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INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

Article DOI: 10.21474/IJAR01/11026
DOI URL: http://dx.doi.org/10.21474/IJAR01/11026

RESEARCH ARTICLE

INFLUENCE OF WATER CONTENT ON SHEAR STRENGTH OF FINE SOILS AT HOUÉYOGBÉ IN BENIN

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Manuscript Info

Manuscript History
Received: 22 March 2020
Final Accepted: 25 April 2020
Published: May 2020

Key words:-
Economic Foundations, Variation, Permissible Stress, Fine Soil, Moisture Content

Abstract

The phenomenon of shrinkage and swelling of fine soils is the cause of several disorders on the structures. Researchers are mainly interested in designing economical foundations that can cope with settlement and swelling movements in these soils. The objective of this study is to study the variation in the permissible stress of fine soils in the locality of Houéyogbé in south-western Benin as a function of moisture content. To accomplish this, we conducted several physical and direct shear tests on fine soil samples collected in the study area, the results of which were used to assess the influence of moisture content. The study of the variation in shear strength of these soils shows that the allowable stress decreases with increasing moisture content. It is therefore imperative to take this parameter into account when dimensioning infrastructures built on these soils.

Introduction:-

Shrinkage and swelling in fine soils is manifested by a large variation in moisture content. These large variations weaken the shear strength of these Z.-S. HONG and al. soils (2013). In Benin, according to Judicaël AGBELELE Koffi and al. (2016), these soils are found in the Lama region. The examples of disorders related to the presence of swelling clays are numerous and varied (Y. KIKI (2004), V. GBAGUIDI and al. 2010). Because they are saturated or not, their shear strength varies. Z.-S. HONG and al. (2013) noted a decrease in the internal angle of friction. In addition, Renonet Karka BOZABE (2017), Matsushi and Matsukura (2006), indicated that the increase in water content leads to a decrease in cohesion. Incorrect estimation of this strength results in excessive settlement and/or soil failure during construction. It is important to be able to assess the variation in soil shear strength as a function of soil wetting for a given mesh size. The objective of this study is therefore to evaluate the variations in the breaking stress of the same soil as a function of the water content. Understanding these variations will make it possible to apprehend the particularities of these soils and to be able to easily indicate the ideal admissible stress for the dimensioning of structures for their good performance.

Materials and Method: -

Presentation of the Study Area:

Benin is a sub-Saharan country located in West Africa. It is subdivided into 12 departments and has 77 communes. Several of these communes located in the southern median zone have swelling soils. The samples were taken in the

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commune of Houéyogbé in the western depression of the Lama. We proceeded to the geotechnical analysis of forty-eight (48) intact samples taken by coring on the sites of our study area at a rate of twenty-four (24) per sampling point and six (6) per depth (0.50m to 1.00m;1.00m to 2.00m and 2.00m to 3.00m from the soil surface).

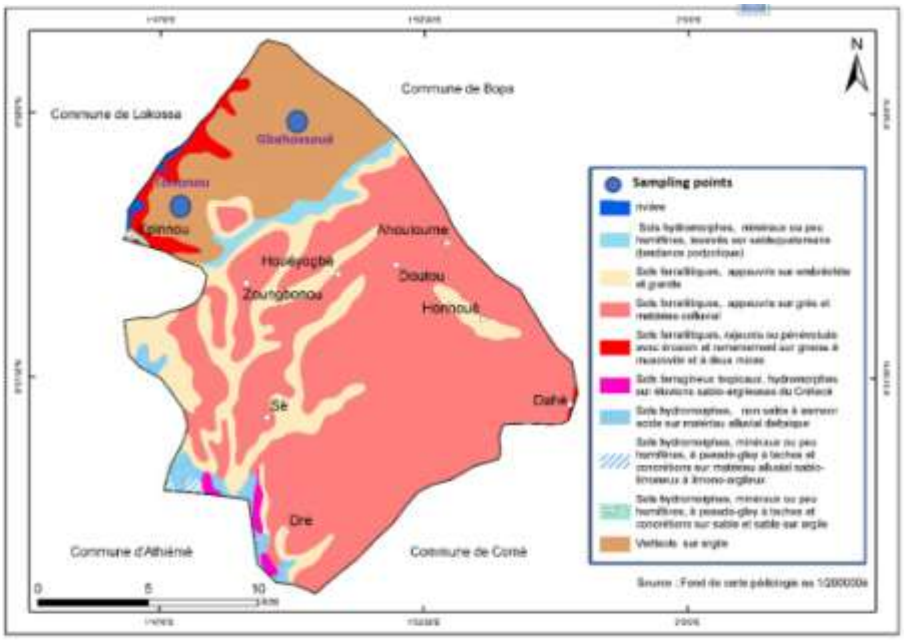


Figure. 1:- Soil map of the study area and sampling points.

