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Determination of the Mechanical Characteristics of Silty Sand Improved to Granite Crushed for Use in Road Construction in Southern Benin

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Abstract Faced with the growing shortage of conventional materials in road construction in South Benin, this study explores the valorization of the silty sand of Tohouè, an abundant local resource but unsuitable for the raw state because of its low lift and its sensitivity to water. The general objective is to evaluate the effectiveness of mechanical stabilization by adding Dan's 0/31.5 granite crusher to allow its use in road construction. The methodology consisted in formulating eight mixtures with crushed contents ranging from 10% to 45%, characterized by standardized geotechnical tests: particle size analysis, Atterberg limits, methylene blue value, modified Proctor and CBR index after immersion. The results demonstrate a gradual improvement in mechanical properties. The mixture with 20% crushed material already shows a marked improvement with a CBR of 58.4% and a density of 1.99 g/cm³, meeting the CEBTP standard. However, it is the 25% blend that constitutes the technical optimum, achieving a CBR of 63.65% and a density of 1.995 g/cm³, fully meeting the requirements of international standards for foundation layers. Therefore, stabilization with 25% granite crushed represents the optimal formulation, offering the best compromise between mechanical performance and economic viability. This solution allows a 75% saving on the use of noble materials while valuing an abundant local resource, thus constituting a sustainable alternative for road construction in Benin.

Keywords: *silty sand, crushed granite, geotechnical tests, foundation layers, stabilization*

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1. Introduction

Materials traditionally used in road construction in Benin, such as lateritic gravel, silty sands and crushed granite [1,2,3,4,5], are becoming increasingly scarce, especially in the south-eastern region of the country. This shortage leads to an interest in locally abundant alternative resources, such as silt sands. However, these materials present major challenges for use as a form or foundation layer because of their low cohesion and their high sensitivity to water. It must be noted that pavements incorporating these sands without appropriate treatment prematurely develop disorders such as rutting, differential compaction and accelerated erosion of the shoulders.

The main causes of these pathologies are intrinsically linked to the unsuitable nature of the raw material, a problem exacerbated by traffic, climatic conditions and implementation techniques. In order to reduce the construction costs and the environmental impact of transporting materials over long distances, the development of local resources becomes an imperative necessity. This approach is only viable if preceded by rigorous geotechnical studies [1,6,7]. It has also been shown that some local materials, although not in accordance with international standards, can be effective after improvement, while structures that strictly comply with these same standards can deteriorate early [1,4,5,6]. It is therefore crucial to develop technical guides adapted to the Beninese geological and climatic context [8].

In the south-east of Benin, and more specifically in the commune of Sèmè-Kpodji, the abundance of silty sand deposits in the village Tohouè, represents an underexploited resource. Its immediate proximity to future road routes makes it a prime candidate from a logistical and economic point of view. However, its intrinsic mechanical characteristics, low lift and plasticity, do not allow its direct use in road construction. This technical inadequacy, coupled with the scarcity of noble materials, makes it essential to seek solutions to improve it [1,2,4,9].

Several stabilization techniques, proven in the literature, can be envisaged to give this type of material the required properties: chemical stabilization using binders such as cement or lime, or mechanical stabilization by addition of aggregates having high technical characteristics [1,4,10,11].

Faced with this observation, the present study aims to stabilize the silty sand of Tohouè with the crushed granite of Dan for its use in road construction. Thus, this work, which is part of a logic of valorization of local resources for the realization of economic and sustainable infrastructure.

2. Materials and Methods

2.1. Materials

2.1.1. Silty Sand

The silty sand, object of this study, comes from the quarry of Tohoué in the district of Tohouè, Commune of Sèmè-Kpodji. It is located 2.5 km from the bus station of Djèrègbé more precisely 35.7km from Cotonou. The commune of Sèmè-Kpodji is located between the parallel 6°22' and 6°28' North latitude and the meridians 2°28' and 2°43' East longitude. The location of the quarry is completed by the following Figure 1.

