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Study of the Geotechnical Parameters of the Different Soils by Correlation Analysis and Statistical, in the Kenitra Region (Morocco)

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Abstract

This study focuses on the geotechnical characterization of soils in the area of study located at the western end of the plain of Sebou. The interest of this work is to identify, quantify and take into account the variability for a better estimate of the geotechnical risk. To this end, a database was created. Firstly, a study of the lithological distribution of soils is performed. Then, a statistical analysis of physical and mechanical parameters is realized in order to look for possible correlations between the main parameters. This simple descriptive analysis is followed by a multidirectional statistical study: a Principal Component Analysis (PCA) and an Ascending Hierarchical Classification (AHC). This study showed that the first three principal axes absorb more than 72% of the total variance and the first principal component explains (CP1 or F1) up to 32%. The AHC method allowed to divide all samples into four classes more or less homogeneous with a degree of dissimilarity of 35.7%.

Keywords: Morocco, Kenitra, Soils, Geotechnical, Mechanical and physical characteristics, Multidimensional statistics.

1 Introduction

Civil engineering projects are dedicated to the realization of efficient and economical works in a short time which requires an acceptable risk increasingly low. Geotechnical studies are highly important in such projects. Thus, a good estimate of the risk associated with geotechnical parameters has become a major issue since most of the new structures are located on sites with difficult conditions.

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So as to make these structures safe, identifying the main physical and mechanical characteristics of these soil types and optimizing how to recognize each characteristic were necessary.
It includes:

- A study of correlation between some physical and mechanical parameters;
- A data analysis (PCA) of each soil so as to determine the various parameters that explain the new factorial axes;
- The Ascending Hierarchical Classification method (AHC), helping to reveal homogeneous classes by taking into consideration the physical and mechanical parameters of the different samples;
- A statistical treatment of compressibility parameters of compressible soils such as compressibility index (Cc), swelling of the soil, void ratio (e0) and consolidation pressure.

The interest of this work is to identify, quantify and take into account the physical and mechanical characteristics of soils for a better estimate of the geotechnical risk (settlement, stability ...), in an area with sub-arid to sub-humid climate.

2 Presentation of the Site of Study

2.1 The Morphological and Geological Context

The area of study is bounded by the hills of LallaZohra to the north, by Maamora plain to the south, by the hills of BelBouDraa and Ksiri to the east and by the Atlantic Ocean to the west. A large closed basin, whose center is occupied by wadis of Sebou and Beht, is situated at less than 10 meters of altitude even if edges do not exceed a few hundred meters.
Towards the sea, the basin is also closed by the dune Sahel wide of 5 to 25 Kmand high of about 30 to 50meters. The numerical model of the ground, introduced by the figure n°1, shows well the dominance of low-lying lands.
From a geomorphologic point of view, the zone of study crosses several geomorphologic sets: The sandy formations of Maamora in the bypass of the city of Kenitra, the Gharb plain with alluvial deposits of the OuedSebou and the cord of coastal dunes beyond the plain of Sebou.

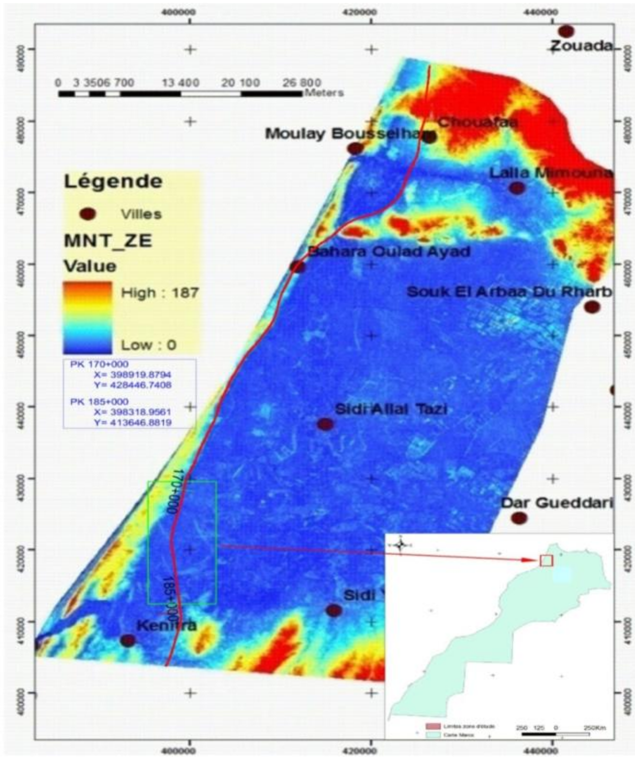

Figure 1: Localization of the zone and digital model of ground of the zone of study

The geological study constitutes a primordial and an essential stage for any geotechnical synthesis. Not only it allows to define well the lithology, the structure and the geological history of the region but it also allows delimiting the geographical spread of the different facies and their distribution modes.

