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Influence of Soil Geotechnical Propreties on Water Erosion in Brazzaville City

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Abstract

Geotechnical results from tests of identification and consolidation in soil samples of sands deposits are presented. It is the sedimentary cover that lies unconformably on the Precambrian rocks. The sedimentary cover has similar characteristics like loess and comparable to those deposits found in other parts of the world. The laboratory results of edometric and sieve tests indicate this soil is sandy and loam, non-cohesive, collapsible leading to differential settlements between 4.3 and 5.5 cm.

Keywords: Sedimentary cover, Loess, Sand, Geological engineering, Differential settlements, Brazzaville.

Introduction

Brazzaville city from the geological engineering viewpoint is mainly characterized by the intensity that the geodynamic processes affect the soil and the appearance of huge gullies and landslides conditioned by the type of non-cohesive soils and water action in these soils. This work has been conducted by field and laboratory study, the main results obtained from laboratory tests are presented in the present paper. Geologically the Paleozoic sedimentary cover from Mesozoic to Cenozoic lies on rocks of Precambrian age.

The groups from Precambrian to Paleozoic outcrop downstream of Brazzaville, while the sedimentary cover from Mesozoic to Cenozoic outcrops upstream of Stanley Pool. Brazzaville city is the capital of the Republic of Congo and stretched along the Congo River. It lies in the mapping area 33S between latitudes 4°10' and 4°17' South and between longitudes 15°16' and 15°45'[1].

Methodology

This work consisted of drilling open pit wells in Brazzaville City, in sand deposits to determine the soils volumetric weight and portable static cone testing at the bottom of the well was conducted to extract altered and undisturbed samples for laboratory tests. The deep wells were drilled with rotary machine, equipped with equipment for the SPT Standard Penetration Test[2,3].

Gibbs and Holtz chart was used to identify the variation of relative density at different depths in the sand deposits. It was determined physical and mechanical soil properties in the laboratory as moisture content, specific gravity, specific gravity of solid were determined and the soils grain size as the total dry weight percentage by sieving and it was plotted grading curve with that the Uniformity Coefficient (Cu) was obtained. It was used Unified Soil Classification System, S.U.C.S, which divides the soil in granular soils (those that are retained on mesh # 200) and fine soils (soils passing mesh # 200)[4]. For identifying the plasticity of fine soil it was used the plasticity chart[5]. Sands strength parameters were determined in direct cutting machine with reconstituted sands samples, which kept the site characteristics such as moisture, relative natural vacuum and volumetric weight wet.

Samples were tested each one with different normal vertical stress and applying low speeds for tangential charge equal to v = 0005 mm/min, to chart the shear stress versus normal stress in each one, thus effective internal friction (φ) angles were obtained. The consolidation test to the high porosity observed in these soils was made from undisturbed samples, taken according to the depth and preserving the microstructure and natural moisture.

To each oedometer cells flooding the sample is caused to different load values. Generally with the presence of water in the soil under load causes sudden destruction of the microstructure form, representing the collapse process.

Results and Discussion

The main problem of the case study of Brazzaville city is the capacity and soil stability. In evaluating erosion from the viewpoint of soil geotechnical properties such as; density, plasticity index, shear strength, fines content (properties that when increase in value, increase resistance to soil erosion); voids index, and swelling (properties that when decrease in value, increase resistance to soil erodibility) Table-1.