soil characterization:

Soil characterization was carried out using geotechnical tests for physical and mechanical identification. The granulometric analysis test by sieving and sedimentation (NF P 94-056), the granulometric analysis by sedimentation (NF P 94-057), the Atterberg limit determination test (NF P94-051) and the specific weight determination test (NF P 94-054) enabled us to identify the nature of the soils in place.

Moisture Content Variation and Direct Shear Test Protocols:

The humidification of the samples was simulated in the laboratory using the free swelling test with an oedometer (Standard XP P94.091) without loading.

Test description:

It was decided for the different tests to vary the water content 6 times by 5%. It will allow to go from 20% of initial water content to 50% of theoretical water content for the different soil samples. Thanks to the dry density (NF P 94-054) and the NF P 94-050 standard, the quantities of water necessary for the adaptation of the desired hydrous state have been estimated.

Foreach target moisture content several test specimens were wetted in accordance with Standard XP P94.091. Each specimen was installed in the odometrical and humidified with the quantity of water previously determined and increased by 5% to compensate for losses due to the absorption of the various constituent elements of the cell.

The evolution of the one-dimensionals welling is measured with displacement sensors at 1/1000 of a mm. The measurements are recorded manually at increasing time intervals until the process is stabilized.

Once the process was completed, the water content of the moistened material was determined using a test tube. The other specimens were used to carry out direct shear tests according to standard NF P 94-071-1.

Each sample after moistening is prepared for direct shearing at the Casagrande box.
Extraction of the sample from the oedometer cell

Photo 1:- Extraction of the sample from the oedometer cell **Photo 2:-** Coring the wetted sample.

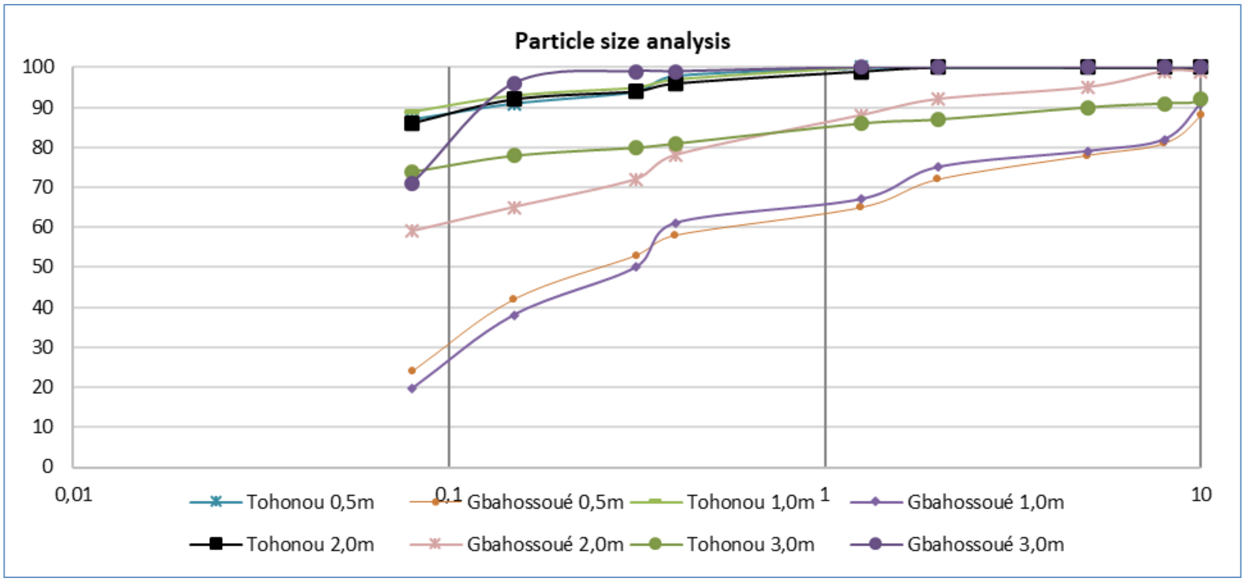
Study materials:
The material used is that of geotechnical tests essentially, we note the oedometric cell and the non-drained shear apparatus

Figure 2:- Shear apparatus equipment and oedometer cell for humidification.