On the whole, the Gharb basin, asymmetrical and hardly subsident since its formation in the middle of Miocene, knew in the course of its evolution several fluctuations of sea level linked to the neotectonic movements. The latter were translated in the coastal zone by faults and by a regular uprising of Meseta, resulting from an isostatic readjustment ([1],[2],[3],[4], [5], [6],[7] and[8]. These variations are, in most cases, due to tectonic activity and to sedimentary provisions. The effect of the short-term sea level fluctuations is added to the long-term tectonic movements.

2.2 Problematic

The Tangier-Kenitra segment is strategic nationally. It connects the two cities of Tangier and Kenitra both experiencing a demographic and an economic increase in recent decades.

Morocco has adopted the realization of a High Speed rail Line (HSL) Tangier-Kenitra. This line is within the scope of a Moroccan project developed in 2005 by ONCF which aims to build 1500 Km high-speed rail lines in less than two decades. As it was reported earlier, the region is a part of the Gharb plain known geologically by a subsidence phenomenon in addition to the presence of surface packing soils. However, the HSL infrastructure is very sensitive to the compaction phenomenon. Thus, the major problem

is to estimate the soil compaction and seek appropriate solutions. To achieve this goal, a campaign of geotechnical investigations was conducted in the area. It consists in the characterization of physical and mechanical properties of soils.
This study showed that a reinforcement of soils by vertical drains introduced par dynamic substitution is the most appropriate.
A parametric analysis of compaction calculations highlighted the sensitivity of the technique of soil reinforcement towards certain geotechnical parameters.

3 Materials and Methods

The geological and geotechnical investigations necessary to the design of the site are conducted in two steps: The APS Phase (preliminary design) and the APD phase (before detailed design).
A total of 289 static penetrometers, 89 core holes, 11 holes with SPT tests and coring, 20 holes with Vane tests were conducted to determine these heterogeneities.
To characterize the soils of the region and for a further exploit of the database, we decided to make a multidirectional statistical treatment (PCA and HCA) and also look for correlations between the different parameters.
The campaign of reconnaissance concluded that a simplified model of five layers is appropriate:
Silt and silty mud, clay and silty clay,clayey silt, silty sand, sand and sandstone.

4 Results and Discussion

4.1 Correlation between Geotechnical Parameters

The method used to determine the correlation between geotechnical parameters of the soil is the principal component analysis (PCA). The principle of PCA is well described by several authors ([2] and [3]. This method is often used in the fields of geosciences ([4], [5] [6] and [7] It is a factorial method that allows building factors considered either as new independent variables or uncorrelated statistically which facilitate the study of links between initial variables. The main objective is to extract, in a condensed form, the largest possible information contained in the data, whether related to links between variables or between individuals (tests). Correlation matrices lead to determining the positive and negative correlations. Correlation between parameters was determined (Table 1).

Table 1: Correlation between the geotechnical parameters of the five types of soils

	Wl		γd	
Type of soil	Positive correlation	Negative correlation	Positive correlation	Negative correlation
Mud	IP		Ic	Wn, Cc, e0
Clay	IP		Ic,	Wn, Cc, e0
Sandy clay	IP, Ic, Pc		Ip, Ic, Pc	Wn, e0
Argillaceous Silt	IP, Ic	Wn		Wn, Cc, e0
Muddysand	IP, Ic			Wn, Cc, e0

With: (Wn) water content, (Ip) plasticity index, (WI) liquidity limit, (Ic) consistency index, (e0) void ratio, (γd) specific weight, (Cs) swelling index and (Pc) consolidation pressure.
According to the previous table, the parameter Wl is always positively correlated with IP while γd is negatively correlated with the two parameters Cc and e0.

4.2 Principal Component Analysis (PCA)

The principal components analysis method (PCA) was conducted on 13 parameters and 181 people in total. It shows that the first three principal axes absorb 72% of the total variance. They absorb respectively 37%, 22.7% and 12.4% (Table 2).

Table 2: analysis of the first three principal axes (ACP)

	F1	F2	F3
Eigen value	3.697	2.271	1.240
Variance percentage	36.974	22.710	12.404
cumulative percentage	36.974	59.684	72.089

We note that many variables are dependent, even weakly. The highly significant correlations appear for physical parameters (for example R = -0.859 between W% and γd is weakly significant when considering the mechanical parameters (eg R = 0.488 between Cc and Cs), but also between physical and mechanical parameters (eg R = 0.42 between W% and Cc) (table 3).

