# INFLUENCE OF SWELLING ON THE SETTLEMENT OF CLAY SOILS OF HOUEYOGBE COMMUNE IN THE LAMA DEPRESSION

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## ABSTRACT

Swelling soils are soils of variable consistency depending on their water content; They have established the instability of the structures that are erected there. The present study is a contribution to the study of the mechanical behavior of clay soils of the Benin Lama depression. It is carried out on the clay soils of the commune of Houéyogbé being part of the depression. It deals with the influence of the swelling of clays on their settlement. For this purpose, oedometric tests with successive increments of charges and tests of free swelling at the oedometer were carried out on intact samples taken by the National Center for Study and Research of Public Works (CNERTP) in order to determine respectively settlement and free swelling. From the analysis of the results of the tests carried out, it appears that the studied soils of the commune of Houéyogbé are plastic clays with very plastic, overconsolidated and moderately swelling. The free swelling of soils has very little influence on the value of the final settlement at the oedometer.

**Key words:** Clay soils, Lama depression, oedometric test, free swelling.

## I. INTRODUCTION

Numerous natural disasters can be observed around the world: a landslide in 1908 on the clay banks of the Hare river which claimed thirty-three victims ([1]); huge mudslide caused in 2008 in Xiangfen in China by the collapse of a basin containing the deposits of an iron mine left 267 dead ([1]); soil shrinkage-swelling phenomena observed around the world, occurring in certain localities of Benin and which result in the dilapidated state of the various infrastructures; which handicaps their sustainability as well as the safety of their users.

Clay soils are the most indexed in this type of disaster because of their aptitude for a strong variation in their volume as soon as the equilibrium conditions (humidity, stress) are modified. These phenomena are manifested by the appearance of disorders, such as bogged downs and cracks, in this case affecting single-family house structures built at shallow depth and without special precautions, as well as the pavements of our roads. They are more pronounced in a part of the southern region of Benin called the Lama depression; mastering the mechanical and rheological behavior of the soils in this region is therefore necessary for the development of this area through the creation of stable and sustainable infrastructures.

According to **SLANSKY M.**, the coastal basin of Dahomey then (today ...) contains quartz and clay minerals where kaolinite is very largely dominant; the presence of attapulgite and montmorillonite is also noted ([2]). The Lama depression contains kaolinite, montmorillonite and illite (ADJATI Mêtonwanou Albert, **[2]**). For Bienvenu **M. NOUHOLIDJI (2014),** in the coastal sedimentary basin in Benin, the swelling parameters differ from one environment to another. **[5]**

According to the work of **Huder and Amberg (1970)**, the kinetics of swelling are characterized by two phases: primary swelling and secondary

swelling. [3]. The study of the stabilization of the clay soils of Issaba (in the Lama depression) by the néré pod revealed that the néré pod lowers the values of the following parameters: methylene blue value, swelling amplitude, inflation pressure, the compression index; on the other hand, the swelling index increases after treatment **(Yvette KIKI, 2004, [4]).**

Indirect methods allow, using certain simple geotechnical parameters (Atterbeg limits, shrinkage limit, percentage of clay, calcium carbonate content, ...), to estimate the swelling potential of a clay soil . Thus, a soil with high plasticity would be potentially swelling (Lundgren et al., 1962; Yenes et al., 2012, Derriche and Cheik-Lounis, 2004). **Kelly Guerrier et al., (2014) [6]**

Our work comes in addition to that previously carried out. This article therefore presents a study on the **influence of swelling on the settlement of clay soils in Houeyogbe commune in the Lama depression.** After having characterized the soils, the amplitudes of free swelling of these soils were measured; an analysis of the behavior of said soils on settlement was made and finally an assessment of the settlement of the soil in the face of the swelling phenomenon was made.

## II. MATERIALS, MATERIALS AND METHODS

The subject of our study requires a number of properly analyzed and interpreted essays. The tests (identification and mechanical) were carried out at the National Center for Testing and Research in Public Works (CNERTP). All the methodology described in this section is based on French standards and applied experimental methods.