Results and Discussions: -

Results of physical characterization tests:
The results of the identification tests allowed us to characterize the soils of the study sites, to assess their nature and their behavior.

The results of the particle size analysis tests by sieving and by sedimentation according to the standards (NF P 94-056) (NF P 94-057) are presented in the graph below.



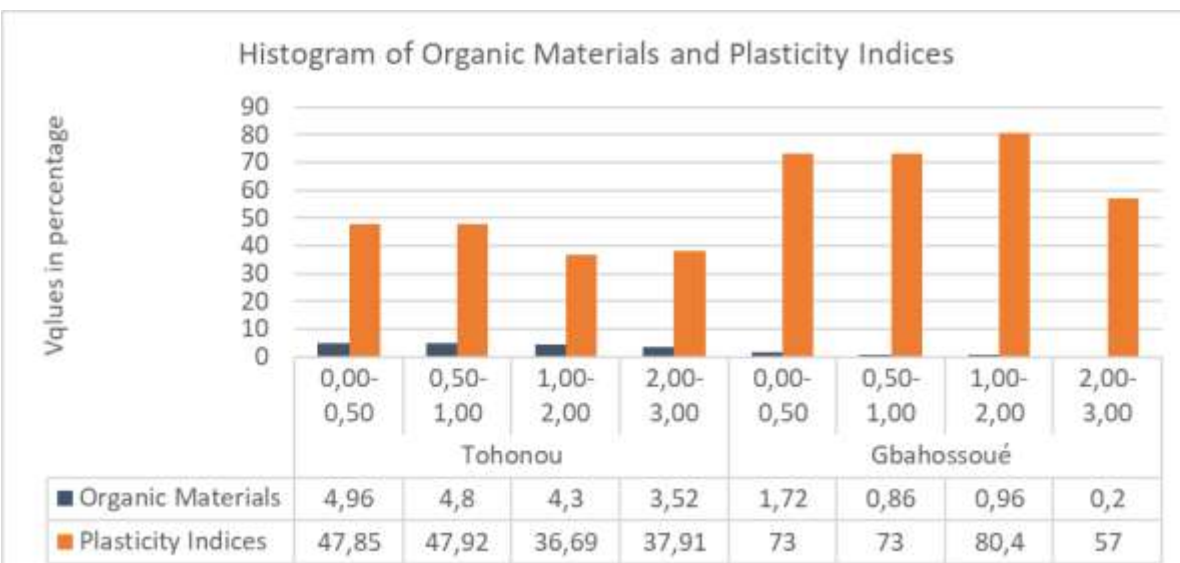
Graph 1:- Results of particle size analysis tests.

These results allowed us to classify the soil according to the US Department of Agriculture (USDA) soil-texture triangle classification.

Table 1:- Soil classification of study sites using the US Department of Agriculture (USDA) soil-texture triangle abacus.

	Localities	
Depths	Tohonou	Gbahossoué
0,00-0,50	Silt Clay	Limon
0,50-1,00	Clay	Limon
1,00-2,00	Clay	Sandy-clay silt
2,00-3,00	Clay	Clay

This classification of these soils has been confirmed by the results of additional identification tests, namely Atterberg limits and percentage of organic matter, which are shown in the graph 2



Graph 2:- Organic Materials and Plasticity Indices results.

Table 2 below summarizes the classification of the soils of Tohonou and Gbahossoué according to the classification of Snethen (1980).