Table 3: Correlation matrix for the parameters used

	X	Y	Z	Prof/TN	gh	gd	Wn	WL	IP	Cc	Cs	Pc	e0
X	1	0.501	-0.098	-0.069	-0.148	-0.151	0.106	-0.021	0.007	0.165	0.099	-0.099	0.104
Y		1	0.190	-0.187	0.062	0.113	-0.129	0.124	0.206	-0.069	-0.037	0.060	-0.115
Z			1	0.096	0.071	0.152	-0.165	0.096	0.143	-0.152	-0.122	0.203	-0.100
Prof/TN				1	-0.045	0.027	-0.056	-0.181	-0.229	0.005	-0.026	0.032	0.030
gh					1	0.760	-0.360	-0.172	-0.166	-0.572	-0.224	0.162	-0.679
gd						1	-0.870	-0.181	-0.085	-0.611	-0.252	0.312	-0.667
Wn							1	0.166	0.025	0.483	0.220	-0.310	0.484
WL								1	0.912	0.294	0.483	0.283	0.288
IP									1	0.229	0.432	0.276	0.238
Cc										1	0.521	-0.134	0.762
Cs											1	0.162	0.393
Pc												1	-0.231
e0													1

We note first that the positional parameters have a moderate impact on other parameters. Further, physical parameters are strongly correlated. The pole % W / Ip / Wl is inversely correlated with the density, and with Ic to a lesser extent. These physical parameters are not correlated with the mechanical ones as soil stress is not related to their physical and mechanical characteristics. This confirms that the phenomenon of soil consolidation is related to loading conditions specific to the site.

4.3 Projection on the Factorial Plan F1F2 (59.68%) (Figures 2-3)

The projection of individuals on the first factorial plan with its first two principal components absorbs 59.68% of the total variance. Individuals are more or less grouped except some who are excluded and seem specific.
The F1 axis is positively correlated with the variables gd and gh while it is negatively correlated with the variables CC, e0 and more or less Wn.
The F2 axis is more or less correlated positively with the variables Wl and IP and it is negatively correlated with no variable.