Source :https://www.google.com/carte Benin and (B) INSAE (Benin)

Figure 1. Location of sampling site

Table 1. Summary of the geotechnical characteristics of silty sand facing the CEBTP [12] thresholds revised [13]

Features	Values of silty sand	CEBTP [12] thresholds revised [13]			
		Foundation layer		**Base layer**	
Percentage passing through the 80 µm sieve (%)	7.67	< 35	Ok	< 20	Ok
Dry density OPM (t/m^3)	1.95	≥1.8-2.00	Ok	≥2.0	No
Linear swelling index (%)	0.15	<1.00	Ok	<1.00	Ok
CBR Index at 95% OPM (%)	44.00	≥30	Ok	≥80	No
Organic matter rate (%)	0.13	≤ 1	Ok	≤ 1	Ok
Methylene Blue Value (%)	0.41	≥0.2-8.0	Ok	≥0.2-8.0	Ok
Optimum water content (%)	8.20	≥7 and ≤ 13	Ok	≥7 and ≤ 13	Ok

Source: Houanou et al. [9]

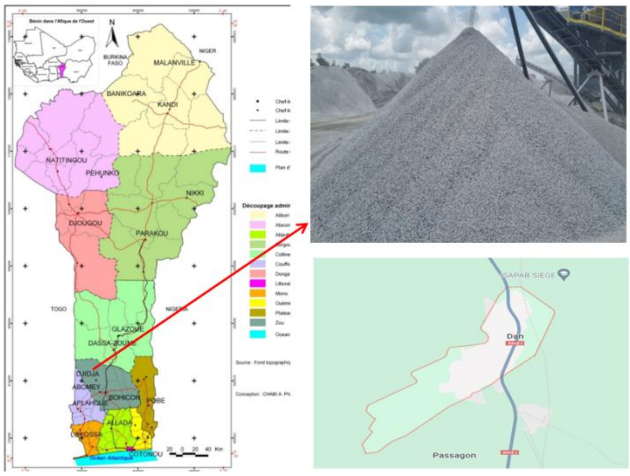
Table 1 summarizes the geotechnical characteristics of the silty sand of Tohouè. These values from Houanou et al. [9] show that the raw material can only be used directly as a foundation layer.

2.1.1.2. Granitic Crushed

In this study, the granite crushers used come from a quarry located in the village Dan, commune of Djidja (department of Zou) in Benin. The municipality of Djidja lies to the north between latitudes 7°10' and 7°40' North, and to the east between longitudes 1°04' and 2°10' East. Dan's crushed granite quarry is precisely located at latitude 7°21'44" North and longitude 2°6'38" East.

In this quarry, the crushed material is sorted and stored by granular class [14]. The materials are directly extracted from massive granite rocks and crushing is carried out in a traditional way. Figure 2 shows the map of Benin and the quarry area and also the material under study.

Table 2 summarizes the geotechnical characteristics of Dan's granite crusher. These values from Houanou et al. [2] show that the material can be used directly in the different pavement layers.



Source :https://www.google.com/carte Benin and (B) INSAE (Benin)

Figure 2. Location of sampling site

Table 2. Summary of geotechnical characteristics of granitic crushed stone with respect to CEBTP [12] thresholds, revised [13]

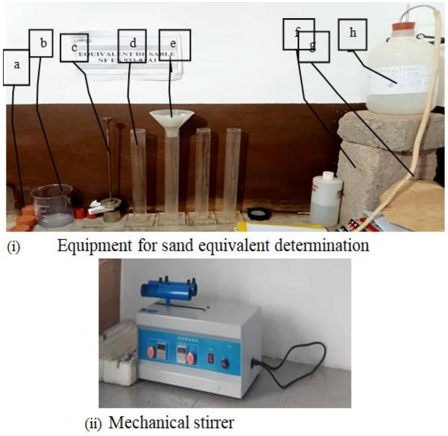
Characteristics	Values for granite crushed rock	CEBTP [12] revised [13] thresholds			
		Foundation layer		Base layer	
Percentage passing 80µm sieve (%)	6,66	< 35	Ok	< 20	Ok
Dry density OPM (t/m^3)	2,26	1.8-2.00	Ok	2.0	Ok
Linear swelling index (%)	0,07	1.00	Ok	1.00	Ok
CBR index at 95% OPM (%)	96,29	30	Ok	80	Ok
Organic matter content (%)	0,14	≤1	Ok	≤1	Ok
Methylene blue value (%)	0,16	0.2-8.0	Ok	0.2-8.0	Ok
Optimum water content (%)	6,66	7 and ≤ 13	Ok	7 and ≤ 13	Ok

Source: Houanou et al. [2]

2.2. Test Equipment

2.2.1. Sand Equivalent Test

The sand equivalent material was produced in accordance with standard NF EN 933-8 [15]. In addition to the elements shown in Figure 3, a 5 mm screen, a scale, a graduated scale, a chronometer and a pin are required.



