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Physical Characterization of the Soils of the City of Oumhadjer (Eastern Chad) as a Foundation for Structures

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Abstract

The study focuses on the physical characterization of soils in the city of Oum-hadjer and classification. The field work showed that the soils of the study area are heterogeneous (fine sand little silty to silty) in most sites. This heterogeneity is related to the geological context of their formation. The results obtained show that the soils of the southern part of the city of Oum-hadjer have a low percentage (22.6%) in fine particles whose dimensions are less than 0.08 mm. According to the GTR 92 classification, these are gravelly soils that belong to class B5 (80µm sieve between 12 and 35%, 2mm sieve ≤ 70% and Ip < 12). The plasticity index varies from 3.6% to 6.5% with an average of 4.7% gives the studied soil a non-plastic character. The use of these soils as foundation of ordinary buildings in the southern part of the city of Oum-hadjer would not present any risk if the footings are laid at 1.5 see 2m depth. As for the northern part of the city of Oum-hadjer, the materials are clayey and their use as foundation requires special attention for a good holding and durability of works.

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Soils, physical parameters, foundation, Oum-hadjer, Chad.

Introduction

Soils are currently of great interest to many researchers because of their complexity and their varied use (Abakar *et al.*, 2017). Nowadays, soils are used as a constituent in certain materials, as raw materials or as foundation soils for structures. Population growth can be seen as one of the potential factors of progress (Amadou, 2008). It is accompanied by a more extensive occupation of the territory and an increased demand for services and goods. Among the latter, housing occupies a prominent place and the realization of structures depends primarily on the quality of its foundations. The foundations of many surface constructions are based on unsaturated soil (Xiang-Ling, 1999). Depending on the distribution of water or air, the soil can be either saturated, dry, or in an intermediate state called unsaturated (Derfouf, 2014). This is why a good knowledge of soil properties is of paramount importance in the construction of structures. In the town of Oumhadjer, the capital of the East Batha Department (Fig.1), geotechnical studies are almost absent and not generalized. It is to contribute to the geotechnical characterization of the soils of the said city that the present work has been initiated. It uses the results of 22 soil samples taken at the Civil Engineering Laboratory in N'Djamena (Chad).

Materials and Methods

Field method

Field work requires a rigorous method because the results of the laboratory tests depend on it. The method adopted consisted in the location of the study and sampling sites. To this end, twelve (12) 2m wells were made in the city of Oumhadjer and the sampling points are presented on the sampling map (Fig.2). Sampling was done by horizon in the dug wells. A total of 22 samples were collected for geotechnical testing (Fig.3).

Laboratory method

The laboratory work consisted of carrying out geotechnical tests in accordance with the laboratory standards. The granulometric analysis of the soils was carried out by wet sieving, the principle of which is based on the (NF P 94 – 056, 1996) standard. The granulometric separation of the fine particles (dimension lower than 0.08 mm) was carried out by sedimentation according to the (NF P 94 – 057, 1992) standard. The study of soil consistency was carried out on the basis of Atterberg limit tests. The plasticity limit was determined by the roller method as described by the (NF P 94 – 051, 1993) standard and the liquidity limit using the Casagrande cup. The plasticity index was determined by calculation. The natural water content of the studied soils was determined by steaming according to the prescriptions of the standard (NF P 94 – 050, 1995).

The density of the solid grains was determined using pycnometers according to standard (NF P 94-054, 1991), and the apparent density was determined by the cutting kit method. The dry density of the soils was determined by calculation using the relationships between the different physical parameters.

Results and Discussion

Observation and macroscopic description of the sequences

The macroscopic description highlighted the nature of the soils encountered in the study area. Levels were identified and described from the base to the top (Fig. 4).

The study area, through which the Batha River flows, contains mainly gravelly soils in the southern part of the river, but fine soils are present in the northern part of the river. The color of these soils varies from one well to another, and also from one horizon to another. In addition, there are alternating layers of fine sand, sandy loam, sandy loam and clay in places.

From this description, it appears that the study area contains heterogeneous layers in most sites. This heterogeneity is a function of the environment of their natural formation (Boudlal, 2013). Moreover, the nature of the layer influences the type of deformation. It can go from a failure by settlement and bulging in the presence of soft layers to a failure by punching exerted by hard layers.

