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Study of the Correlation between Menard Pressuremeter Modulus and Peak Dynamic Resistance Obtained by the Super Heavy Dynamic Cone Penetrometer of Sands of Lome in Togo

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ABSTRACT

The bearing capacity of soils is obtained in various ways using in situ tests, especially pressuremeter and penetrometer tests which are in fact frequently used for the design of foundations. The pressuremeter provides detailed information on the resistance and deformability characteristics of soils at depth. The dynamic cone penetrometer test, on the other hand, is simpler to produce and used to assess the dynamic resistance of the soil, i.e. its behavior under dynamic loads.
This study establishes correlations between the dynamic resistance qd of the soil obtained with the super heavy dynamic cone penetrometer and the pressuremeter modulus EM measured with the Menard pressuremeter. The data used in this analysis are those obtained during geotechnical investigations on sands in Lome in Togo and which combined on the same site the super heavy dynamic cone penetrometer test and the Menard pressuremeter test. It appears that for the sands studied, the EM/qd ratio can be bounded as follows: $0.60 \leq EM/qd \leq 0.92$.

Keywords: Correlation, pressuremeter modulus, dynamic resistance, sand.

INTRODUCTION

In Togo, the bearing capacity of soils is obtained in various ways using in situ tests, especially pressuremeter and penetrometer tests which are in fact frequently used for the design of foundations based on the recommendations of DTU 13.1 [1] and 13.2 [2], as well as Fascicle 62 – Title V [3]. The pressuremeter provides detailed information on the resistance and deformability characteristics of soils at depth. The dynamic penetrometer, for its part, is simpler to carry out and makes it possible to assess the dynamic resistance of the soil, i.e. its behavior under dynamic loads. The dynamic cone penetrometer test, therefore due to its simplicity of implementation, makes it possible to multiply the geotechnical investigation points on a construction site. However, it has a limitation, as it is limited to the measurement of the dynamic resistance of the soil, which limits the amount of information obtained compared to the Menard pressuremeter test which allows the determination of more varied parameters, such as the pressuremeter modulus and the ultimate pressure [4]. This difference reduces the ability to fully characterize the mechanical properties of soils solely from the results of the dynamic cone penetrometer.

Although some soil properties can be related by mathematical equations, others, such as the pressuremeter modulus and the dynamic peak strength of the penetrometer, do not present a direct correlation [5]. Thus, by seeking to establish correlations between these two parameters, it becomes possible to enrich the interpretation of the data from the dynamic cone penetrometer and to obtain more exhaustive and relevant geotechnical parameters [6]. This approach is particularly advantageous in the design of foundations, because it allows the extrapolation of the pressuremeter parameters from the dynamic cone penetrometer data. This leads to an improvement in the accuracy of the calculations while reducing the use of pressuremeter tests, which are often more expensive.

In this paper, a statistical analysis is conducted on the EM/qd ratios, i.e. the pressuremeter modulus in relation to the dynamic resistance of the cone penetrometer. These ratios are derived from data collected during geotechnical campaigns combining pressuremeter and penetrometer tests carried out on sandy soils of Lome, in southern Togo. The results obtained are then compared with the results of the existing literature.

MATERIALS & METHODS

In this study, surveys were carried out on 4 sites (Ablogame, Adakpame, Baguida, Lome Port) located in the Golfe 1 and Golfe 6 communes of the Autonomous District of Greater Lome (DAGL), in the South of Togo. The locations of these sites are presented in Figure 1.

Geologically, these sites are part of the coastal sedimentary basin made up of marine sands of the coastal strips. The formation of these coastal strips took place during periods of sea level oscillation. With a maximum thickness of 25 m, they occupy the entire maritime facade of the country, from Lome where they reach 2 km wide, to Aneho where they measure less than 1 km [7].