### II.1. Site search and location

Taking into account the tests to be carried out (identification and mechanical tests), reworked and intact samples were taken. The figure below shows the situation of the different sampling wells.

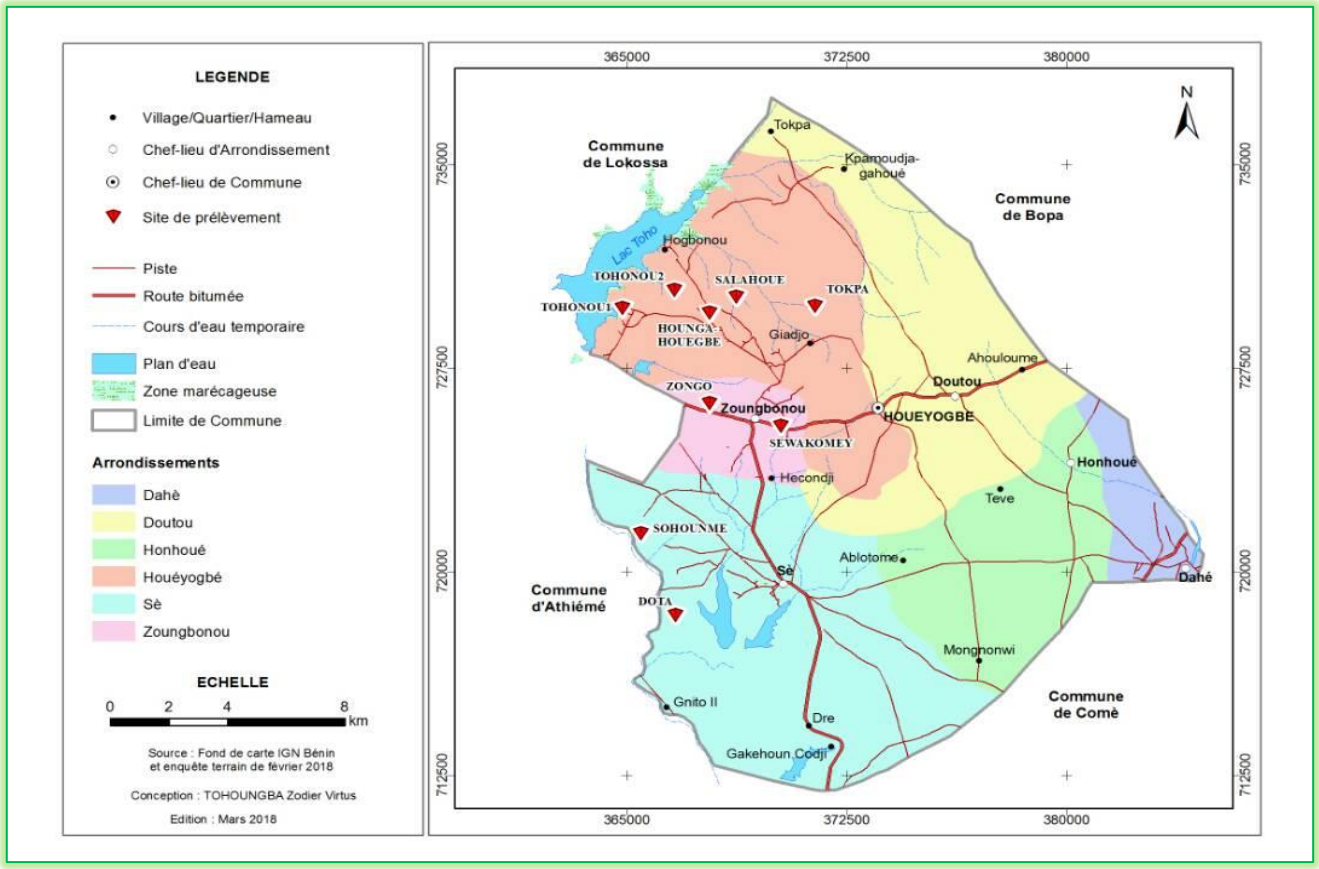



***Figure : Direct debit card [2]***

### II.2. Sample collections

The intact samples were taken using cubic boxes for intact sample collection, checkers for threshing, wooden boxes for transport. For each sample, a well at least 1.5 m deep is dug.

