

Original Article

Influence of a Geotextile Made from Pineapple Leaf Fiber on Sandy-Clay Soils

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Abstract - In response to the need for new high-performance materials in the road construction sector, this work focused on a geotextile made from Pineapple Leaf Fibres (FiFA) as reinforcement in four soil matrices of type A1 and A2 bar soil. An evaluation of the performance of soil-geotextile composite materials led to the conclusion. For all four soils, the loss of CBR value after immersion decreased very little with the incorporation of geotextiles. This incorporation of geotextiles in FiFA significantly improved the soil bearing capacity even after 96 hours of immersion. For all types of soil, the ability of geotextiles to improve the mechanical characteristics of soils, even in contact with water, has been demonstrated. In summary, geotextiles made from pineapple leaf fibers represent an ecological and sustainable alternative to traditional synthetic geotextiles because they have demonstrated good mechanical performance when incorporated into soils in dry and humid conditions, with the corollary benefits in terms of material reduction, costs, and environmental impact.

Keywords - Plant fibers, Composite materials, CBR index, Immersion.

1. Introduction

Road construction is crucial for a country's economic and social development. The quality of these roads depends largely on the mechanical properties of the soil material used. In Benin, desaturated ferrallitic reddish clayey sands are quite widespread, occupying almost all of the exposed land; they are composed of clayey. Widely available in all departments of Benin, these soils constitute a source of material for road construction [1]. However, it has, however, sometimes insufficient mechanical properties and is associated with a sensitivity to humidity [2]. Among the proposed solutions to improve the stabilization of these soils and enable their use in road construction to address the problem of over-exploitation of conventional materials, reinforcement with plant-based fibres is suggested.

Indeed, adding fibres generally improves the physical and mechanical properties of soils, thus extending road lifespan and reducing maintenance costs. Given the problem of overexploitation of conventional materials and the use of synthetic products, transforming agricultural waste into industrial agro-materials is now becoming a valuable opportunity [3]. In the field of road construction, several authors are interested in the mechanical performance of soils reinforced with plant fibres, and particularly the influence of their incorporation on soil properties. The loose incorporation of pineapple leaf fibers has been particularly explored; indeed, a study of the influence of soil type on the

strength gain of pavement layers focused on the behavior of three soil types (bar land, lateritic gravel, and silty sand) reinforced with pineapple leaves used in their natural state and cut to a length of 2.5 cm. They are incorporated into soils at mass concentrations of 1% and 2%. Experimental studies show that the percentage and type of leaves used strongly influence the behavior of the soils studied. Clay soil incorporated with 1% pineapple leaves yields better results, with a 42% increase in strength (CBR index). A 28% improvement is obtained with a 1.5% concentration of 6 cm long leaves. Pineapple leaf fibres thus improve the useful mechanical properties of clay soils for durable pavements.

In road geotechnics, geotextile-type materials are increasingly used to improve the quality of road structures. These are flat, permeable polymer fabrics (natural or synthetic) used in contact with soil for functions including reinforcement and separation of pavement layers. In Benin, the beneficial use of biomass from pineapple production is a subject of several discussions, including its contribution to environmental protection by valorizing waste to improve soil and road base materials. Textiles made from natural fibres can be used to produce various composite materials. [4-7] Thus, geotextiles made from pineapple leaf fibers, compared to coconut fiber geotextiles produced in India, could exhibit acceptable characteristics due to the partially crystalline nature of these pineapple fibers. This research article, which reports on tests conducted on clay soil + geotextile composites in Floor Area and Environment



(FIFA), aims to assess their long-term water (humidity) resistance [8, 9]. The present work consisted of developing a geotextile material for improving road durability using plant fibers from pineapples of the "sugarloaf" variety and bar land.

The basic materials for this study are locally available materials from the municipality of Allada. These are pineapple leaves and clayey sands. A geotextile was produced by weaving fibers extracted from pineapple leaves (Figure 1).