Legend:
a: rubber stoppers for test piece.
b: beaker;
c: 1 calibrated piston
d: 100 mm and 380 mm graduated plexiglass test pieces
e: wide neck funnel
f: measuring bottle capacity 200 ml.
g: 1 tap and siphon irrigator tube.
h: 1000 ml of concentrated stock solution.

Figure 3. Equipment for Sand Equivalent test

Figure 4. Micro-Deval Machine

2.2.2.2. Micro-Deval Test

The abrasion test was carried out according to the protocol of standard NF EN 1097-1 [16]. The core of the experimental device was a Micro-Deval machine (Figure 4), a set of control sieves. A precision scale and drying oven, bins and trowels.

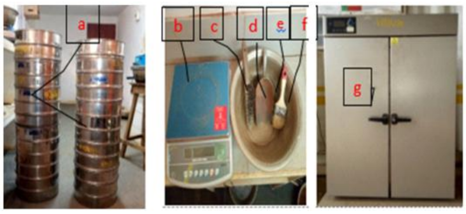
2.2.2.3. Los Angeles Test

The experimental device for the impact fragmentation test was carried out according to standard NF EN 1097-2 [17,18]. Figure 5 shows the standardized Los Angeles machine. As with the Micro-Deval test, it is important to add a specific set of sieves, a scale, a drying oven, bins and trowels.

2.2.2.3. Particle Size Analysis

All the equipment for carrying out the particle size analysis by sieving was selected in accordance with standard NF P 94-056 [19]. Thus, Figure 6 shows said equipment.

Figure 5. Los Angeles Machine

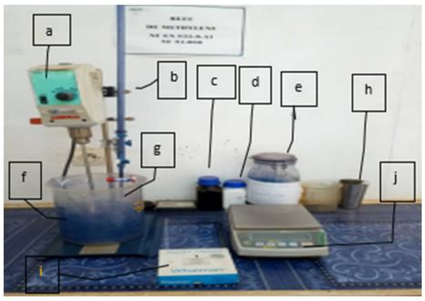


Legend:
a: Series of sieves
b: Scale of 30kg±0.2g
c: Brush
d: Scoop hand
e: Brush
f: Container
g: Oven with adjustable temperature 50°C to 105°C 2°C

Figure 6. Equipment for particle size analysis

2.2.2.4. Methylene Blue (MBV) Value

Figure 7 shows the methylene blue value test equipment according to the rigorous protocol of standard NF P 94-068 [20]. In addition, mesh screens (80 µm, 5 mm and 50 mm), a thermometer, a chronometer, an oven at 90 ℃, a desiccator and a precision burette must be added.



Legend:
a: Finned stirrer
b: Stand
c: Yellow glass flask
d: Dried kaolinite
e: Volumetric flask
f: Beaker
g: Burette
h: Methylene blue
i: White filter paper
j: Scale of 1000g±0.1g

Figure 7. Equipment for determining the methylene blue value

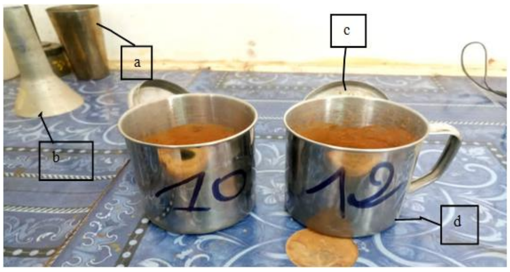
2.2.2.5. Water Content by Weight

Figure 8 shows the experimental device for producing the water content according to the reference method described in the standard NF P 94-050 [21]. It is important to add a scale with a capacity of 30 kg and an accuracy of ± 1 g, dishes and Petri dishes or vases.