According to (Nathalie, 2002), the lack of information concerning the heterogeneity (lithology and/or mechanical properties) of the foundation materials can lead to a bad evaluation of the differential settlements, prejudicial to the structure of the building and to a lack of consideration of the risks in the choice of the foundations, as much in their dimensioning as in the execution constraints.

Geotechnical characteristics

The study of the physical characteristics of the soils of the city of Oumhadjer was carried out on 22 samples. The physical tests determined are particle size analysis, Atterberg limits and consistency parameters, bulk density, solid grain density and dry density. These physical characteristics are determined by relatively simple, reliable and inexpensive methods, which explains their wide use in civil engineering.

Fine particle content, Atterberg limits and consistency parameters

The results of the percentage of passings through the 0.08mm sieve and the consistency parameters are presented in Table 1.

The granulometric results (the passings of the 80µm sieve vary from 3.3% to 34.7% with an arithmetic average of 22.6%) show that apart from a few samples consisting of clayey materials and clayey silts, the soils of the town of Oumhadjer are essentially grainy.

For the great majority of samples, the percentages of the passings of the sieve of 0,080mm are very weak and largely lower than 50%, which confers on the studied soils the character of grainy soils. The surface texture is mainly sandy-silty on the left bank of the Batha River and clayey on the right bank. According to the GTR classification (NF P 11-300, 1992), these soils are considered as gravelly soils.

The data in Table 3 show that the liquid limit wLvar ranges from 27.4% to 32.8%, with an arithmetic mean of 29.9% and a standard deviation of 2.7. The plasticity limit wpvarie in a range of 23.8% to 26.3%, with an arithmetic mean of 25.1% and a standard deviation of 1.3. The plasticity index of the studied materials varies between 3.6% and 6.5%, with an arithmetic mean of 4.7% and a standard deviation of 1.6.

These values give the soils studied a non-plastic character. According to the Guide des Terrassements Routiers, the values of the plasticity index obtained make it possible to classify the soils studied as being essentially gravelly soils of class B5. A soil with a low plasticity index is not very sensitive to atmospheric conditions, because the lower the plasticity index, the less swelling and shrinkage due to desiccation of the soil. Chikhi and Houari (2004) have shown through the characterization of Constantine clays that the soil that contained them had a medium to high plasticity with values of Ip between 15 and 45%. This leads to consider Ip as one of the important parameters in the water retention properties of the soil and therefore of swelling. The plasticity index of the study area is not found in this range, therefore, the studied soil is non-plastic and its use as a foundation soil does not require prior treatment.

Some authors such as (Snethen, 1980) and (Snethen, 1984) relate the swelling potential to a single parameter, the plasticity index (PI). The swelling character of the soil is then estimated from the following thresholds: Ip > 35% swelling potential is very high; Ip is between 25 - 48% swelling potential is high; Ip is between 22 -32% swelling potential is medium;Ip<18% swelling potential is low. Based on this classification, the soil in the study area has low swelling potential because its plasticity index is less than18%. Chen (1988) presents the degree of swelling as a function of the plasticity index, following a series of tests performed on undisturbed US soils.

It shows a classification of swelling soils according to Ip: when Ip > 35% the swelling potential is very high Ip is between 10 - 35% the swelling potential is medium; Ip is between 0 - 15%, the swelling potential is low.

Based on this classification, the soil in the study area has a low swelling potential because its plasticity index is in the range of 0- 15%. More recently, (Prian *et al.*, 2000) have refined the relationship estimating swelling potential from the plasticity index. The thresholds are indicated as follows: when Ip> 40%, the swelling potential is very high; if Ip is between 25 - 40%, the swelling potential is high; Ip is between 12 - 25% the swelling potential is medium; Ip < 12%, the swelling potential is low. Based on this classification, the soil in the study area has low swelling potential because its plasticity index is less than12%.

The values of the plasticity index of the city of Oumhadjer do not agree with those of the clays of the 2nd district of the city of N'Djamena obtained by (Al-hadj *et al.*, 2021) which are from 13 to 40.7% with an average of 28.2%. This discrepancy is due to the nature of the materials studied.

The non-plastic state of the soil in the study area is explained by the fine fraction content which is less than 50% in all the samples analyzed with an average value of 22.6%.