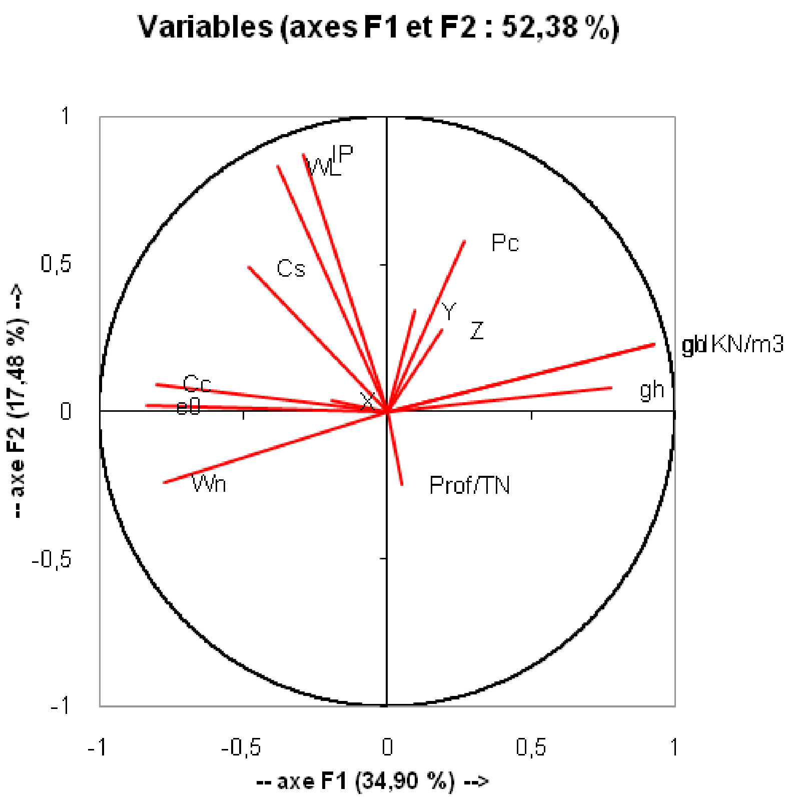

Figure 2: Correlation circle of variables

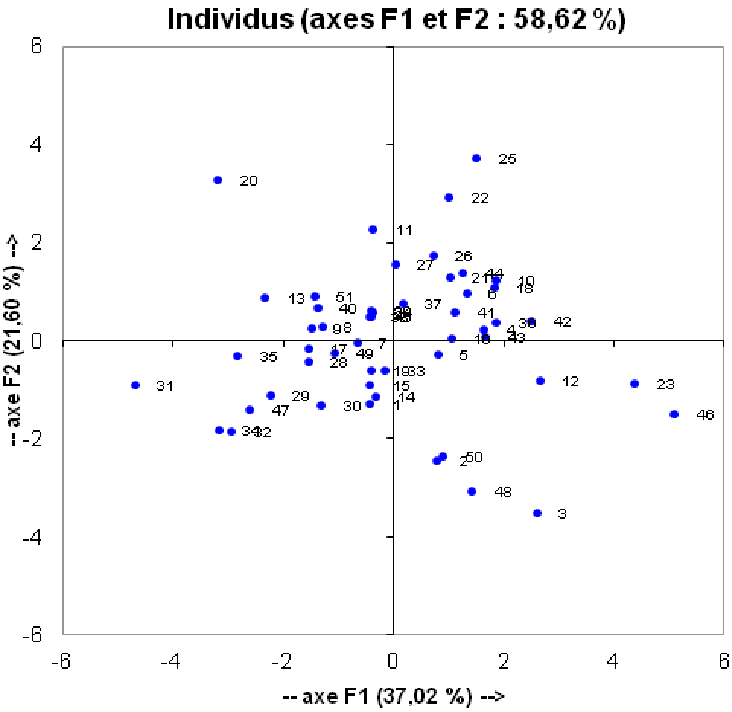

Figure 3: First factorial plan (F1F2) of individuals

4.3 Projection on the Factorial Plan F1F3 (45.84%) (Figures 4-5)

The second factorial plan F1-F3, absorbs 45.84% of the global information. So, it is important to analyse the contribution of the third factorial axis.

The axis F3 absorbs only 11,13% of the total variance. In addition, we note that only the depth is more or less positively correlated with this axis F3. The F1 axis shows the same previous correlations.