2. Materials and Methods



(a) pineapple leaves (b) Geotextile in FIFA
Fig. 1 Woven geotextile materials based on pineapple leaf fibers

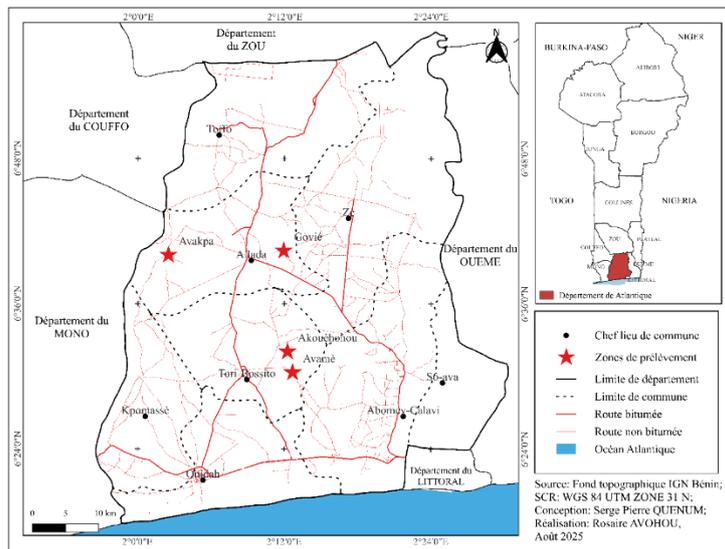


Fig. 2 Geographical and administrative situation of the Atlantic department

Soil samples were taken from four sites in the Atlantique department (Figure 2). These are silty-clayey sands of the ferrallitic type, quite widespread and often used as fill material or material for the subgrade layer.

The determination of physical and mechanical parameters was carried out in the laboratory to complete the identification of the four soils. The results of particle size analysis by sieving and Atterberg limits were obtained according to standards NF EN ISO 17892-4 and NF EN ISO 17892-12, respectively [8, 11] Enabled the geotechnical classification to be carried out according to the NF P 11-300 standard [12] The Proctor test was performed according to standard NF P 94-093. [13] This allowed us to determine the compaction characteristics, namely the optimal water content (wopt) and the maximum dry density of the soils (Figure 3). These characteristics represent the specific conditions under which the materials must be used in situ.



Fig. 3 Proctor test in progress

The California Bearing Ratio (CBR) test, according to standard NF P 94-078 [14], made it possible to determine the soil bearing index, which is a parameter taken into account in the dimensioning of pavements.

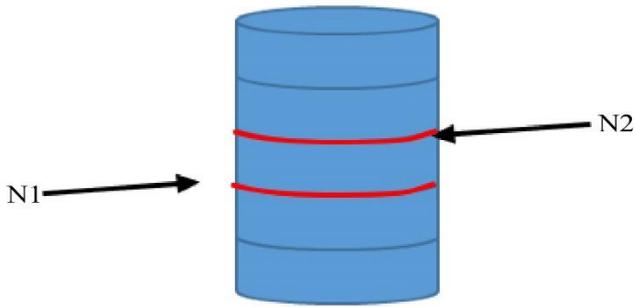


Fig. 3 Preparation of test specimens for Proctor and CBR tests

In performing a CBR test in a Modified Proctor mold, soil compaction is typically done in five layers. To evaluate the performance of composite materials (clay soils + geotextiles in FIFA) The preparation of the test specimens was carried out according to the principle of the CBR test; the geotextile was cut according to the diameter of the mold and incorporated into the test specimen; In order to better understand the optimal position of the geotextile within the layers of pavement in situ, two levels of positioning in the mold were studied: level N1 corresponds to the surface of the 2nd layer of soil compacted in the mold and level N2 to the surface of the 3rd layer of soil compacted (Figure 4)

The four soils each constitute a matrix into which the FiFA (G) geotextile has been incorporated. After positioning the FiFA layer in the mold, the compaction of

the other layers continues until the mold is full, following the principle of the CBR test. Each composite is designated by the acronym G Si Nj. Ordinarily, the puncture test for the CBR test, according to standard NFP 94-078, is performed after 96 hours of immersion. For this protocol, punctures were performed immediately after compaction, after 48 hours, and after 96 hours to assess the influence of water on the composite materials. The composites produced are grouped in Table 1 below.

Table 1. Summary table of the different composite materials studied

Floors	Designation
Allada bar land S1	G S1 N1
	G S1 N2
Bar Land by Tori Akouèhonou S2	G S2 N1
	G S2 N2
Tori Avame bar land S3	G S3 N1
	G S3 N2
Bar land by Tori Akouèhonou S4	G S4 N1
	G S4 N2

3. Results and Discussion

3.1. Geotechnical Characterization of Soil Materials Used

The results of particle size analysis on the soils are presented in Figure 5.