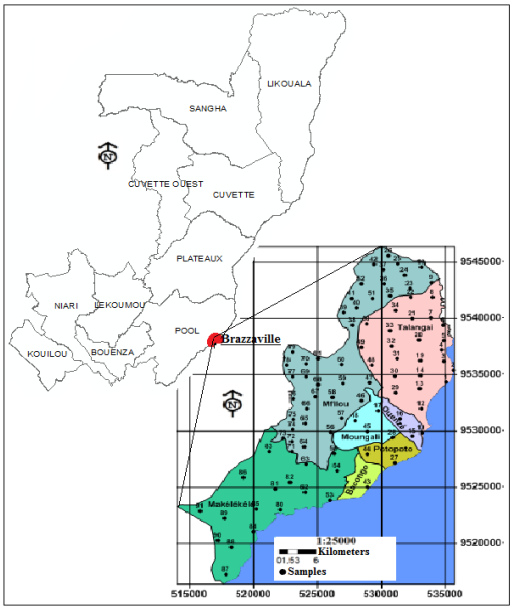

Figure-1
Study area location

Table-1
Physical and mechanical properties of soils in Brazzaville city

Physical and mechanical properties	Unidad	Valores		Valor promedio
		Minino	Máximo	
Dry unit weight	kN/m^3	12.2	14.5	13.0
Wet unit weight	kN/m^3	14.9	16.8	15.2
Liquid Limit (LL)	%	15	18	16
Plasticity Index (IP)	%	0	4.0	2.5
Sand fraction (> 0,1 mm)	%	69.3	76	…….
Silt fraction (0,1mm - 0,002 mm)	%	3.9	9.2	-
Clay fraction (< 0,002 mm)	%	1.9	2.7	-
Colloids%	%	0.8	1.7	-
Organic matter	%	1.02	1.42	
Degree of deformation (Cu)	--------	1.30	4.96	2.25
Permeability	mm/h	……	>300	-
Specific gravity (ρ)	KN/m^3	21	27.3	-
Natural moisture	%	12	15	-
Internal friction angle φ’	º	9.44	33.24	-
Effective cohesion c’	kN/m^2	-	< 6	(~ 0)
Confined Modulus to natural moisture (*) (a 100 kPa)	kN/m^2	1500	8000	4000
Confined saturation modulus (*) (a 100 kPa)	kN/m^2	1000	4000	(1900)
Unconfined compression strength	kN/m^2	45	130	(85)

It is noted that the internal friction angle of sand, depends not only on the grain size characteristics, but also the shape of the grains and the roughness of their surfaces, this strength largely affects water erosion and particularly gully erosion, since by reducing this strength increase the chance of developing this phenomenon. Experience shows that the grain size of loamy sand as underlying to Brazzaville city soils are of great practical importance to erosion processes in manifest. The fine sandy soils appear in Inkisi, Stanley Pool and Batéké groups from Brazzaville city and are represented as the oldest deposits. The origin of these soils is linked to its geological history, appearing under various geologic processes. These soils are slightly cemented and classified as loess.

Brazzaville city loess are fine sandy - loamy soils to the size which grains of the most abundant fraction varies from 0.06 mm to 0.002 mm. Grain size, grain shape and low plasticity have been well defined by laboratory tests. Moreover, these deposits have a very fine sand fraction and grains are very rounded (Figure-2).

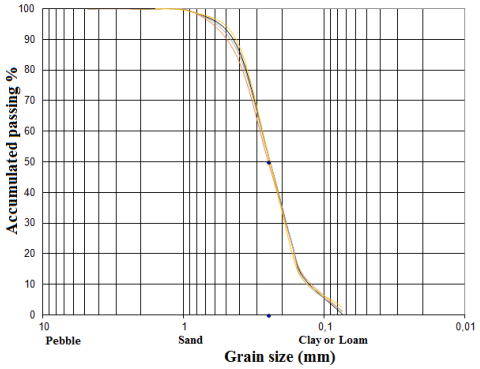

Figure-2
Sieving curve of samples taken at different sites of Brazzaville city

The grain composition marked a predominance of the sand fraction with very low levels of silt and clay is denoted, which is in line with that reported for soils in the study area and characterized by having in common very sandy surface layers. A distinctive feature of these soils is that the sand and silt fraction are formed mainly of feldspar, mica and quartz with a very limited specific weight of 21 kN/m^3 to 27.3 KN/m^3.

The structural characterization of the sandy-loamy soils of Brazzaville city is of paramount importance in geotechnical engineering for predicting the mechanical behavior and provides considerations for the design of foundations for different types of engineering works. From the geotechnical point of view these soils in the north, northeast and northwest of the city are classified as low plasticity. The dry density is usually between 12.5 kN / m^3 to 14.5 kN/m^3 and its aspect is stable mainly due to its natural condition of half saturation (the natural moisture is between 12% and 15%). In Table-1, the specific gravity (ρ) in this soil reaches maximum values of 26.3 KN / m^3, typical of soils with high sand content. In general, the studied soil is classified as one, not plastic sand type SM from SUCS classification.

The angle of internal friction is closely related to the slope of the surfaces, being 10 to 40 ^{o} and plays an important role when these sands contain a small amount of water (Figure-3).