2.2.2.6. Organic Matter Content

The test device for the organic matter content was carried out in accordance with Annex B to standard NF P 94-051 [22]. Figure 9 provides an overview of some of the test materials. To this must also be added a muffle oven set at a constant temperature of 500 ℃, a precision balance (30,000 g ±1 g), a 2 mm sieve and a desiccator.

Figure 8. Equipment for measuring water content



Légende :
a : Mortier
b : Pilon
c : Couvercle
d : Creusets

Figure 9. Equipment for testing organic matter content

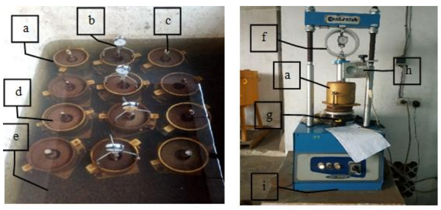
2.2.2.7. Normal Proctor Test

The experimental equipment for determining compaction references (OPM) was determined in accordance with standard NF P 94-093 [23]. Figure 10 provides an overview of some of the test materials. A lady weighing 4,535 kg (± 5 g) and a height of 457 mm (± 2 mm) must also be added, with a straight ruler at the base, a 20 mm sieve, an oven and thus a laboratory scale (30,000 g ±1 g).

Legend:
a: Modified Dame Proctor
b: CBR mold
c: Baseplate
d: Material tray
e: Tray
f: Scoop hand
g: Sieve
h: Hammer
i: Modified Proctor mould
j: Accessories
k: Container

Figure 10. Equipment for determining compaction references

2.2.2.8. CBR Test



Legend:
a: CBR mould
b: Comparator
c: Overload series
d: Perforated metal disc
e: Immersion tray
f: Cadencenter
h: Comparator
g: Extensions
i: CBR press

Figure 11. Equipment for determining the CBR load-bearing index

The experimental equipment for the California bearing index (CBR) test complies with standard NF P 94-078 [24]. Figure 11 shows some of the material from this test. A lady weighing 4,535 kg (±5 g) and a height of 457 mm (± 2 mm) must also be added, with a straight ruler at the base, a 20 mm sieve, an oven and thus a laboratory scale (30,000 g ±1 g).

2.3. Methods

2.3.1. Sample Collection Method

The samples are taken according to standard XP P94-202 [25]. The silty sand and crushed granite samples were dried in the open air before the various tests were carried out; because the pretreatment method in the oven reduces the liquidity limit and increases the dry weight per unit volume of the material to the modified Proctor optimum [1,4,26,27].

2.3.2. Method of Formulation

It should be recalled that geotechnical tests carried out on the silty sand of the Tohouè quarry show that this material can only be used as a foundation layer for flexible roadways according to the specifications of the modified CEBTP [12] revised [13]. For the majority of authors who worked on litho-stabilization, the percentage of granitic crushed varies between 10 and 45%. Thus, the silty sand of Tohouè is improved by adding 10%, 15%, 20%, 25%, 30%, 35%, 40% and 45% of the granitic crushed material of class 0/31.5. Figure 12 shows the preparation of mixtures of silty and crushed granite sand.

Six steps are required for the formulation of silty sand/crushed granite mixtures. They are listed below ([1,4,10]):

Step 1: Dry the samples of silty sand and crushed granite in an oven at 50℃ for 2 hours or in air for a suitable time at room temperature.

Step 2: Define the different proportions of the granite crushed empirically, for example: from 10%, 15%, 20%, 25%, 30%, 35%, 40% and 45%.

Step 3: Calculate the quantities of each mixture (silty sand and crushed granite) according to the type of test.

Step 4: Determine the water content of each mixture.

Step 5: Mix manually to prevent grain size change in a short time.

Step 6: Pack the quantities of material collected in airtight plastic bags or self-closing polyethylene bags to keep the water content constant.

Figure 12. Preparation of Mixtures

2.3.3. Geotechnical Test Method

The various geotechnical and mechanical test methods are carried out in accordance with the standards mentioned in §2.2.2.