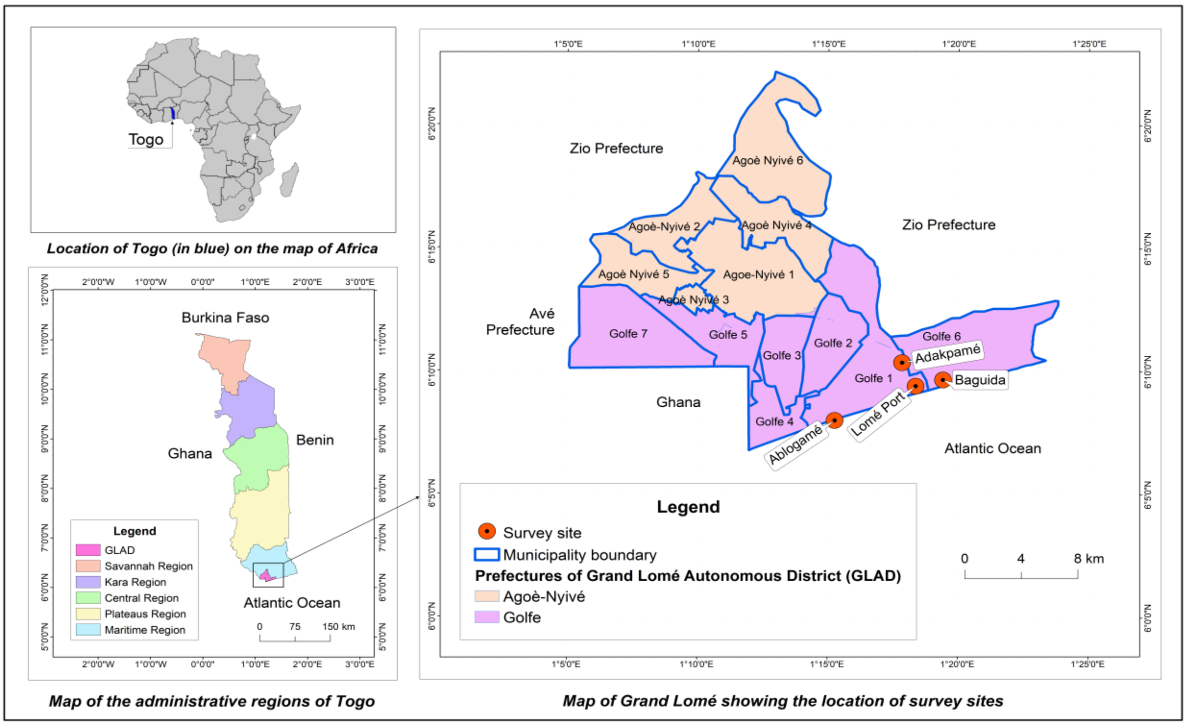

Figure 1: Location of survey sites

The approach consists of establishing a correspondence between the pressuremeter modulus EM and the dynamic resistances "qd" obtained with the dynamic cone penetrometer tests on the 4 study sites.

First, the main parameters characterizing the nature of the soils of these sites, such as the granulometry, the methylene blue value (VBS), the particle density, as well as the classification according to GTR (Guide des Terrassements Routiers) [8], were determined in order to better contextualize the results.
The pressuremeter tests were carried out in accordance with standard NF P 94-110 [9], while the super heavy dynamic cone penetrometer tests were carried out in accordance with standard NF EN ISO 22476-2 [10].
For each pressuremeter measurement depth p, an average penetration resistance value is calculated in a depth interval centered on this point (p-50 and p +50 cm). This method made it possible to associate with each pressuremeter modulus value EM obtained during the pressuremeter test, an equivalent penetration resistance value qd. The statistical analysis of the relationships between these values was then carried out.
Table 1 gives the total quantities of surveys carried out during the mixed campaigns for all 4 sites studied, as well as the number of combinations of EM/qd ratios obtained, noting that a pressuremeter survey at a point is associated with several penetrometer surveys carried out in the vicinity of this point on the same site.

Table 1: Quantity of materials used

Designation	Number
Dynamic cone penetrometer test	16
Pressuremeter test	8
EM/qd ratio	151

The objective of this study is to establish ranges of values for EM/qd ratios characterizing sands. By statistically analyzing the data, intervals were determined by considering the extreme values (minimum and maximum) among the following four statistical values: the mean, the median, the mode of the distribution and the slope of the linear regression line. This method allows to take into account the dispersion of the data and the uncertainties related to in situ tests.

RESULTS & DISCUSSION

Table 2 and Figure 2 present the main geotechnical parameters characterizing the nature of the soils of the sites studied.