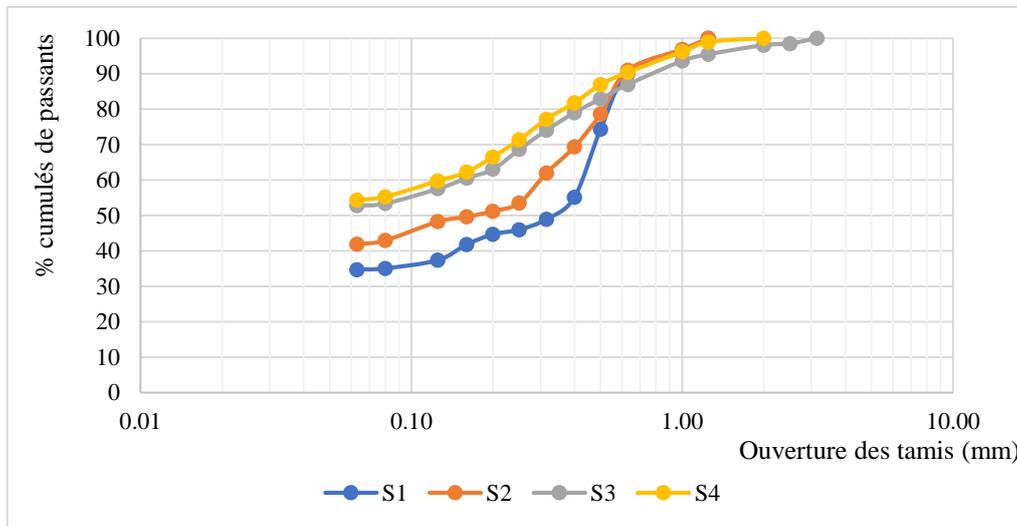


Fig. 5 Particle size distribution curves

These are summarized in Table 2, which includes the percentages passing at 2mm and 0.08mm, as well as the results of the Atterberg limit tests (liquid limit, plastic limit, and plasticity index).

Table 2. Summary of soil identification test results

Essay	S1	S2	S3	S4
% passing to 2mm	100	100	98.02	100
% increasing to 0.08 mm	35.05	42.95	53.38	55.25
Liquidity limit	40	41	46	45
Plastic limit	23	22	38	37
Plasticity index	17	19	8	8
Classified according to the Road Earthworks Guide	A2	A2	A1	A1

The four soil types of clay-rich soils that yielded sieve contents greater than or equal to 35% on the 0.08 mm sieve place us, according to the Road Earthworks Guide [15]. In class A soils, based on the "Plasticity Index (PI)" parameter, a value below 12 indicates class A1 soils, while a value between 12 and 25 corresponds to class A2 soils. Thus, soils S1 and S2 are class A2 (medium plasticity fine soils), while

soils S3 and S4 are class A1 (low plasticity fine soils). The former are silty loams or low plasticity silts, and the latter are clayey loams.

The Proctor curves of the studied soils are presented in Figure 6. Table 3 summarizes the Proctor references of the soils studied as well as their CBR indices.

