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Improving the Stability of the Inflatable Soil of Diamniadio by Using Typha Australis in Order to Value It in Partitioning Wall

Ahmadou Diop, Macodou Thiam, Mamadou Babacar Ndiaye, Oumar Diallo, Harouna Mamadou Bal, Salif Gaye

Laboratory of Materials and Energetics (LME), University Institute of Technology (IUT), Thiès, Senegal
Email: ahmadou2010@hotmail.fr

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Abstract

The construction industry in Senegal is experiencing an upsurge in the development of residential housing units and administrative buildings within the new Diamniadio municipality, an area located just about 35 km from the capital city of Dakar. Laboratory oedometer or expansive-index tests, however, show poor density and compromised shear strength in the soil samples within the area -posing serious construction problems due to significant volume changes (swellings) that occur when subjected to moisture, thus, bringing into question the structural performance integrity of the soil, and the financial implications of substitute soil types used to compensate for its poor tensile strength. By way, the companies collect the soil of this location (Diamniadio) and throw it to make pile or micro-pile (pious) for their structures. This article demonstrates how we can value the soil of Diamniadio and the Typha Australis in residential building with a reasonable cost. Typha Australis is a plant generally luxuriant within the northern and central belts of Senegal but also known for its negative ecological impacts on the agricultural production of rice. The valorisation of the soil of Diamniadio will pass by the ability to increase its stability or to decrease its shrinkage/swelling rate. When we achieve it, the soil associate with Typha Australis will be used for small bricks which can be useful for partition wall and so the soil will not be ever thrown as a non-useful material. Tests results of soil specimens extracted from the site show a shrinkage rate of 29.19% with estimated cracking depths of 3.5 cm. But by adding gradually Typha Australis, the shrinkage rate will pass from 29.19% to 5.13% with the material treats with 10% by mass of Typha Australis. Moreover, the crackings in the cylindrical specimen disappear. That shows the increase of the stability; thus the composition will be used for building bricks. However, the densities will also be affected by the presence of

Typha Australis. The density is decreased from 2032.28 Kg/m^3 for the soil without Typha Australis to 937 Kg/m^3 for the one with 10% of Typha Australis.

Keywords

Buildings, Clay, Cracking, Fine Particle, Shrinkage Rate, Stabilization, Typha Australis, Valorisation

1. Introduction

In Senegal we use a lot of building materials like cement, bio-sources materials and others for construction. Furthermore, in Senegal with the saturation of the capital town Dakar, the Senegalese government has chosen Diamniadio to build a new town. This town will receive some administrative buildings and some offices. The particularity of Diamniadio is its soil is very rich in clays [1]. The presence of clay is responsible for some cracks seen in some walls and the shrinkage/swelling phenomena. These phenomena are responsible for the instability of the soil. The instability of land due to swelling can be explained by several factors [2]. Some of these factors are related to the physical conditions of the environment. Some of these factors are due to the physical conditions of the environment. In some situations, the shrinkage and swelling are responsible for the presence of cracks in several structures. But it is also possible to predict its consequences by specific methods [3].

Indeed, the enterprises, when they build the new constructions, collect the soil of the site and throw it so far from where they have to build the construction. This is the cause of the high cost of the constructions. The purpose of this paper is to enhance the soil rich in clays and thrown by the building enterprises. The enhancing of these clay materials will be beneficial for Senegal country and some companies will use this new material built for new construction. Moreover, in north and west of Senegalese country, a vegetable called Typha Australis is growing with a proliferation of about 10% per year [4]. This vegetable is right now taking as a nuisance because of its dense proliferation that hinders rice culture. The Typha Australis is occupying the perimeter of the rice cultivation due to its rapid proliferation velocity. This consequence of Typha Australis's presence makes the rice farmers in a difficult situation [5]. However, Senegalese and Mauritania governments work together in a program called TYCCAO to stop the proliferation of the Typha Australis [6]. The program is led by the government of Senegal and based on six (6) objectives of which the main is to stop the proliferation of Typha in rice perimeters but to use it in other domains [6]. That is the reason why, in our research we think to mix the Typha Australis with the clay of Diamniadio to build new bricks (clay/Typha) more stable. These bricks will be able to be used in a partition wall. Indeed, other authors have already worked in some similar domains and their motivation was to make buildings with energy efficiency. For example they used agricultural waste [7], recycled polymer [8], millet pod [9] etc. By using these new materials they made buildings with good energy performance. So based on all these information we think if we achieve our goal, we will improve the stability of the inflatable soil of Diamniadio, the valorisation of the Typha Australis and moreover the soil of Diamniadio will be more useful in building industry.