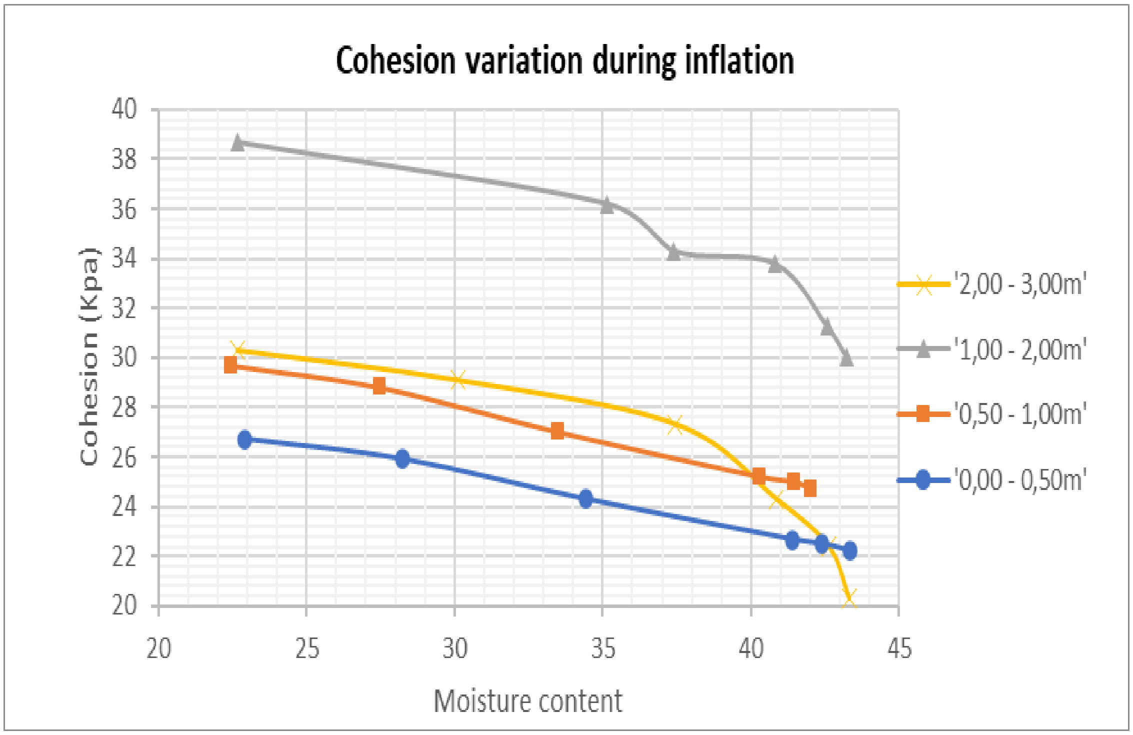
Table 2:- Soil classification of study sites based on Snethen (1980) classification.

Sites	Depths	IP	Snethen classification (1980)
Tohonou	0,00 – 0,50m	47,85	**High swelling**
	0,50 – 1,00m	47,92	
	1,00 – 2,00m	36,69	
	2,00 – 3,00m	37,91	
Gbahossoué	0,00 – 0,50m	73	**Very high swelling**
	0,50 – 1,00m	73	
	1,00 – 2,00m	80,4	
	2,00 – 3,00m	57	

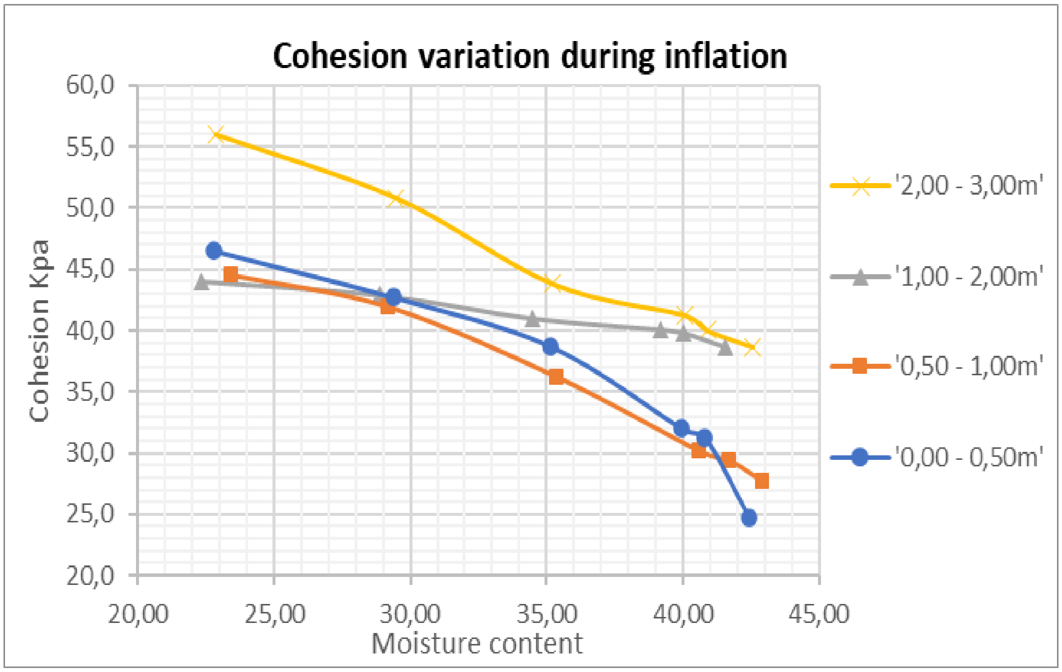
The soils at the two locations studied are therefore fine clay or silt soils with high swelling potential according to Snethen's (1980) classification.