Table 2: Parameters of the nature of the soils studied

Site	D < 80 µm (1) (%)	D < 2 mm (1) (%)	D_{max} (2) (mm)	VBS (3)	Particle density γ_S(g/cm^3)	GTR Class (4)
Ablogame	2.3	95.3	2	0.05	2.53	D1
Adakpame	6.5	95.1	2	0.07	2.59	D1
Baguida	11.2	93.8	3.15	0.08	2.56	D1
Lome Port	1.5	87.7	4	0.03	2.60	D1

"D<x" = percentage of passages through the sieve with mesh size x
Maximum diameter of soil particles (diameter for which 95% of the particles are of a smaller dimension)
VBS: Methylene Blue Value
GTR: Guide des Terrassements Routiers [8]

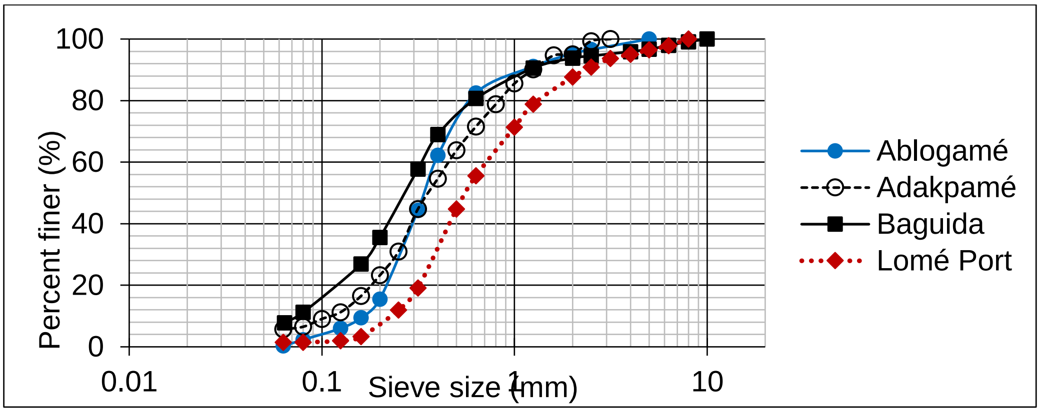

Figure 2: Granulometric curve of studied soils

The median of the EM/qd ratios is 0.79 and their mean is 0.92. Figure 3 shows the scatter plot of EM values as a function of qd. The values are organized in the form of a spindle around a linear regression line with a slope of 0.60.

By grouping the EM/qd values on the one hand, and the log (EM/qd) values within classes, we notice that the EM/qd distribution follows a log normal distribution with a mode EM/qd = 0.69. The EM/qd and log (EM/qd) distributions are represented by the histograms in Figure 4.