2. Methods and Materials

The aim of this party is to build samples that allow us to know the impact of the Typha Australis on the shrinkage/swelling and cracks phenomenon of the soil of Diamniadio. Because it is seen that, for the sample built with only water and soil of Diamniadio, we have presence of cracks due to the shrinkage. By the way, we have to build two types of specimens with different geometrical. The specimens with cylindrical geometry are built to show the cracking phenomena and the parallelepipedal geometrical are used to estimate the volume and then to determinate the rate of shrinkage. The procedure of building samples consists is the following:

A sample of the soil from a depth of about 1.5 m was obtained from the site due because at this depth the sample was more suitable and easy to use for the sieve particle analysis. In the surface the soil presents some alteration due to agriculture activities practiced by the people in a few years. The Typha Australis is obtained in Thies area and in the accordance with Senegalese association of normalization, the Typha Australis is dried for 7 to 10 days with a relative humidity from 10% to 12% [10]. After the step of drying the Typha Australis is ground with a mill, because we want a perfect adhesion with the soil matrix. Figures 1-3 show the raw materials and the space occupied by Typha Australis in Senegal.

After the stage of collection of raw materials, we mix them together with right proportions.

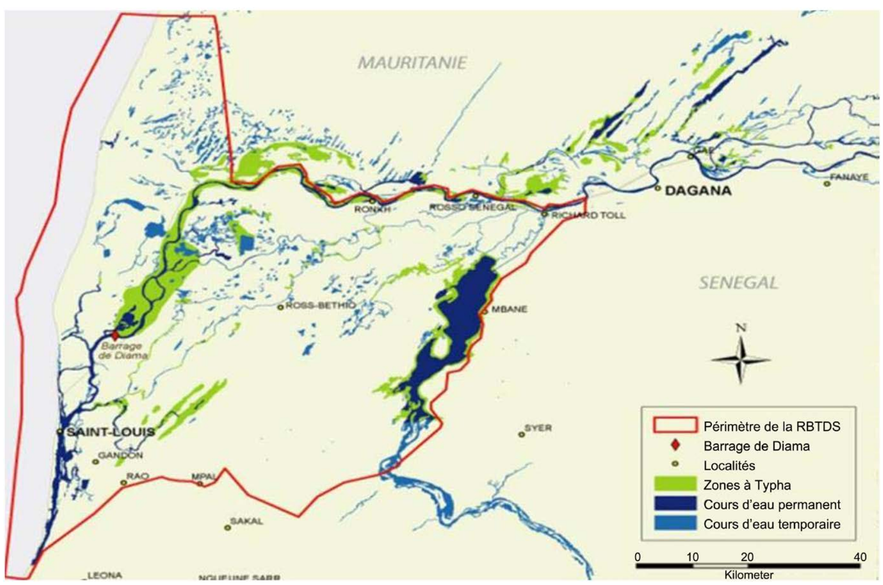

Figure 1. Spaced occupied by Typha Australis.

Figure 2. Soil raw materials.

Figure 3. Typha Australis milled.

The procedure is described as and based on three series (A, B and C):

- We build 5 cylindrical sample with only soil of Diamniadio and water, 5 other cylindrical samples with 4.48% of Typha Australis and 5 other cylindrical samples with 10% of Typha Australis;
- We repeat the same experience with parallelepipedal samples;
- We measure the volume of the sample without Typha and we compared it with the volume of the specimens to estimate the rate of shrinkage. By doing it we use parallelepipedal samples;
- We measure also the densities of all the samples and we compare the impact of the Typha Australis on the densities;
- The last paramter will be the observation of the evolution of the cracking.

The target with cylindrical sample is to show the cracking appearance on the surface and the dimension of the cylindrical test-tube has 15 cm diameter and 30 cm^3 of height. For the parallelepiped specimen, we have 10 × 10 × 03 cm as dimension.

To do our experimentations, we use many devices as Casagrande device, sieve for particle size analysis of the soil and the Typha Australis… Some photos during the experimentation are shown by the following figures:

2.1. Methylene Blue Test

This test is practiced on our samples and will tell us the degree of clay in our material. The figure of experience is shown in Figure 4.

Table 1 gives the different volumes of methylene blue added gradually.

Base on the indicators v from the geotechnical laboratory, we conclude that our soil is very rich in clay.