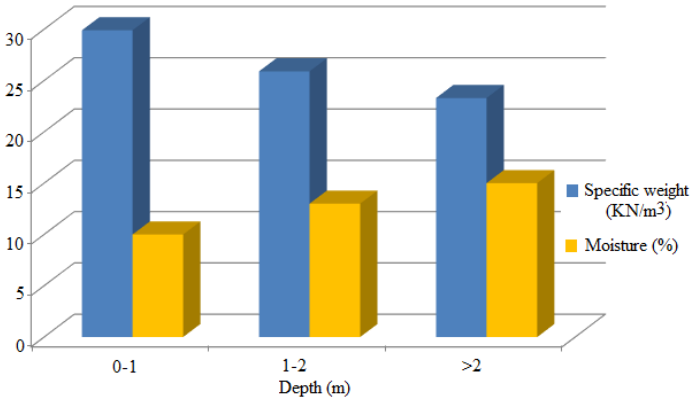

Figure-3
Variation of the specific weight and moisture with respect to depth

The sandy soils collapse process of Brazzaville city occurs when the charging process takes place together and flooding. During the consolidation test, different samples in cells subjected to gradually increasing pressures until a maximum consolidation under loads of 800 kPa, continuous pores index changes were recorded during loading and unloading. The collapse coefficient calculated C_{COL} ranges is from 0.022 (2.2%) for the sample under load of 100 kPa and 0.007 (0.7%) under the maximum load (800 kPa). Comparing these results with the interpretation of other tests performed on the same material m_v calculated varies from 0.018 to charging intervals of 0-50 kPa at 0.034 m2/kN for loads of 800-1600 kPa. Within the empirical collapsibility indices (Ic) is most commonly used criterion of Feda[6], according to which values above 1% would indicate problematic soils. Ic values obtained for sandy soils vary between 1.50% and 2.23% (Figure-4).

Collapsibility index, Ic, is defined as.

$$i_c = \frac{(\frac{w}{s_o}) - Lp}{IP} \quad (1)$$

Where: W is the natural moisture of the sample, s_o means the initial saturation degree, LP represents the plasticity limit and IP is the plasticity index.

During consolidation tests sudden compressions phenomena were recorded when samples were flooded during various stages of loading edometric test. Estimates and settlements are important to consider when planning a civil infrastructure in

these areas, settlements ranging from 4.3 cm and 5.5 cm are estimated.

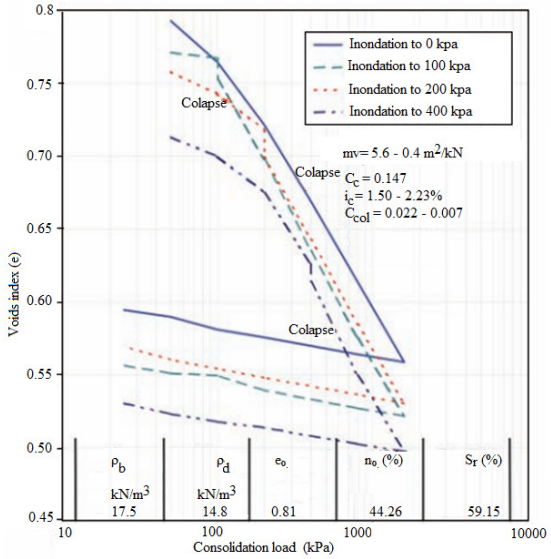

Figure-4
Consolidation curves for samples of fine sandy soils of Brazzaville city. ρb: Wet unit weight of soil, ρd: Dry soil Unit weight e_o: Voids index, n_o: initial porosity, Sr: saturation index, m_v: deformation modulus, Cc: compression modulus, C_{COL} coefficient of collapse, C_I collapsibility index[6]

Discussion: The coefficients of uniformity of grains size are of less than 5 order (Cu <5) indicate that these soils are eroded under the gradient of erodibility accepted by the World Food Organization. Cohesion is almost zero and reinforces soil instability and erodibility. The presence of powerful soils redeposited by water erosion and their own geotechnical properties as natural base of buildings can be considered special soils[7].

Conclusion

The lithology consists of sandy soils with low clay content, located in areas of steep slopes results in high rates of soil transported by water erosion and then deposited in rivers courses, which reduces the level of risk occurrence by flooding appearance. The soil is classified as loamy sand, with high sand content (76%) and very little presence of clay (2.7%). Both the moisture content as the soil density determine the magnitudes and trends shown by the macro structural soil parameters studied. It is evident that to the extent that increases the moisture content decreases mechanical strength, and density is increased. The properties determined experimentally showed typical values for this type of soil and the shear modulus values varies from 1 820.58 KPa to 2 739.36 Kpa. The internal friction angle of soil is ranging from 10° to 40°; and the lower effective cohesion is 6 KN / m^3.

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