Density parameters

Densities give the possibility to judge the quality of the constructive properties of soils. The results obtained are presented in Table 2.

The data in Table 2 show that the soil bulk density (ρ) ranges from 1.34 to 1.63g/cm^3, with a mean of 1.50g/cm^{3}and a standard deviation equal to 0.1.

Soil solid particle density (ρ_s) varies in a range of 2.15 to 2.58g/cm^3, with an arithmetic mean equal to 2.45g/cm^3 and a standard deviation equal to 0.1. These values do not agree with those found by (Al-hadj *et al.*, 2017). This discrepancy could be explained by the lithological nature of the studied soils.

The dry density (ρ_d) varies from 1.17 to 1.61 g/cm^3, with an arithmetic mean of 1.47 g/cm^{3}and an equal standard deviation of 0.1%.

The present work has provided a precision on the geotechnical characteristics of the soils of the city of Oum-hadjer. In the southern part of the city, the soils studied show a non-plastic character with a plasticity index between 3.6% and 6.5% with an average of 4.7%. The absence of plasticity is due to the low content of soil particles smaller than 0.08mm. The soils are mainly gravelly, made up of fine sands, with little silty to silty content of class B5 according to the GTR classification.

Table.1 Fine particle content, Atterberg limits and consistency parameters.

Statistical indices	Particle content < 0,08mm	w_L(%)	wp%)	Ip (%)	Ic	I_L
Xmin(%)	3,3	27,4	23,8	3,6	4,4	**3,4**
Xmax(%)	34,7	32,8	26,3	6,5	6,6	**5,6**
Xmoy(%)	22,6	29,9	25,1	4,7	5,7	**4,7**
Standard deviation	**8,59**	**2,7**	**1,3**	**1,6**	**1,1**	**1,1**

Table.2 Densities of the studied soils.

Statistical indices	ρ_s (g/cm^3)	ρ (g/cm^3)	ρ_d (g/cm^3)
Xmin	2,15	1,34	**1,17**
Xmax	2,58	1,63	**1,61**
Xmoy	2,45	1,50	**1,47**
Standard deviation	**0,1**	**0,1**	**0,1**