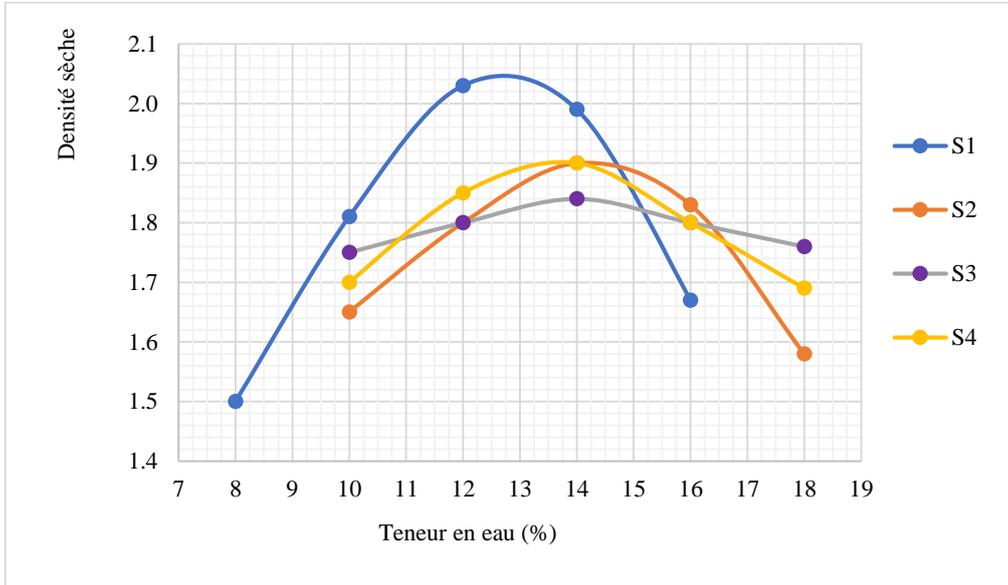


Fig 6. Proctor curves of the studied soils

Table 1. Summary of Proctor benchmarks and CBR indices

	S1	S2	S3	S4
Maximum dry density	2.04	1.90	1.84	1.90
Optimal water content	12.75	14.20	14.00	14.00
Immediate CBR Index	27	30	62	64
CBR index after 48 hours of immersion	23	28	17	26
CBR index after 96 hours of immersion	21	25	7	10

Soil S1 has the best Proctor values. Soils S2, S3, and S4 have practically the same Proctor values, even though they have different plasticity values (19 for S2; 8 for S3 and S4).

For soil in its natural state, analysis of the values reveals a decrease in the CBR index as a function of soaking time for all soil types in class A2 (S1 and S2) and class A1 (S3 and S4). Indeed, natural soils S1 and S2 show a moderate loss of bearing capacity after immersion, decreasing from 27 to 21 and from 30 to 25, respectively. Conversely, although soils S3 and S4 have an excellent immediate CBR index (in the dry state), their CBR indices decrease from 62 to 7 and from 64 to 10, respectively, after immersion at 96 hours, indicating a very high sensitivity to water. Thus, although soils S1 and S2 are more deformable due to their plasticity (IP 17 to 19), these soils have better water resistance than soils S3 and S4, which have a plasticity index of 8. This observation is justified given the granular nature of these two soil categories, as indicated by the classification system [15]. Class A1 soils are silty loamy soils with low plasticity, while Class A2 soils are clayey

loamy soils. A fine, low-plasticity soil loses cohesion in the presence of water, whereas a relatively more plastic fine soil offers better water resistance, meaning a smaller decrease in its bearing capacity. In short, S1 and S2 soils are better suited for road construction; however, S3 and S4 soils require stabilizing treatment before use or, if necessary, an effective drainage system after installation; these soils are therefore more appropriate for dry environments.

In all cases, based on the classification of CBR values, all the soils studied are admissible for use in subgrade layers because they have a CBR index between 5 and 30 (CEBTP, 1994).

3.2. CBR Index of Composite Materials

Following the experimental protocol established to evaluate the performance of composite materials with the four soils, each constituting a matrix into which the FiFA(G) geotextile was incorporated, the results obtained are presented in Table 4 and translated into Figure 7 (for class A2 soils) and Figure 8 (for class A1 soils).

Table 2. Summary of CBR index values for the composite materials of the soils studied

Class	Composites	0h	48 hours	96h
A2	S1 Natural	27	23	21
	G S1 N1	42	37	34
	G S1 N2	47	42	38
	S2 Natural	30	28	25
	G S2 N1	47	42	39
	G S2 N2	52	48	45
A1	S3 Natural	62	17	7
	G S3 N1	68	21	12
	G S3 N2	64	18	11
	S4 Natural	64	26	10
	G S4 N1	69	32	15
	G S4 N2	66	27	12