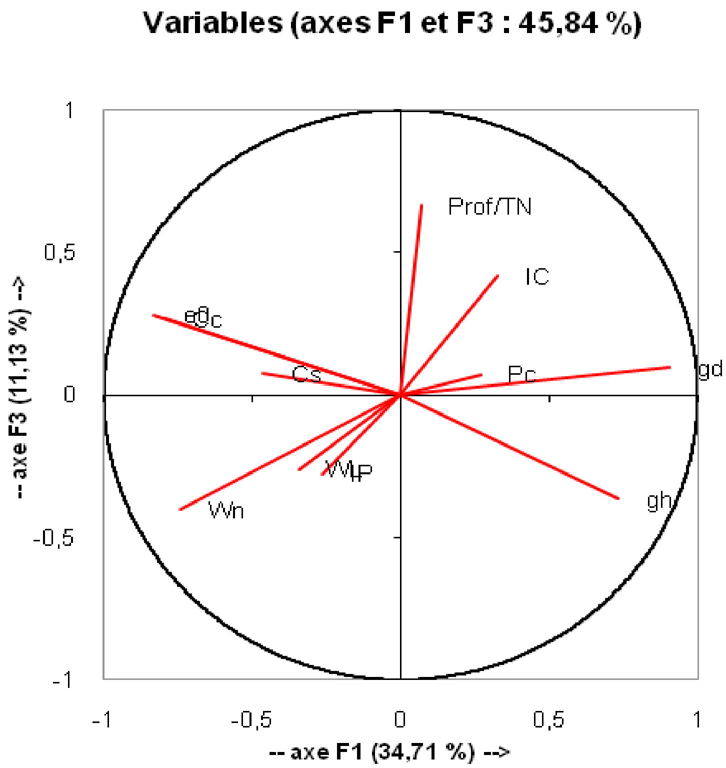

Figure 4: Correlation circle of variables

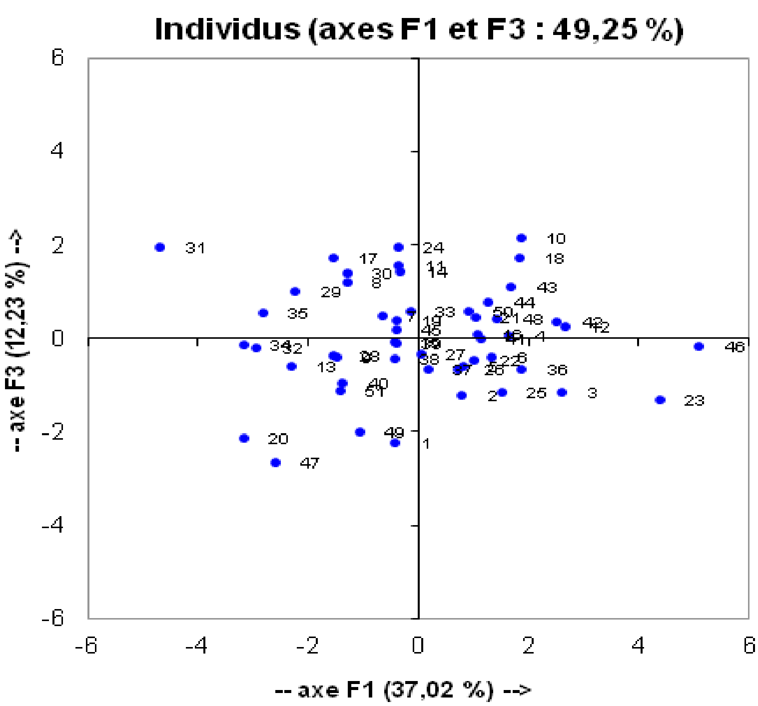

Figure 5: Second factorial plan (F1F2) of individuals

The principal components analysis take into account neither the position of points in space, neither the degrees of similarity between the parameters. To overcome this, we started to use the Ascending Hierarchical Classification method (AHC).

4.4 Ascending Hierarchical Classification

The AHC Classification allowed to reclassify individuals in 4 classes more or less homogeneous. The level of dissimilarity was of 35.7% (Figure. 6).

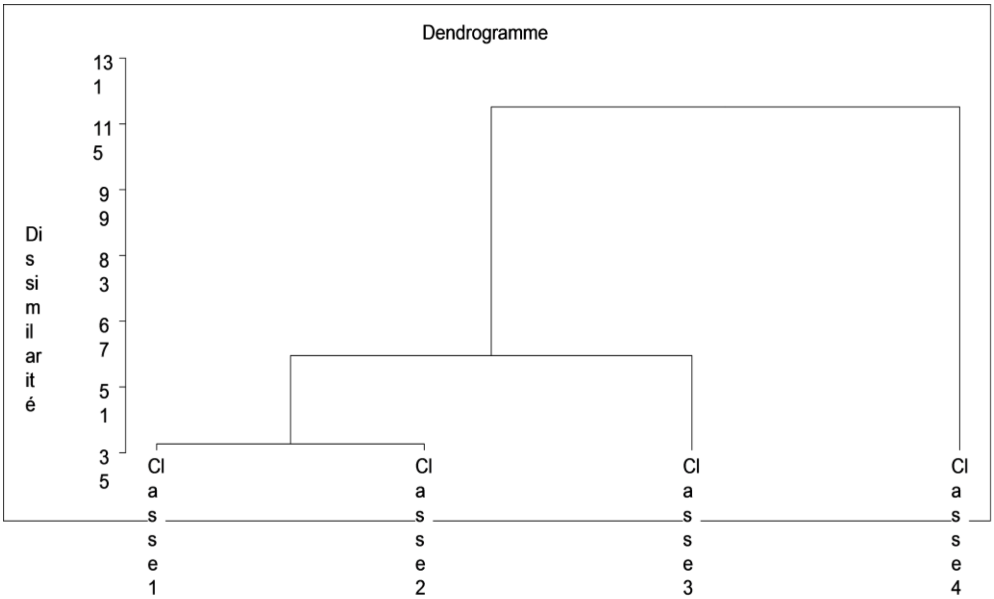

Figure 6: Level of dissimilarity – Ascending hierarchical Classification

The analysis of the level index resulting from the CHA has shown that, for a number of four classes, the interclass inertia is smaller. The spatial distribution of these classes was done and the four sub-areas defined are well represented on the longitudinal geotechnical profile.

5 Conclusion

This work shows the importance of having a complete view of all geotechnical recognitions campaigns.The analysis and interpretation of geotechnical parameters allowed to identify with more precision four types of compressible soil with the following characteristics: Vase and silty vase, clay and silty-clay, clayey silt, silty sand.
Results obtained from PCA: The correlation matrices were used to determine the positive and negative correlations between variables γd and Wl with other parameters. PCA showed that the first three factorial axes (F1, F2 and F3) absorb more than 72%.The CHA has divided the samples into four different classes with physical and mechanical characteristics more or less homogeneous.

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