Fig.1 Location map of the study area

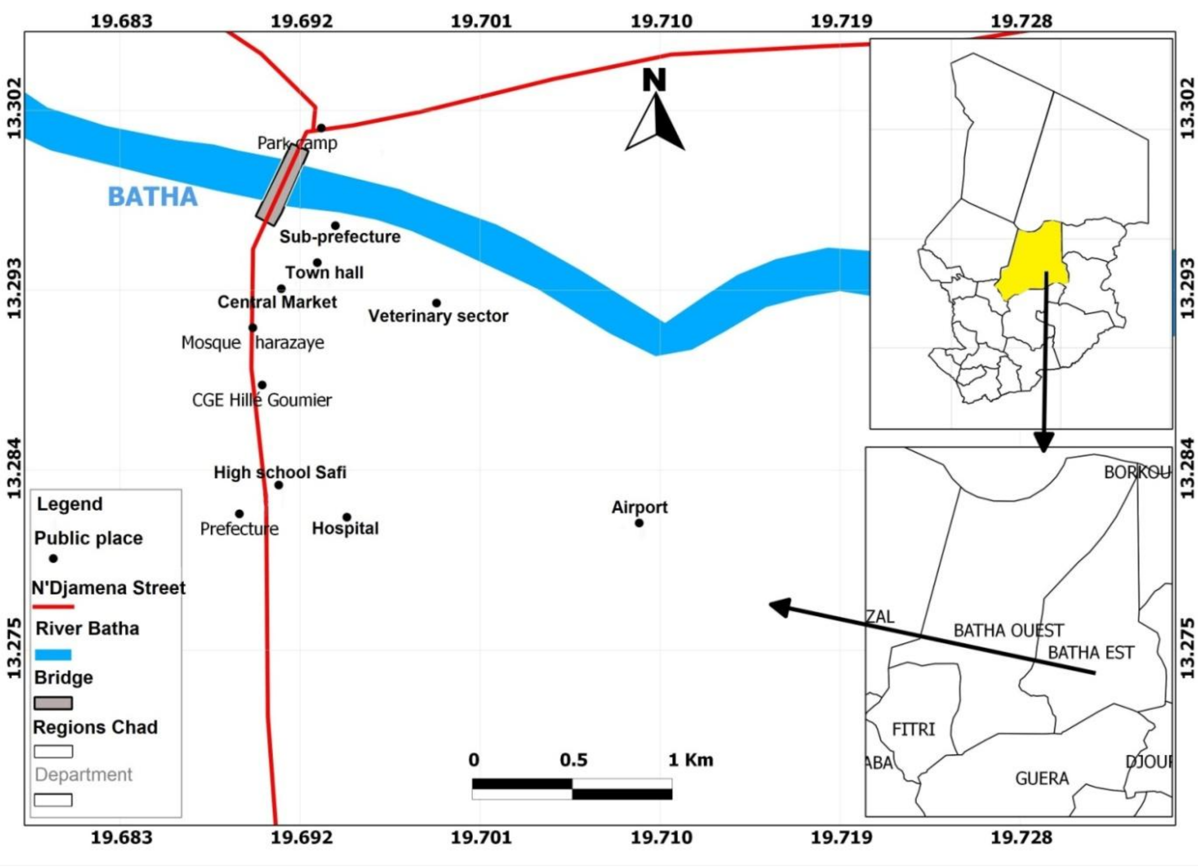


Fig.2 Sampling map

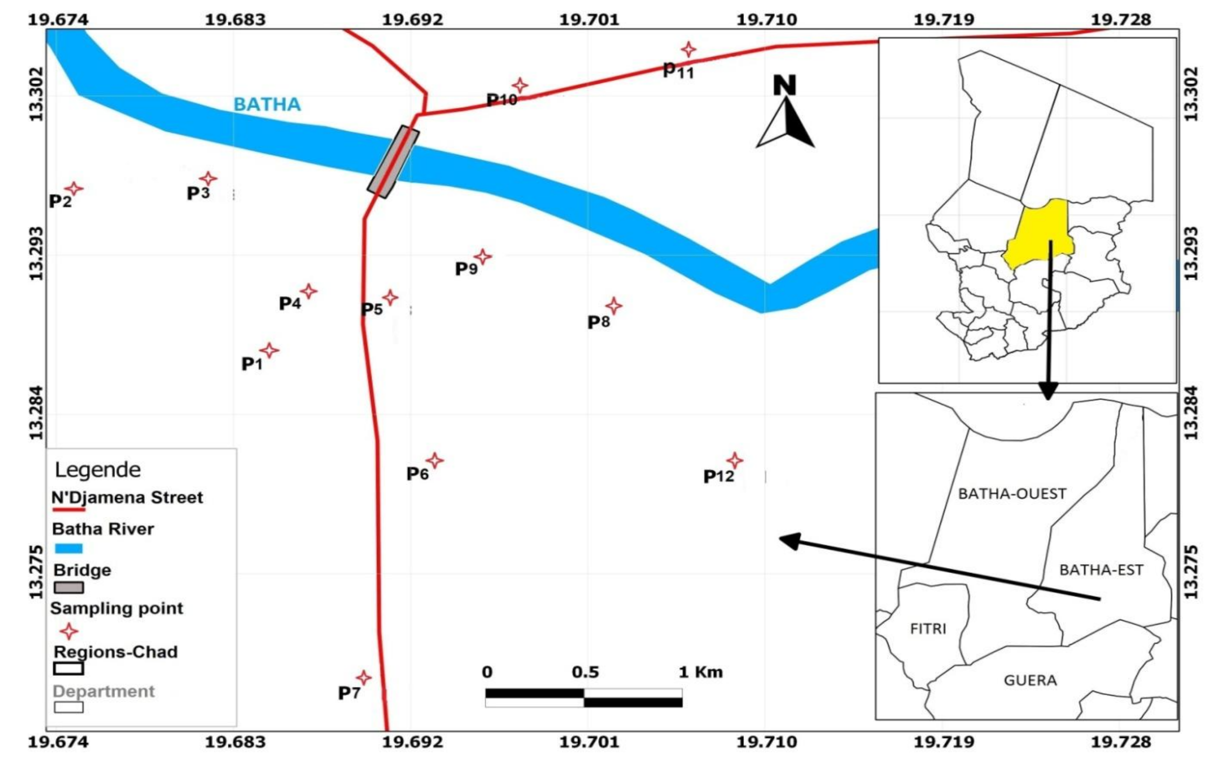
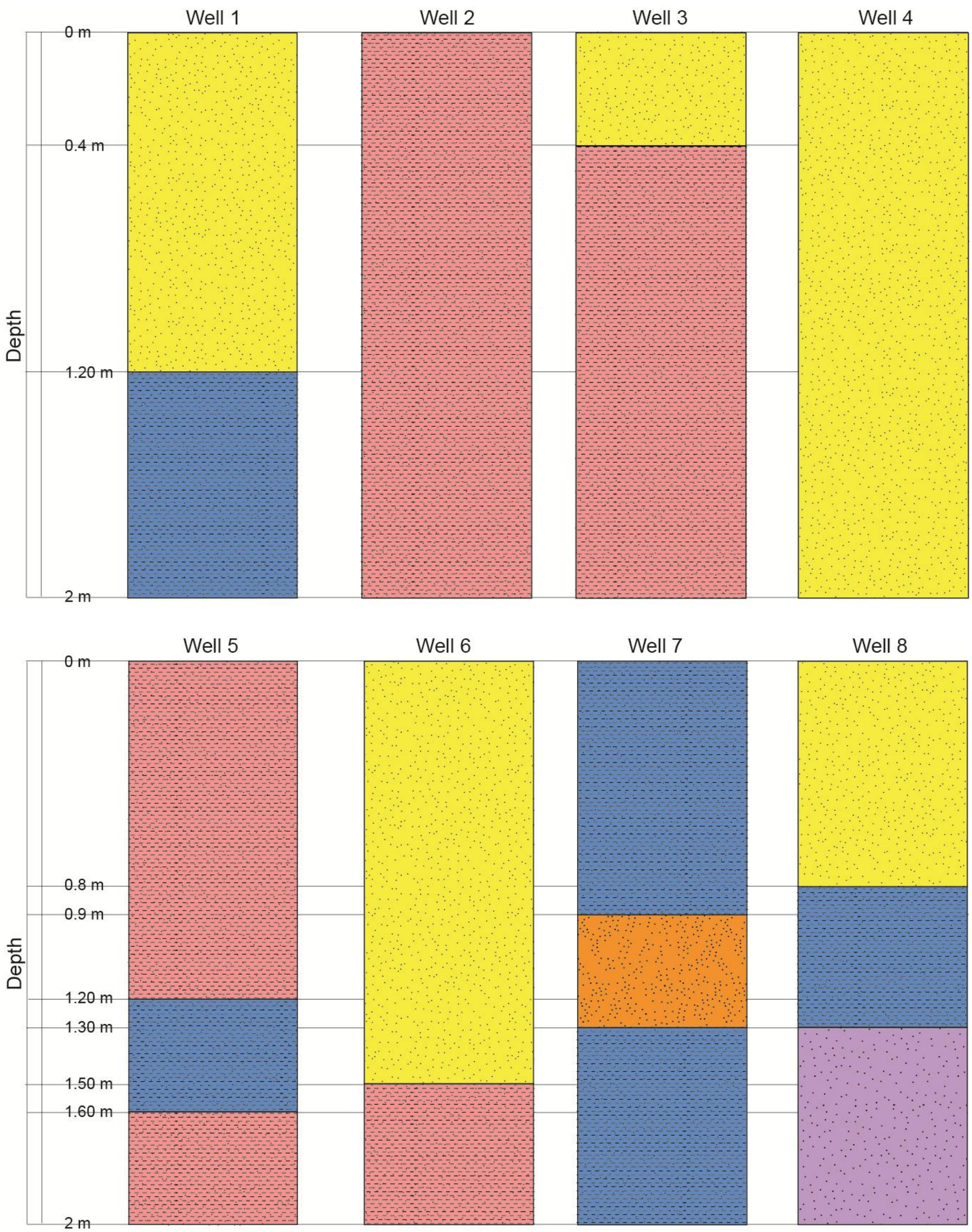
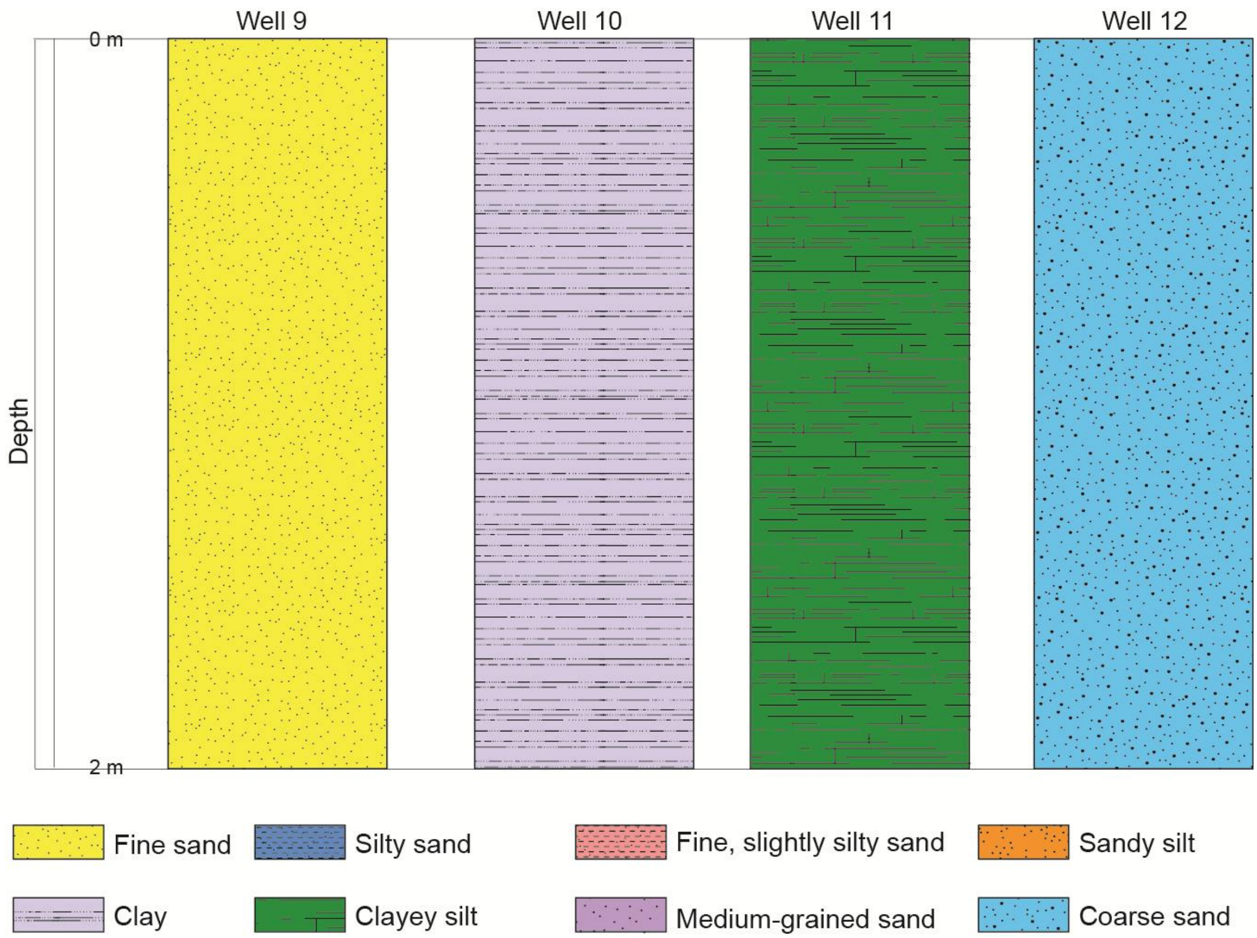


Fig.3 Samples collected

Fig.4 Lithological logs of the wells





The use of these soils as foundation for ordinary buildings would not present any risk if the footings are laid at a depth of 1.5 to 2m. As for the northern part of the city, the materials are clayey and their use as foundations requires special attention for good performance and durability of the structures.

Overall, the use of the soils of the city of Oumhadjer as foundation bases for structures requires the determination of mechanical parameters for a better dimensioning of the foundation.

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