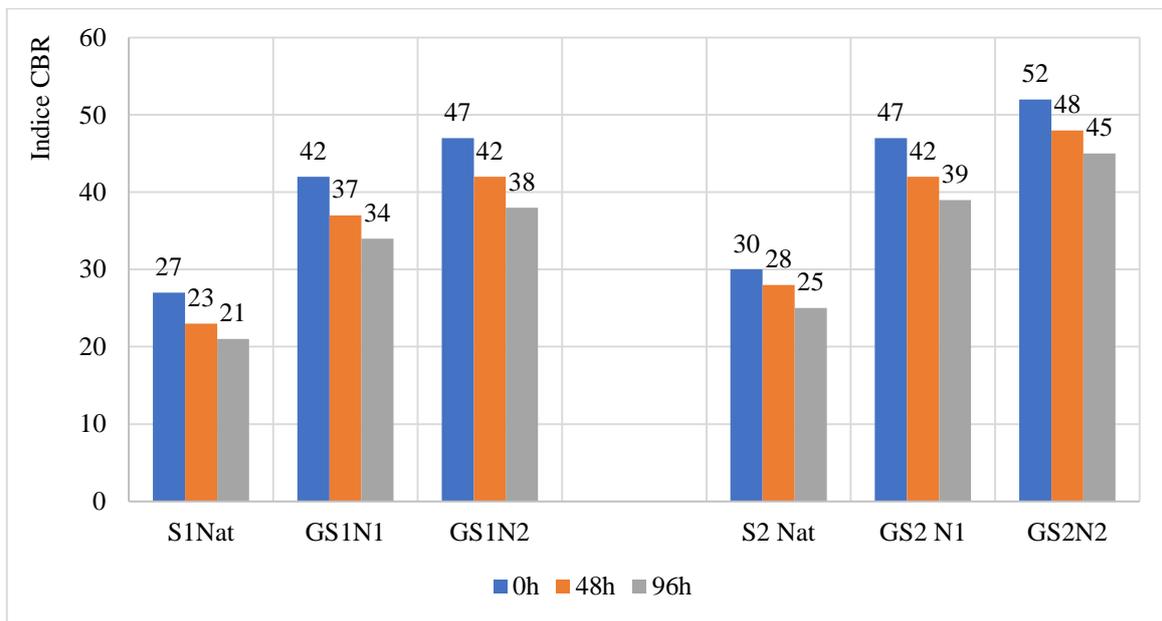


Fig. 7 Summary of immediate and post-immersion bearing capacity values of composite materials for the studied soils of class A2 + FiFA

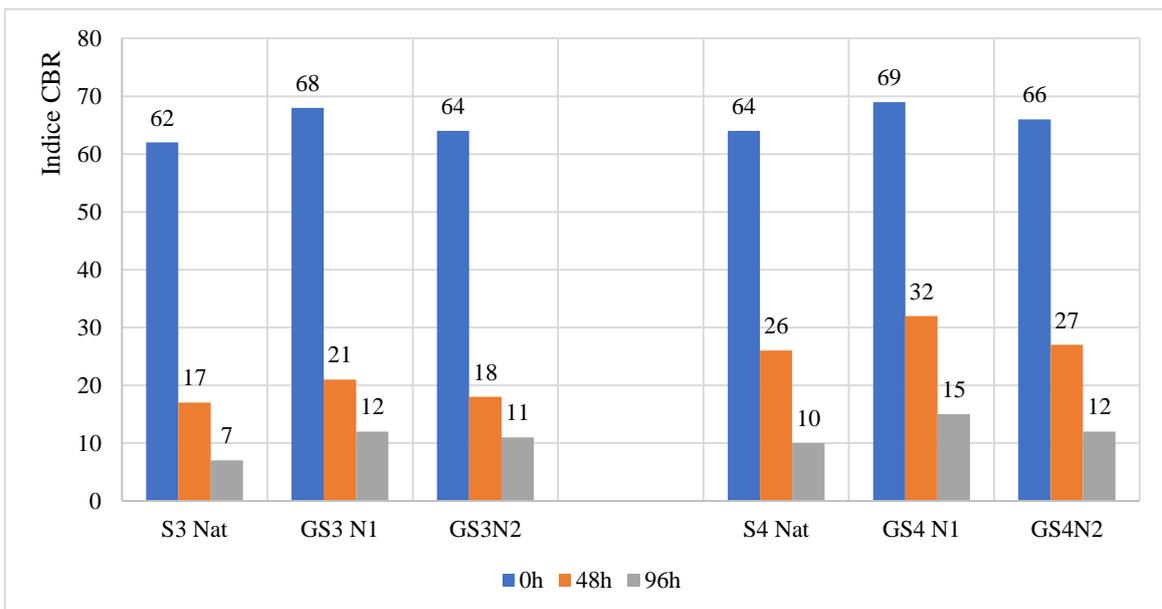


Fig. 8 Summary of immediate and post-immersion bearing capacity values of composite materials for the studied soils of class A1 + FiFA

These graphs reveal that all reinforced materials showed an improvement in their CBR index regardless of the immersion time and the positioning of the geotextile. At 96 h of immersion, for example, the following values (without geotextile; with position N1 and with position N2) were recorded: S1 (21; 34; 38); S2 (25; 39; 45); S3 (7; 12; 11); S4 (10; 15; 12).