### II.3. Description of tests

#### II.2.1 Identification tests

- **Test for determining the water content by weight (NFP 94-050) [7]**
- **Particle size analysis by sieving (NF P 94-056) [8] and by sedimentometry (NF P 94-057) [9]**
- **Determination of the organic matter content (XP P 94-055) [10]:** The objective of this test is to determine the proportion of organic matter
- **Determination of the specific weight of solid grains (NF P 94-054) [11]:** The test consists of the determination of the density of the solid grains of a soil sample using a pycnometer
- **Atterberg limits (NF P 94-051) [12]:** Atterberg limits allow us to know the limit of liquidity (ωL), plasticity (ωP) and the plasticity index (PI)
- **Methylene blue test (NF P 94-068) [13]:** Used to determine the content of clay elements.

#### II.3.2 Mechanical tests

The following mechanical tests were carried out:

- **Odometric test (XP P 94-090-1) [14]:** This test consists of determining for a soil, among other compression index Cc, decompression index Cs, the effective vertical reconsolidation stress σ'p, the index of the voids of the soil in place e0, coefficient of vertical consolidation Cv, coefficient of compressibility mv, vertical permeability Kv.

- **Odometer free swelling tests:** The test consists of determining the swelling potential εs and the swelling neutralization pressure σg. The two parameters are determined as follows: by means of the readings taken on the comparator, the swelling potential is evaluated, which is the ratio of the uniaxial swelling to the initial height of the specimen;

the swelling pressure corresponds to the final stress which made it possible to neutralize the swelling after successive application of load.

## III. RESULTS AND DISCUSIONS

### III.1. Overall results and interpretations of identification tests

The classifications used to specify the nature of these soils are **the triangular classification of Taylor (1948)** which is based mainly on the percentage of refusals to the 50 µm sieve and that of passing through the 2 µm sieve, the American classification of soils entitled **Highway Research Board (HRB) [15]** which considers the percentage of passers-by to the 0.315mm and 80µm sieves as well as the WL liquidity limit then the **Guide des Terrassements Routiers (GTR) classification [16]** which takes into account the granularity, the l plasticity index Ip and methylene blue value VBS.

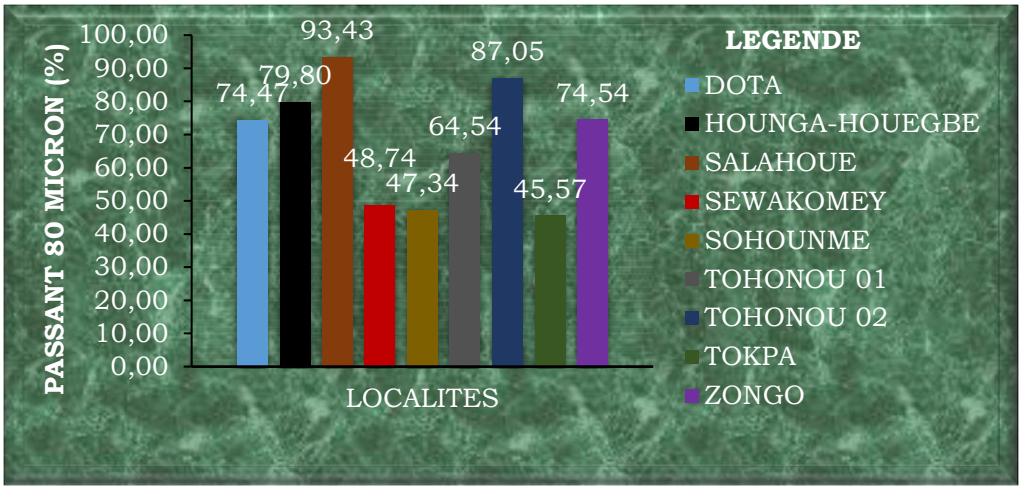
The various results obtained during these various identification tests are shown in the following table.