If $V_{BS} \leq 0.2\%$ then we have sandy soil;

$0 \leq V_{BS} \leq 2.5\%$ then we have loamy soil;

$2.5\% \ V_{BS} \leq 6\%$ then we have silty clay soil;

$6\% \leq V_{BS} \leq 8\%$ then we have clay soil;

$V_{BS} \geq 8\%$ then we have clay-laden soil.

With V_{bs} is methylene blue volume.

Figure 4. equipment for the test.

Table 1. Volume of methylene blue added.

N°	Quantity of bleu add in mL	Duration of agitation in mn	Test +	Test −
1	2	5		−
2	2	3		−
3	2	3		−
4	2	3		−
5	2	3	+	
6	2	3	+	

2.2. The Particle Size Analysis

The following curve and Table 2 show respectively the particle size of the Typha Australis and the soil of Diamiadio (see Figure 5).

Like the analysis done on Typha Australis, the table also tells us about passers-by according to the size of the mesh. In addition, this analysis allows us to determine other geotechnical parameters such as, the coefficients of curvature C_c of, of uniformity C_u and the fineness module M_f $C_u = \frac{0.311}{0.132} = 2.36$ and $C_c = \frac{0.19^2}{0.31 \times 0.132} = 0.88$. In addition the fineness module is given by the following relation:

$$M_f = \frac{1}{100}(0.55 + 2 + 9 + 33 + 80) = 1.32$$

Table 2. Particle size of the soil of Dianmniadio.

Sieve diameter	Partials refusals	Cumulative refusals	%cumulative refusal	% passing
8 mm	0	0	0	100
5 mm	4	4	0.55	99.45
2 mm	6.2	10.2	1.39	98.61
1.60 mm	1.7	11.9	1.62	98.38
1 mm	5.9	17.8	2.43	97.57
800 µm	5	22.8	3.11	96.89
500 µm	19.3	42.1	5.75	94.25
250 µm	287.4	329.5	45.00	55
200 µm	152.3	481.8	65.81	34.19
125 µm	207.6	689.4	94.61	5.39
100 µm	26.3	715.7	97.76	2.24
63 µm	8.7	724.4	98.94	1.00

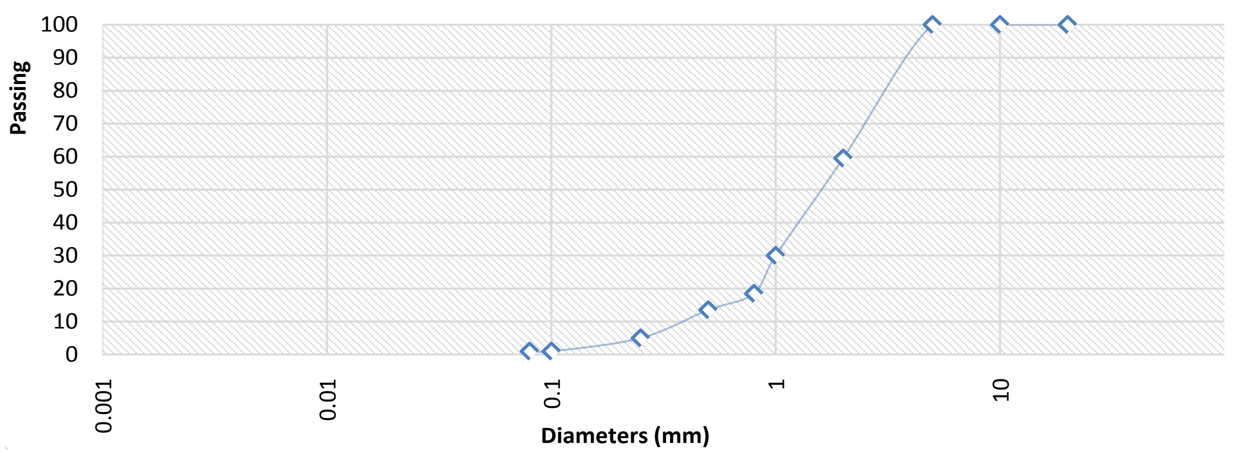

Figure 5. Particle size of the Typha Australis.

So in conclusion, we can say that the soil has a close and uniform grain size. Due to its fineness module, we have a majority of fine particles and therefore will need a lot of water for its use. Now let's talk about the Atterberg limits.

2.3. Atterberg Limits

The curve below is showing the determination of Atterverg limits (see Figure 6).

The plasticity limits are the average of the water content of the Tares 4 and 5. From these two values, we can determine the plasticity index which is the difference between the limit of liquidity and that of plasticity.

$$I_p = W_L - W_p = 25.2\% - 4.72\% = 20.47\%$$

So in conclusion the soil of Diamniadio is plastic based on the indicators from Table 3.