Results of direct shear tests:-

The results of the unconsolidated and undrained shear tests of the soil samples before, during and after the swelling are shown in the following figures:



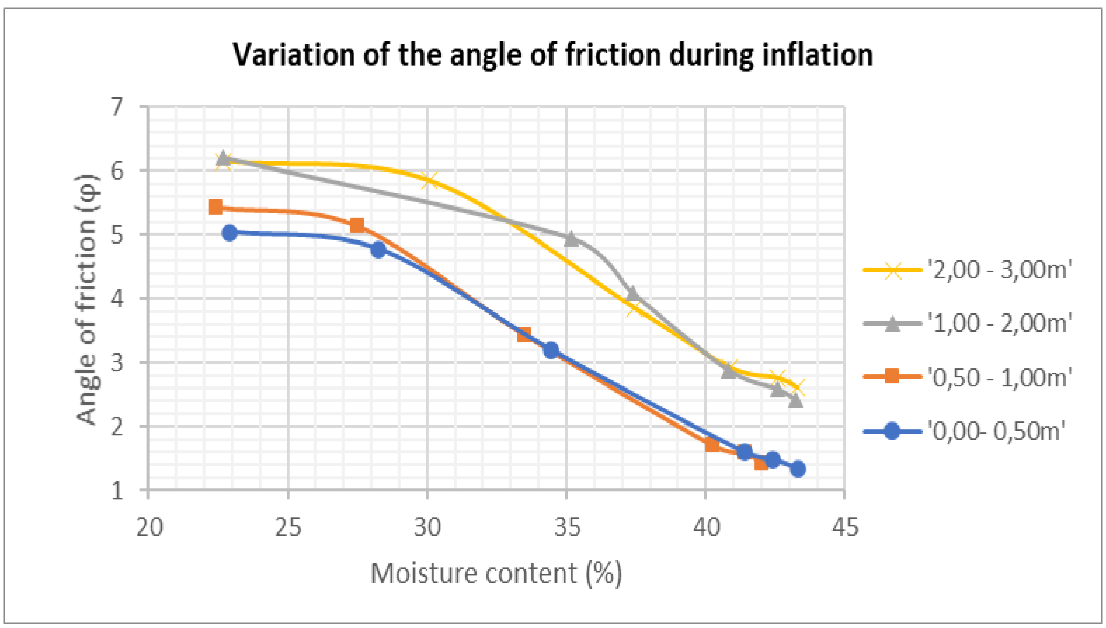
Graph 3:- Cohesion variation during the swelling of the Tohonou soils.