***Table 1: The results of the identification tests [2]***

| | DOTA | HOUNGA-HOUEGBE | SALAHOUE | SEWAKO MEY | SOHOUNME | TOHONOU 01 | TOHONOU 02 | TOKPA | ZONGO |
|---|---|---|---|---|---|---|---|---|---|
| **Inf 0,315 mm (%)** | 84.55 | 85.21 | 94.38 | 71.46 | 65.97 | 66.39 | 66.39 | 82.13 | 84.26 |
| **Inf à 0,08 mm (%)** | 74.47 | 79.80 | 93.43 | 48.74 | 47.34 | 64.54 | 64.54 | 45.57 | 74.54 |
| **WL (%)** | 69.00 | 90.00 | 94.00 | 45.00 | 35.00 | 77.00 | 77.00 | 48.00 | 74.00 |
| **WP (%)** | 37.00 | 49.00 | 50.00 | 25.00 | 23.00 | 41.00 | 41.00 | 28.00 | 40.00 |
| **VBS** | 0.92 | 11.94 | 5.65 | 1.00 | 0.58 | 9.14 | 8.00 | 4.46 | 5.38 |
| **MO (%)** | 0.96 | 0.58 | 0.84 | 0.08 | 0.78 | 0.56 | 0.03 | 0.04 | 0.69 |
| **ɣs (T/m3)** | 2.13 | 2.21 | 2.23 | 2.18 | 2.58 | 2.31 | 2.22 | 2.32 | 2.25 |
| **IP** | 32.00 | 41.00 | 44.00 | 20.00 | 12.00 | 36.00 | 42.00 | 20.00 | 34.00 |
| **Ac** | 0.50 | 0.60 | 0.63 | 0.60 | 0.33 | 0.62 | 0.62 | 0.67 | 0.58 |

### III.1.1. Particle size analysis

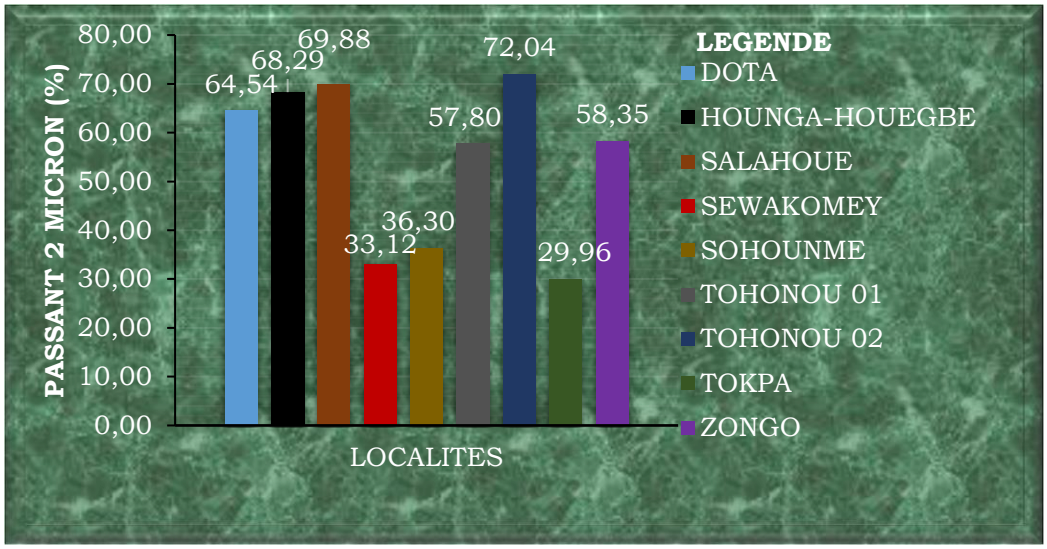
- **Passing through an 80 µm sieve**




***Graph 1: Percentage passing through the 80 µm sieve [2]***

After analyzing this graph, we can report that in addition to the localities of SEWAKOMEY, SOHOUNME and TOKPA, all the soils sampled in the said commune contain fine particles which led us to carry out the particle size analysis by sedimentation.