1) Estimation of the volume of the different samples

Table 4 is showing the estimation of the different volumes for our parallelepipedal samples that are used for determination shrinkage phenomenon.

The proportions chosen are due to the fact that we want to have a significant impact of Typha on the final material.

Table 5 shows the data about densities for the same sample.

3. Results and Discussion

3.1. Results

3.1.1. Estimation of the Shrinkage Rate of the Sample

The estimate of the volume shrinkage is based on the assessment of the volume

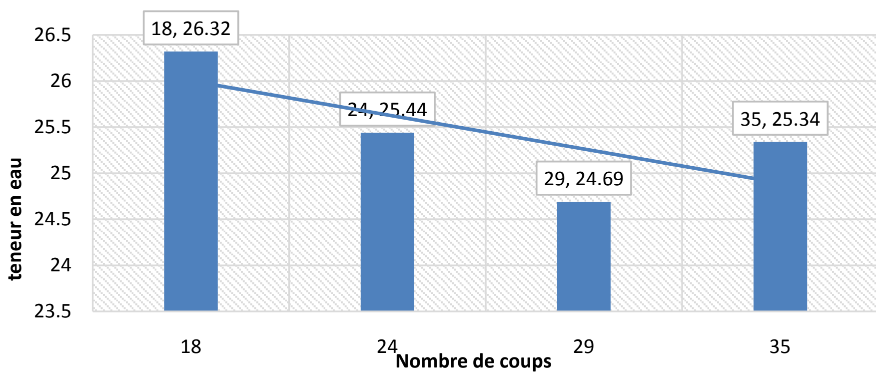

Figure 6. Atterberg limits determination.

Table 3. Interpretation of the IP.

Indicators	Degree of plasticity
0 < IP < 5	Not plastic
5 < IP < 15	Moderately plastic
15 < IP< 40	Plastic
IP > 40	Very plastic

Table 4. Estimation of different volume.

Specimens / Contents/Procedures	Specimen or Series A	Specimen or Series B	Specimen or Series C
Size of Volumetric Tubes (cm^3)	10 × 10 × 03	10 × 10 × 03	10 × 10 × 03
Value of Aggregate Mixture	73.9% of soil + 26.1% of water	4.48% of Typha + 71.54 of soil + 23.88% of water	10% of Typha + 70% of Soil+ 30% of Water
Result (cm^3)	VT_a1 = 216.27	VT_b1 = 267.90	VT_c1 = 282.00
	VT_a2 = 216.26	VT_b2 = 267.90	VT_c2 = 285.00
	VT_a3 = 216.26	VT_b3 = 267.90	VT_c3 = 285.00
	VT_a4 = 216.26	VT_b4 = 270.75	VT_c4 = 285.00
	VT_e5 = 216.26	VT_b5 = 270.75	VT_c5 = 285.00

Table 5. Estimation of the densities.

Specimens / Contents/Procedures	Specimen or Series A	Specimen or Series B	Specimen or Series C
Form and Size of Volumetric Tubes (Kg/cm^3)	10 × 10 × 03	10 × 10 × 03	10 × 10 × 03
Value of Aggregate Mixture	73.9% of soil + 26.1% of water	4.48% of Typha + 71.54 of soil + 23.88% of water	10% of Typha + 70% of Soil+ 30% of Water
Result (Kg/cm^3)	ρ_a1 = 2045.0	ρ_b1 = 1471.0	ρ_c1 = 0925.2
	ρ_a2 = 2032.5	ρ_b2 = 1440.0	ρ_c2 = 0927.3
	ρ_a3 = 2028.0	ρ_b3 = 1449.4	ρ_c3 = 0930.0
	ρ_a4 = 2033.4	ρ_b4 = 1440.5	ρ_c4 = 0934.4
	ρ_e5 = 2026.0	ρ_b5 = 1444.3	ρ_c5 = 0923.2

of the samples in relation to the volume of the specimen. The specimen used for building the sample has 300 cm^3 as volume.

We use this formula for the volumetric shrinkage rate noted T:

$$T = \frac{V_{spec} - \overline{V_{sample}}}{V_{speci}} \quad (1)$$

with $\overline{V_{sample}}$ the average of the volume.

For example, we have for A series, $T = \frac{300 - 212.42}{300} = 29.19\%$.

And the same computation is done for series B and C. That will allow us to get the following curve (see **Figure 7**).