In numerical terms, the Figure 9 and the Figure 10 present, respectively, for class A2 and class A1 soils, the gains in resistance of the soils studied compared to the unreinforced soil and by duration of immersion (immediate punching, after 48h, and after 96h).

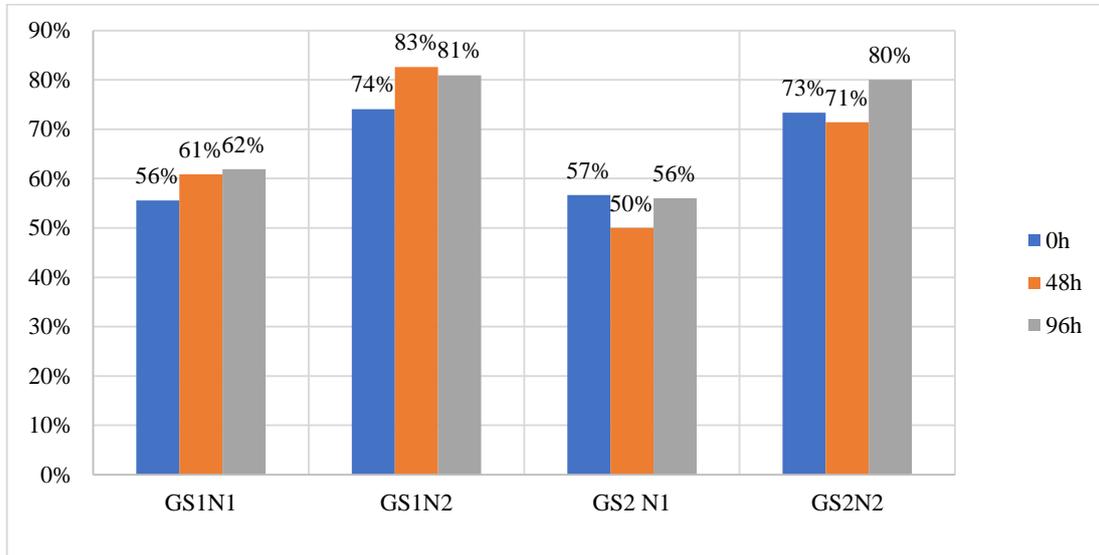


Fig. 9 Gain of reinforced soils compared to unreinforced soils of class A2 as a function of immersion time

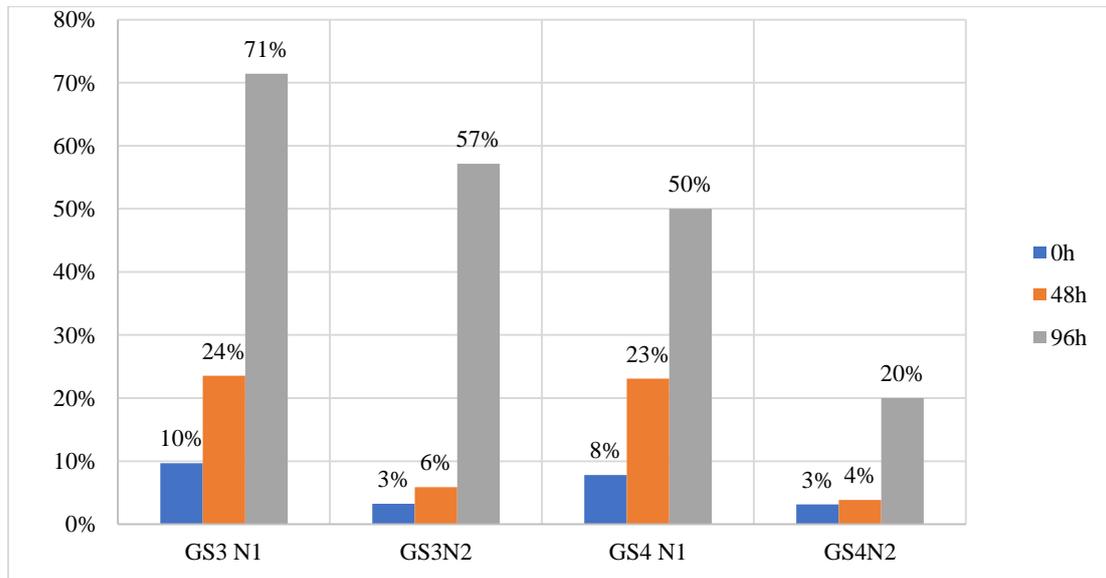


Fig. 10 Gain of reinforced soils compared to unreinforced soils of class A1 as a function of immersion time

As observed, the influence of immersion time and positioning differs between A2 and A1 class soils.