- **Passing through an 2 µm sieve**




***Graph 2 : Percentage passing through the 2 µm sieve [2]***

From the particle size analysis by sedimentation, it appears that the percentage of fine particles (<2µm) is very high. It varies from 29.96% to 72.04%. According to Gérard Degoutte et all (2009), the samples from these different sites therefore contain clay particles.

### III.1.2. Classification triangulaire de Taylor

***Table 2 : Types of clay soils according to the triangular classification of Taylor (1948) [2]***

| Localities | % > 50 µm | % ≤ 2 µm | Nature |
|---|---|---|---|
| **Dota** | 26.84 | 64.54 | Clay |
| **Hounga-Houegbe** | 21.97 | 68.29 | Clay |
| **Salahoue** | 09.52 | 69.88 | Clay |
| **Sewakomey** | 53.41 | 33.12 | Sandy clay loam |
| **Sohounme** | 54.19 | 36.30 | Sandy clay loam |
| **Tohonou 01** | 35.46 | 58.03 | Sandy clay loam |
| **Tohonou 02** | 15.52 | 72.04 | Clay |
| **Tokpa** | 57.26 | 29.96 | Sandy clay loam |
| **Zongo** | 30.28 | 58.35 | Sandy clay loam |

After analyzing this table, we note that the soils in the study area are either clay soils and loamy-clay-sandy soils.

### III.1.3 Classification GTR 92

According to the French Guide des Terrassements Routiers (GTR 92), six (06) soil categories are defined according to the methylene blue value.

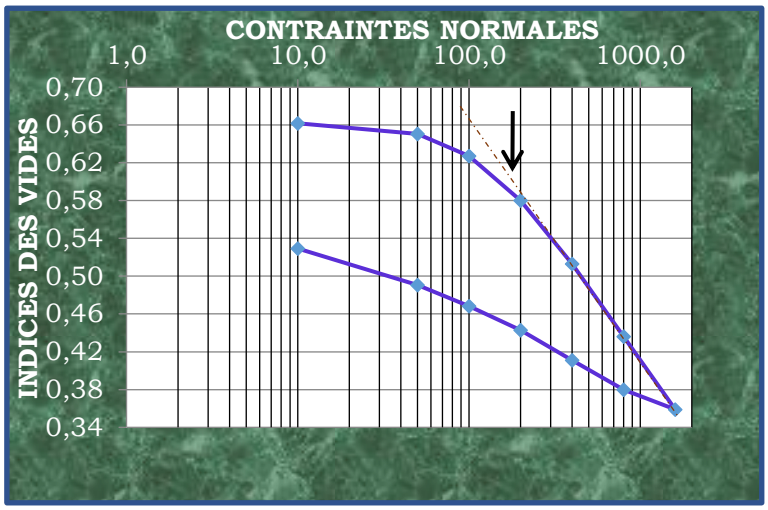
***Table 3 : GTR classification of soils in the study area [2]***

| Localities | VBS | Dénomination |
|---|---|---|
| **Dota** | 0.92 | Sandy silty soil, sensitive to water |
| **Hounga-houegbe** | 11.94 | Very clayey soil. |
| **Salahoue** | 5.65 | Silty soil of medium plasticity. |
| **Sewakomey** | 1 | Sandy silty soil, sensitive to water |
| **Sohounme** | 0.58 | Sandy silty soil, sensitive to water |
| **Tohonou 01** | 9.14 | Very clayey soil. |
| **Tohonou 02** | 8 | Very clayey soil. |
| **Tokpa** | 4.46 | Silty soil of medium plasticity. |
| **Zongo** | 5.38 | Silty soil of medium plasticity. |

From the classification table according to the VBS value from the French Terrassing Guide notified above, we can conclude that our soils are either clay or sandy loam soils.