After the decrease of the shrinkage, the cracking disappear also as we see in **Figures 8-11**.

3.1.2. Variation of the Densities

For the densities we have also the evolution mentioned in the following curve (see **Figure 12**).

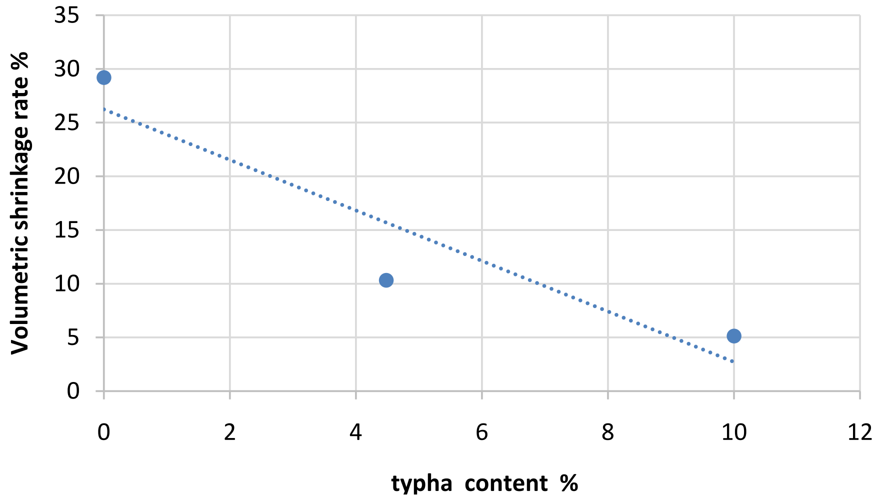

Figure 7. Evolution of the shrinkage rate.

Figure 8. Sample without Typha (presence of cracking).

Figure 9. Sample with Typha (no cracking).

Figure 10. Sample without Typha (shrinkage important).

Figure 11. Sample with Typha (decreasing of shrinkage).

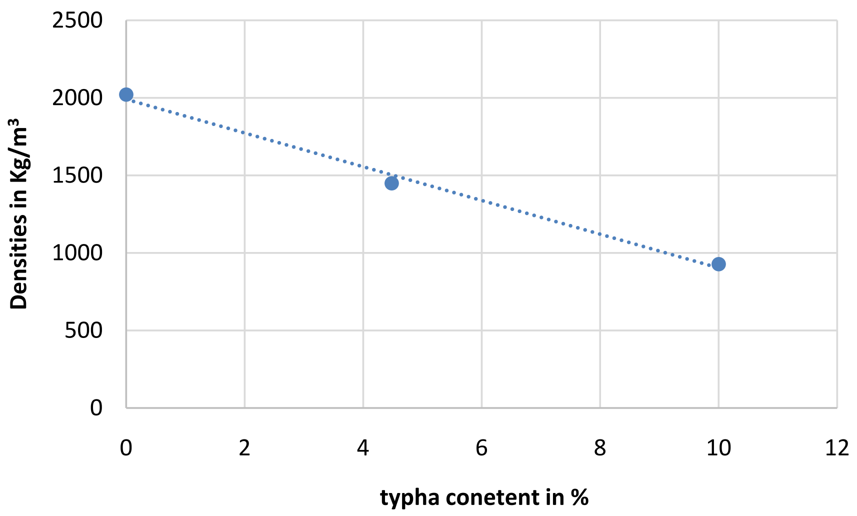

Figure 12. Evolution of the densities.

3.2. Discussion

The cracking of the sample is caused by the shrinkage/swelling phenomena. The estimation of shrinkage rate shows, for the soil alone we have 29.19% and an appearance of cracking on the cylindrical samples. By adding the Typha Australis with gradual proportion the shrinkage rate decreases to 5.13% for the sample treated with 10% by mass of Typha Australis. This will make all samples more stable and without cracking. These bricks built with association of Typha Australis, Soil and water will be used in the partition wall and that will enhance the soil of Diamniadio and the Typha Australis.

4. Conclusions

At the end of the work, we know now that the instability of soil of Diamniadio (explained by the presence of crack on the cylindrical specimens) is due to the presence of clay. Indeed, the work proposed solution of mixing the clay material with Typha Australis and building small brick for partition wall in houses. That will allow us to promote the soil of Diamniadio thrown by the companies when they build their structures.

In prospect of the work, we look for the mechanical, thermal and acoustic characterization of the materials build with Soil and Typha Australis and also the sustainability impacts of Typha Australis including life-cycle cost and not just short-term cost.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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