For immediate punching (0h), for class A2 soils, the incorporation of geotextile gives a gain of 56 and 57% (S1 soil and S2) for position N1 and 74 and 73% (soil S1 and S2) for position N2; for class A1 soils, the gain is much lower (10% for S3 and 8% for S4) for position N1 and much lower or almost non-existent (3% for S3 and S4) for position N2.

Thus, without any contact with water, apart from the amount needed for compaction, the incorporation of geotextile in FIFA resulted in a gain of 56.5% for position N1 and 73.5% for position N2. However, for soils in A1, the gains are significantly lower, with position N1 showing the most favorable gains at 9% and position N2 at 3%.

Regarding positioning in the CBR mold, one could conclude that for A2 soils, the N2 position is better; for A1 soils, the N1 position is better for immediate punching.

For a punch after 48 hours of immersion, for A2 class soils, the incorporation of geotextile results in a gain of 61% and 71% (soils S1 and S2) for position N1 and 83% and 71% (soils S1 and S2) for position N2; for A1 class soils, the gain is much lower (24% for S3 and 23% for S4) for position N1 and much lower or almost non-existent (6% for S3 and 4% for S4) for position N2. The same observation made previously regarding positioning is observed for 48 hours of immersion. N2 is better.

For a puncture after 96 hours of immersion, for A2 class soils, the incorporation of geotextile results in a gain of 62% and 56% (soils S1 and S2) for position N1 and 81% and 80% (soils S1 and S2) for position N2. For A1 class soils, a reduction in the gain is observed (71% for S3 and 50% for S4) for position N1, and a much smaller or almost non-existent gain (57% for S3 and 20% for S4) for position N2. An improvement in the composite is observed with the placement of the geotextile at position N2.

While, for all reinforced soils of class A2, the average gains did not vary greatly for 0h (65%); 48h (66%) and 96h (70%), the variation is significantly more dynamic for soils of class A1 depending on the duration of immersion: 0h (6%); 48h (14%) and 96h (50%).

This observation highlights the strengthening of the bonds between particles in this soil category when in contact with moisture, thus revealing the benefits of incorporating geotextiles in Flood Reinforced Asphalt (FiFA). For all soil types, the geotextile's ability to limit soil settlement and maintain its structure in the face of water intrusion is evident. This indicates that the geotextile acts effectively as reinforcement, even under saturated conditions. The geotextile mechanically resists the accumulation of deformation caused by repeated stresses, which manifests as

localized failure surfaces in the soil, and reduces settlement in soils with low bearing capacity.

These results are supported by studies conducted by researchers on the use and mechanical behavior of reinforced clay materials and geotextiles. The inclusion of geosynthetics influences the bearing capacity characteristics of the clay material [16] by its ability to limit deformations of the foundation soil under a given load or to increase its load-bearing capacity [17]. Similarly, the effectiveness of the reinforcement depends on the type of soil and its particle size; in particular, cohesive or compacted soils interact better with geotextiles made of plant fibres [8, 9]. Several authors have confirmed the mechanical performance of soils reinforced with plant fibers, and in particular, the influence of their incorporation on soil properties [8, 9]. The results obtained in this study confirm the ability of the geotextile in FiFA to limit soil subsidence while maintaining its structure in a hydrated environment. This actual behavior of the soil and the geotextile in this experimental study is also reported by other authors [9, 18, 19].

4. Conclusion

During this study, two soils, S1 and S2, of class A2 (silty loam soils), and two soils, S3 and S4, of class A1 (clayey loam soils), were tested. An evaluation of the performance of the soil-geotextile composite materials led to the conclusion that, for the four soils, the incorporation of geotextile significantly improves soil bearing capacity, even after immersion, particularly for soils of class A2. This incorporation significantly increases the load-bearing capacity of the soils while limiting water penetration into the soil layers for both geotextile positioning levels; position N1 is generally better. These results suggest that the use of geotextiles is a relevant solution for construction projects on water-sensitive and low-bearing soils.

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