## III.2. Mechanical tests

### III.2.1 Odometric test




***Graph 3 : Odometric curve of HOUNGA-HOUEGBE [2]***

***Table 4 : Summary of the parameters from the oedometric test [2]***

| | Dota | Hounga-Houegbe | Salahoue | Sewakomey | Sohounme | Tokpa | Zongo |
|---|---|---|---|---|---|---|---|
| $e_i$ | 0.365 | 0.662 | 0.839 | 0.376 | 0.426 | 0.330 | 0.567 |
| $e_o$ | 0.360 | 0.685 | 0.850 | 0.446 | 0.420 | 0.324 | 0.548 |
| $\sigma'_{vo}$ (KPa) | 27 | 27 | 33 | 27 | 27 | 27 | 27 |
| $\sigma'_{p}$ (KPa) | 95 | 175 | 250 | 40 | 185 | 110 | 245 |
| $C_c$ | 1.25E-01 | 2.56E-01 | 2.91E-01 | 2.03E-01 | 1.52E-01 | 1.35E-01 | 1.76E-01 |
| $C_s$ | 2.22E-02 | 1.05E-01 | 9.64E-02 | 1.15E-02 | 1.16E-02 | 4.27E-02 | 5.95E-02 |
| Cv | 7.12E-09 | 7.90E-10 | 4.02E-09 | 1.16E-06 | 4.75E-07 | 5.04E-09 | 3.30E-09 |
| mv | 3.50E-02 | 5.8 E-02 | 6.58E-02 | 3.50E-02 | 4.20E-02 | 3.90E-02 | 5.20E-02 |
| Kv | 2.46E-11 | 4.57E-13 | 2.64E-12 | 2.46E-11 | 1.99E-10 | 1.97E-12 | 1.70E-12 |

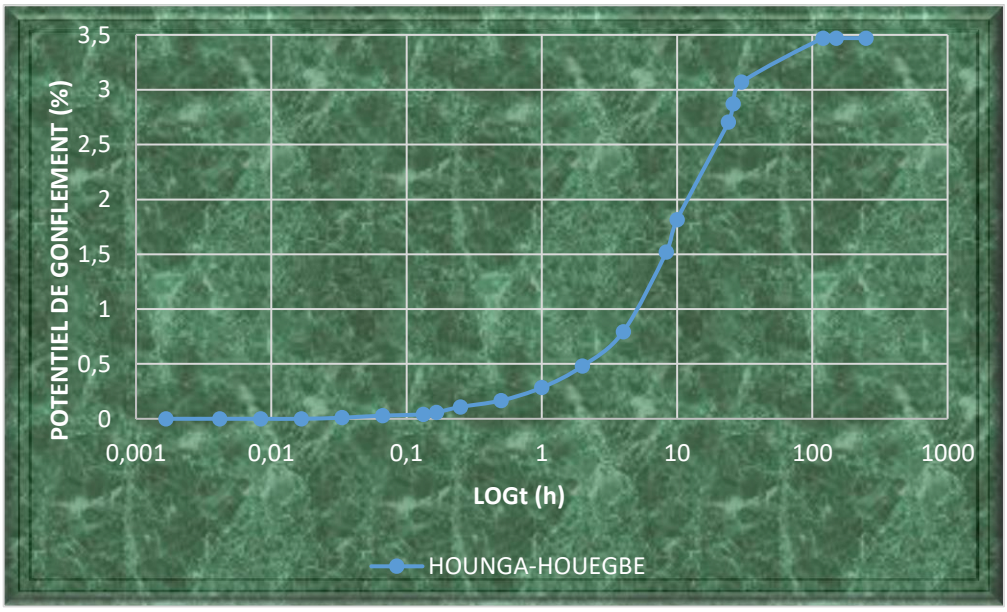
Examination of the graph shows that the Odometric HOUNGA-HOUEGBE curve looks like a swelling soil. Its consolidation curves are therefore studied using the CASAGRANDE method.

Examination of the table makes it possible to state:

- according to σ'vo and σ'p all clay soils from these localities are overconsolidated;
- according to Cs that the soil of Hounga-Houegbe is the most swelling;
- according to Cc that the soil of Salahoue is the most compressible;
- According to Kv, Sohounme soil is the most permeable.