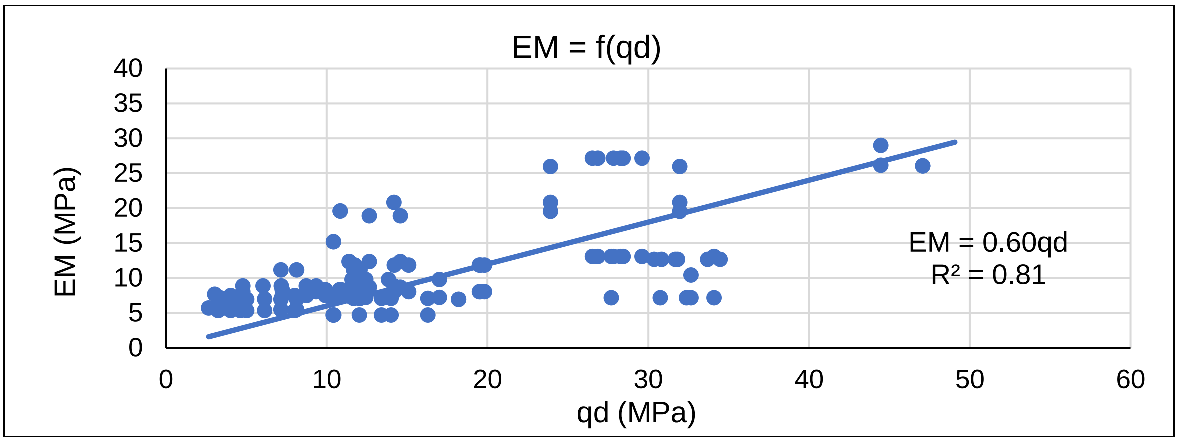

Figure 3: Variation of EM as a function of qd

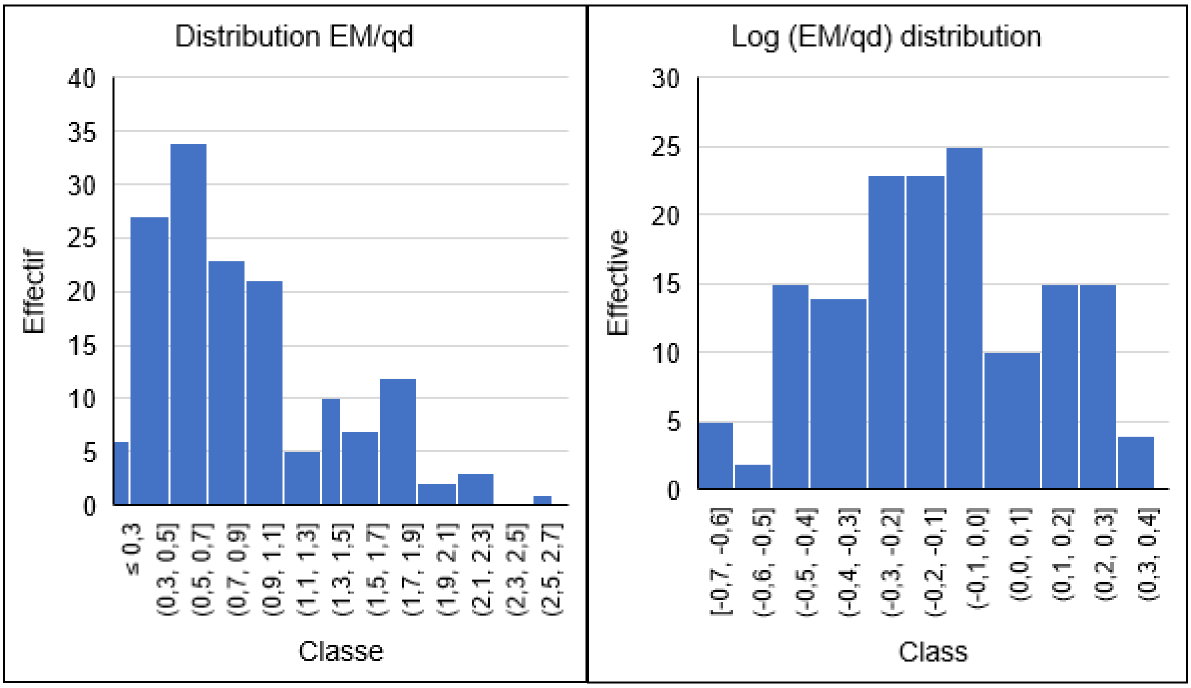

Figure 4: Histograms of EM/qd and log (EM/qd)

The statistical indicators obtained from the distribution of EM/qd ratios are then summarized in Table 3.

Table 3: Statistical indicators of EM/qd distribution

Indicator	Value
Median EM/qd	0.79
Average EM/qd	0.92
EM/qd linear regression slope	0.60
Mode of the log normal distribution EM/qd	0.69
Minimum indicator	0.60
Maximum indicator	0.92

Based on the values in Table 3, we then propose, for the sands of Lome, the following interval: 0.60 ≤ EM/qd ≤ 0.92.

In the existing literature, comparisons between pressuremeter tests and penetration tests mainly focus on static cone penetrometer tests (CPT). Studies that specifically explore correlations between pressuremeter tests and dynamic cone penetrometer (DCP) tests are relatively rare, if not absent. However, in the absence of work directly comparable to dynamic cone penetration tests, indications on the relevant geotechnical parameters will be drawn based on the results of previous studies on static cone penetration tests. These results will then be used to draw parallels and hypotheses for the work of the current study, keeping in mind the intrinsic differences between the two types of tests.

Concerning sands, if we synthesize the different values obtained in the literature for the EM/qC ratios, qC being the resistance obtained with the static cone penetrometer, we obtain the intervals in table 4.

Table 4: EM/qC ratios

Authors	EM/qC
Vaillant and Aubrion (Fondasol Study) [11]	0.8 ≤ EM/qC ≤ 1.4
Bachelier and Parez [12], Barata [13], De Mello and Cepollina [14] Schmertmann [15], Poulos [16], Elson [17]	0.25 ≤ EM/qC ≤ 1.87
Cassan [18]	1.0 ≤ EM/qC ≤ 1.5
Costet and Sanglerat [19-20],	0.5 ≤ EM qC ≤ 1.7
Baguelin and al.[21]	0.5 ≤ EM/qC ≤ 2
Van Wambeke and D' Hemricourt [22]	≈ 1.5

The results of the present study and the bibliographic synthesis are compared in Figure 5, thus verifying the general consistency of the results of this study (0.60 ≤ EM/qd ≤ 0.92) with those of the different authors.

