Once again, the other curves are very similar.

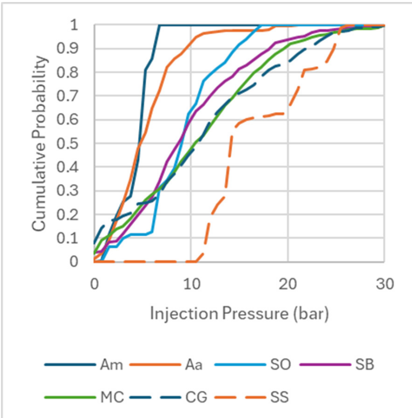

Figure 6 *Distribution probabilities for injection pressure (cross-bit 64 mm).png*

Finally, analysing the Somerton index distributions in Figure 7, Saint-Ouen Limestone is seen to have lower values with low variance. On the other hand, the Coarse Limestone layer presents a very wide curve with a relatively high average. Superior Sand tends to have the highest values, and all other geological formations had very similar distributions.

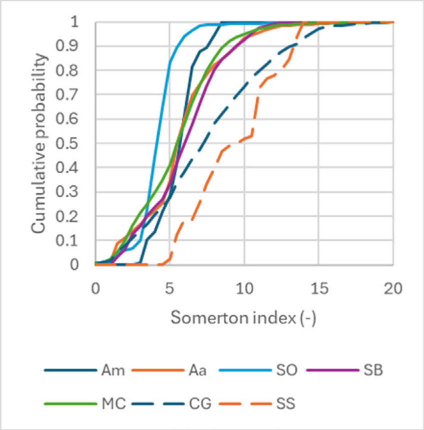

Figure 7 *Distribution probabilities for Somerton index (cross-bit 64 mm).png*

The lack of differentiation in the distribution curves could be the result of all layers found in the investigations being very resistant and highly compact, with pressuremeter results also presenting similar values regardless of the geological formation. It is likely that in a region with soils of different compacities, there would be less overlap between the probability distributions.

The Somerton index may also not be the best suited to characterize these soils. There are many other compound parameters that consider more of the base parameters to calculate the energy spent by the drilling process, but they could not be used in this analysis because the drilling logs lacked the rotation speed needed for those formulas.

Similar patterns were seen in the distribution functions for the other drill bits, with the curves very close together or overlapping. Although the geological formations encountered in the Nanterre investigations were different from the others, the distribution curves were also overlapping each other. Same as before, these layers are very compact, except for the most recent layer (modern alluvions), and tend to have very similar pressuremeter results as well, which could explain the lack of differentiation seen in the MWD logs.

CONCLUSION

This paper evaluated the distribution functions of the values logged during MWD investigations using 91 drillings in cities northwest of Paris. It was seen that the different soil layers encountered had different distribution functions, but they overlapped each other or were too close to allow for soil identification based solely on these curves. This can be partially explained by all layers being very compact and having similar values when tested with the Ménard pressuremeter as well.

At the same time, it could be seen that the same soil presented different distribution functions depending on the type of drill bit used, showing how the choice of equipment also has an influence on the data acquired. The choice of parameters monitored also influenced the analysis, as the lack of rotational speed data prevented the use of compound parameters other than the Somerton index. As there was no data of drilling fluid flow, soil permeability also couldn't be properly analysed.

Still, some differentiation could be seen in the curves and the use of a different compound parameter could lead to better results. Repeating this study in an area with more variation in soil compaction could also be useful in finding ways of differentiating layers.

REFERENCES

BRGM (2025). Contexte Géologique du Bassin Parisien [online], available at: ***https://sigessn.brgm.fr/spip.php?article18***, accessed: 3/3/2025 [in french]

Delmas J., Houel P., Vially R. (2002). Rapport régional d'évaluation pétrolière - Paris Basin, Institut Français du Pétrole. Paris. France. [in french].

Kreziak C., Pioline M. (2005). Exploitation des paramètres de forage en génie civil, partie 2 : rapport d'expérimentation, LRPC, Rouen, France, Rep. 6682. [in french]

Lasseur E. (2007). La craie du Bassin de Paris (Cénomanien-Campanien, Crétacé supérieur) . Sédimentologie de faciès, stratigraphie séquentielle et géométrie 3D, PhD thesis, Université de Rennes 1. Available at: ***https://theses.hal.science/tel-00350422v1***, accessed: 4/3/2025. [in french]

Mottet G. (1999). Géographie Physique de la France, 3rd ed., Presses Universitaires de France, Paris, France. [in french]

Moussouteguy N. (2002). Utilisation Combinée des Essais Pressiométriques et Diagraphies Instantanées pour Mieux Évaluer le Risque Géotechnique en Reconaissance des Sols, PhD thesis, Université de Bordeaux 1. [in french]

Reiffsteck P. (2010). Paramètres de forage en géotechnique : Méthode d'essai n° 79, LCPC. Paris. France. [in french]

Reiffsteck P., Benoit J., Bourdeau C., Desanneaux G. (2018). Enhancing geotechnical investigations using drilling parameters, Journal of Geotechnical and Geoenvironmental Engineering, 14(3), ***https://doi.org/10.1061/(ASCE)GT.1943-5606.0001836***.