### III.2.2. Free swelling and compressibility tests

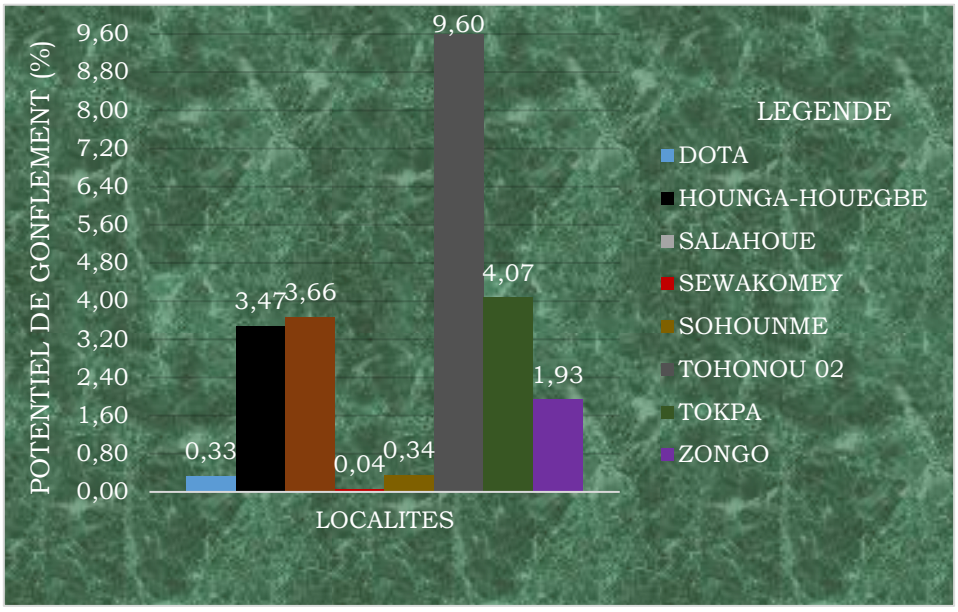
Odometer free swelling tests carried out on different samples show that swelling increases over time.




***Graph 4 : Evolution curve of the swelling potential as a function of time [17]***

***Table 5 : Summary of inflation pressures and inflation potential [17]***

| | Dota | Hounga-Houegbe | Salahoue | Sewakomey | Sohounme | Tohonou 2 | Tokpa | Zongo |
|---|---|---|---|---|---|---|---|---|
| **εS (%)** | 0.33 | 3.47 | 3.66 | 0.04 | 0.34 | 9.60 | 4.07 | 1.93 |
| **σg (kpa)** | 20 | 200 | 100 | 10 | 05 | 400 | 250 | 125 |



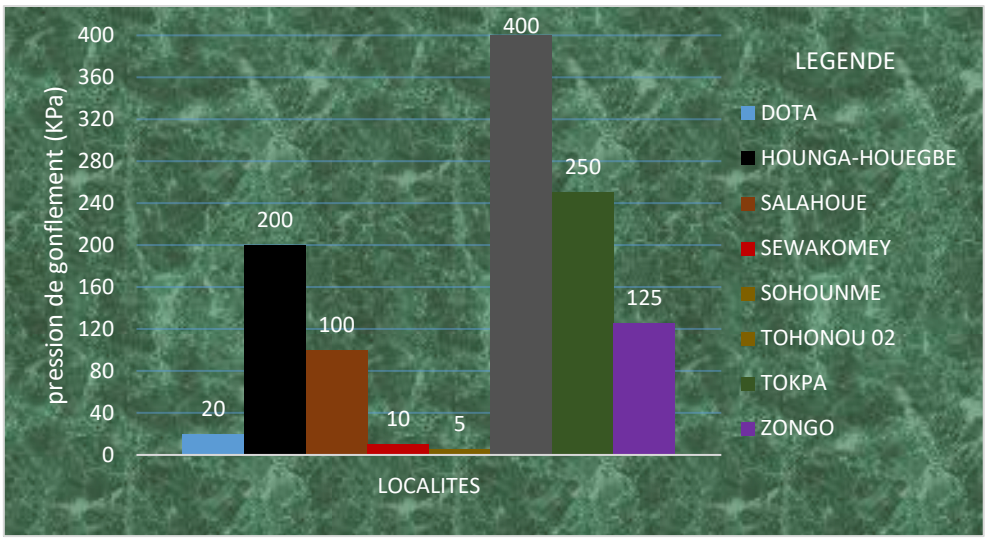

***Graph 5 : Swelling potential of the studied sites [17]***

After a comparison of the ranking according to the localities of the swelling index values in Table 4 with those of the swelling potential, we observe that these rankings are not the same.