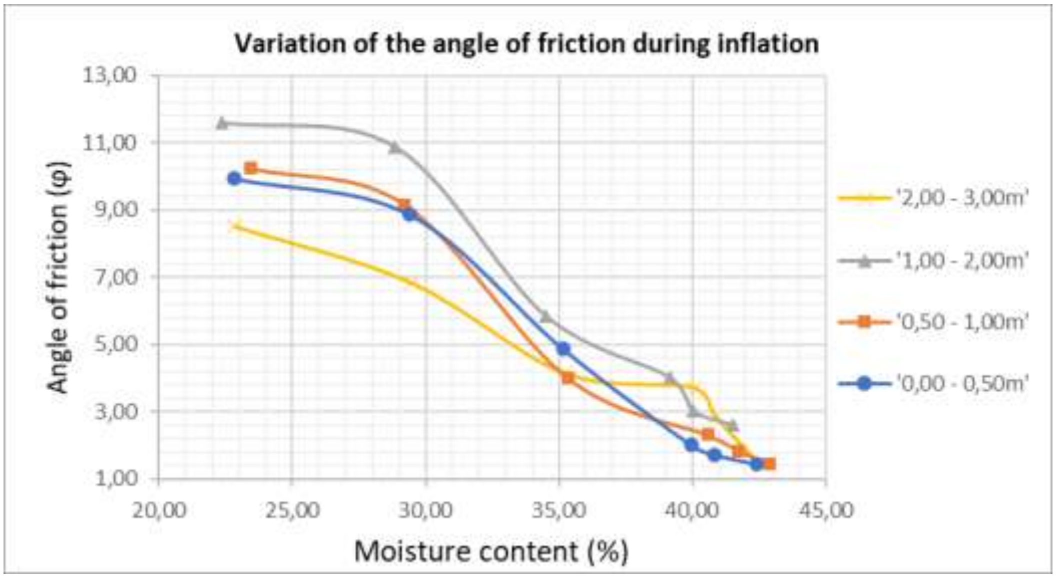
Graph 4:- Variation of cohesion during the swelling of the Gbahossoué soils.

As the suction increases within the same sample (decrease in moisture content through the drying path), the material becomes more and more resistant for clay soils and has a higher cohesion and angle of friction. Khaled Boussaid (2005), F.L. Pellet (2013), Tatsuya Ishikawa (2016), think that this decrease in cohesion by increasing the amount of water in the soil can be explained by the fact that as the water content increases, the distance bet went he clay particles becomes greater and the electrostatic and electromagnetic attractions decrease. **Muawia Dafalla (2013)** and Dr. Thillai Backiam (2019) reached the same conclusions.

The other parameter from the shear test that changes during wetting is the internal angle of friction.



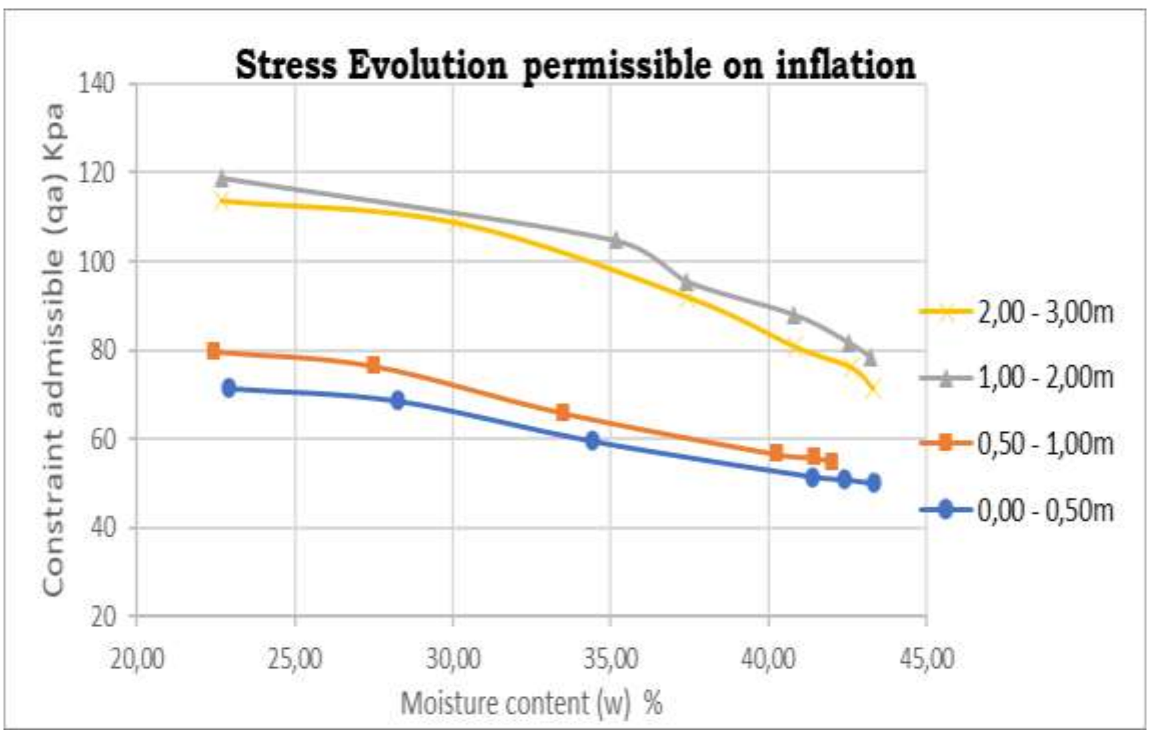
Graph 4:- Variation of the angle of friction during the swelling of the Tohonou soils.