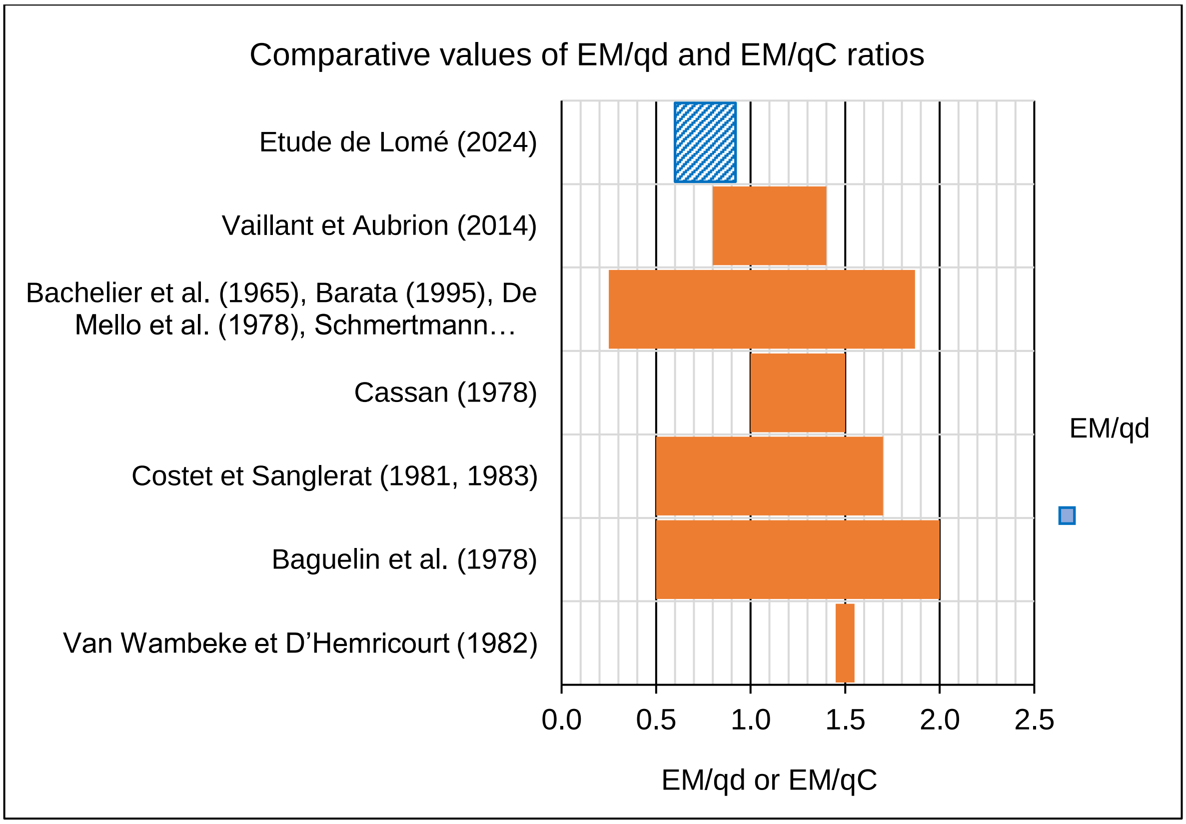

Figure 5: Comparative values of the EM/qd ratios of Lome to the EM/qC ratios of the literature for sands

CONCLUSION

The results of this study provide crucial information on the relationships between pressuremeter modulus (EM) and dynamic cone resistance (qd) for the sands of Grand Lome. By establishing an interval for the EM/qd values between 0.60 and 0.92, it was possible to confirm the consistency of these results with the trends observed in the literature, although previous studies focused on static cone penetrometer tests whose measured quantity is the static cone resistance qC.

This study thus provides a solid basis for the geotechnical analysis of sands in Lome and highlights the interest in further exploring the correlations between pressuremeter and dynamic tests, which are often less studied. The ranges of values obtained can serve as a reference for the design of foundations in local engineering projects and invite similar research to be continued on other types of soils.

Declaration by Authors

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