This graph shows that the Tokpa soil is the most swelling.

Regarding Tohonou 2, which actually has the highest swelling rate, it should be noted that this swelling rate is not the final one for this soil. In fact, during the free swelling test on the oedometer, we could not go to the end. The oedometric frame we have at our disposal could not allow us to reach the final

value because of its lever arm jamming during inflation. We therefore need to find an adequate oedometric frame.




***Graph 6 : Swelling pressure of study sites [17]***

This graph shows us that of the different soils, Tohonou 2 is the one with the highest swelling pressure.

***Settlement estimates and comparisons***

***Table 6 : Settlement values of the sites studied [17]***

| LOCALITIES | Δhoed (mm) | Δhc (mm) | Δhg (mm) | Moyenne (mm) | Ecartype (mm) |
|---|---|---|---|---|---|
| **Hounga-Houegbe** | 3.720 | 3.980 | 3.480 | 3.727 | 0.250 |
| **Salahoue** | 3.360 | 3.470 | 3.410 | 3.413 | 0.055 |
| **Dota** | 2.550 | 2.430 | 2.590 | 2.523 | 0.083 |
| **Sewakomey** | 4.650 | 4.550 | 4.60 | 4.600 | 0.050 |
| **Sohounme** | 2.250 | 2.130 | 2.150 | 2.177 | 0.064 |
| **Tokpa** | 2.890 | 2.750 | 2.370 | 2.670 | 0.269 |
| **Zongo** | 2.460 | 2.550 | 2.48 | 2.497 | 0.047 |

We notice that the final geometric settlement after the oedometric test with successive load increment Δhoed, the final settlement calculated on the basis of the oedometric parameters Δhc then the final geometric settlement obtained with the oedometer after the free swelling test Δhg are almost of the same order of magnitude. We can say that the free swelling of the soil has very little influence on its settlement.

## IV. GENERAL CONCLUSION AND OUTLOOK

Natural phenomena such as landslides, mudslides and in this case the shrinkage, swelling and compaction of the soil lead to disasters in infrastructures or even their ruin. These different phenomena are observed in particular on the clay soils of the Lama depression in southern Benin. In order to mitigate these orchestrated disasters, we carried out a physico-mechanical study of the clay soils in the town of HOUEYOGBE which is located in this depression in order to determine certain parameters which will be used for the design and construction of the infrastructures. To this end, we carried out identification tests and mechanical tests on the various samples taken in this municipality. From these different tests, we obtained results which were analyzed and interpreted. Thus we mention through the:

- ❖ Identification tests that:

the samples from the various sites are clayey and loamy-clayey-sandy soils. They are Allophane, Attapulgite and Illite mineralohic in nature with a swelling potential ranging from “low” to “high”.

- ❖ Mechanical tests:

- according to σ'vo and σ'p all clay soils from these localities are overconsolidated;

- according to Cs that the soil of HOUNGA-HOUEGBE is the most swelling;
- according to Cc that the soil of SALAHOUE is the most compressible;
- according to Kv that SOHOUNME's soil is the most permeable;
- according to εS obtained in free swelling, TOHONOU 02 is the most swelling.

We summarize by notifying that all the clay soils of the municipality of HOUEYOGBE have different physico-mechanical characteristics and that the free swelling of these soils has very little influence on their settlement.

In perspective, to better deepen our research, we suggest studying through

- ❖ Crystallography, the influence of clay minerals on the results found;
- ❖ Tomography, the influence of pores too.

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