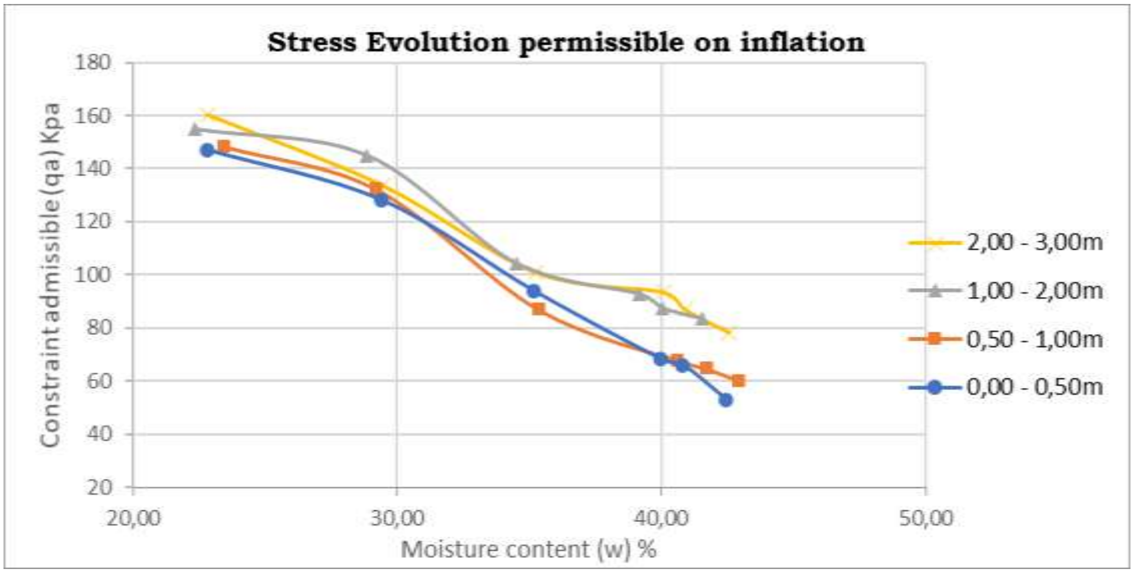
Graph 5:- Variation of the angle of friction during the swelling of the Gbahossoué soils the decrease in the angle of friction with the increase in water content reflects the increase in the lubricity of the clay particles. Such results of variations in intrinsic soil parameters are confirmed by the work of Brendan C. O'Kelly (2013) and Badee Alshameri (2017).

Effect of moisture content on the shear strength of Houéyogbé clay soils:

By applying the method of calculation of the bearing capacity of Terzaghi (1943) on the results of previous shearing's, we notice a variation in the resistance of the Houéyogbé soils.



Graph 6:2- Evolution of the permissible stress during the swelling of the Tohonou soils.



Graph 7:- Evolution of the permissible stress during the swelling of Gbahossoué soils.

Through graphs 6 and 7 we can see that the allow able stress drops with increasing water content for all our sites and at all depths. Similar results were obliterated by, Yujie Wei and al. (2019), Kristýna Bláhová (2013), Rohit Ghosh (2013).When designing a structure, an engineer is al ways on the side of safety and will have to take into account the worst-case scenario. In today's context, the worst case is the final swollen state of the ground with the lowest permissible stress.

Conclusion:-

The study of the variation in allowable stress in the soils of Tohonou and Gbahossoué reveals that the allowable stress decreases with increasing moisture content. This decrease in allowable stress is due to the variation in the angle of internal friction and cohesion. It can be explained by the fact that during swelling, water penetrates into the inter-foliar space of the clay structural units. The various tetrahedral and octahedral layers move away from each other, thus reducing internal friction. Together, this vertical movement of the various tetrahedral and octahedral layers causes the soil to swell and reduces the cohesive forces of the particles and, by analogy, those of the soil.

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