Test method on formulated materials

The particle size analysis is carried out according to standard NF P 94-056 [19] while the determination of the water content by weight is carried out according to the specifications of standard NF P 94-049-2 [28] .As for the natural water content, it was carried out according to standard NF P94-050 [21]. The methylene blue value is determined according to the recommendations of standard NF P 94-068 [20]. In addition, the organic matter content shall be determined in accordance with standard XP P94-047 [29]. The tests for determining the compacting references are carried out according to the standard NF P94-093 [23]. While that of CBR index after immersion is carried out according to standard NF P94-078 [24].

3. Results and Discussion

3.1. Results

3.1.1. Characterization Tests on Each Type of Mixture

The following tables present the results of the tests of the litho-stabilized mixtures at 10%, 15%, 20%, 25%, 30%, 35%, 40% and 45% of granitic crushed 0/31.5. These tests are: particle size analysis by sieving, methylene blue value, Modified Proctor and CBR.

Table 3 presents the results of the mixture of 10% Crushed+90% Silty Sand of Tohouè.

The analysis in Table 3 reveals geotechnical characteristics that are limited by the standards in force. The average CBR of 56.5% is below the requirements of the NF P 94-078 standard, which generally requires a minimum of 80% for the base layers. However, this value remains acceptable for the CEBTP standard which prescribes a minimum of 30% for the foundation layers. The methylene blue value of 0,33 indicates a persistent water sensitivity, in line with the Ndiaye observations [10] on sandy materials with low aggregate content. The dry density of 1.94 g/cm ³ is comparable to the results obtained by Gidigasu ([26]) on similar materials in tropical contexts [30].

Table 4 presents the results of the mixture of 15% Crushed+85% Silty Sand of Tohouè.

The analysis of Table 4 shows that the increase to 15% of granite crushed brings an improvement; but it is insufficient to meet the standards in force in road construction. The average CBR of 55.7% remains unsuitable for the requirements of the NF P 94-093 standard for the base layers of roadways. This performance nevertheless corresponds to the specifications of certain African countries such as Senegal and Côte d'Ivoire for embankments selected as a base layer.

The results of the mixture of 20% crushed granite+80% silty sand of Tohouè are recorded in Table 5.

From the analysis of Table 5, it appears that with a substitution of 20% of granite crushed to silty sand, an improvement in the CBR index of 55.7 to 58.4% and a density of 1.955 to 2.02 g/cm ³ are observed. The value of the CBR index is less than 80% to be used as a base layer while the value of the density is greater than 2.00 to be used as a base layer according to the thresholds recommended by the modified CEBTP guide [12,13] The water stability improves (VBS=0.33), which is in line with Weinert's observations [31] on the optimization of granular mixtures in subtropical zones.

The results of the mixture of 25% crushed granite+75% silty sand of Tohouè are recorded in Table 6.

From the analysis of Table 6, it appears that with a substitution of 25% of granite crushed to silty sand, an improvement in the CBR index from 58.4% to 63.65% and a density from 2.02 to 2.03 g/cm ³ are observed. The value of the CBR index is less than 80% for use in the base layer. On the other hand, the density value is greater than 2.03 to be used as a base layer according to the thresholds recommended by the modified CEBTP guide [12,13]. This performance fully meets the requirements of the CEBTP for foundation layers and meets the specifications of Moroccan standards ([32]).

The results of the mixture of 30% crushed granite+70% silty sand of Tohouè are recorded in Table 7.

Analysis of Table 7 shows a deterioration of the material with a drop in CBR to 35.4% despite the increase in density (2.05 g/cm ³). This underperformance is explained by a grain size imbalance where excess coarse grains impair structural homogeneity. This phenomenon, documented by Riverson [33] in Africa and Molenaar [6] in various contexts, makes this mixture unacceptable according to all international standards, whether European, African or Asian.

The results of the mixture of 35% crushed granite+65% silty sand of Tohouè are recorded in Table 8.

From the analysis of Table 8, it appears that the value of the CBR index is 38% and the dry density is 2.07 g/cm3. This drop in the CBR index shows a particle size imbalance where the excess of large grains is detrimental to the homogeneity. On the other hand, the increase in density shows the presence and the quality of the coarse grains in the mixture in a high proportion. These values are unacceptable according to the standards referenced above. The increase in VBS (up to 0.38) suggests a contribution of crushed clay fines, exacerbating water sensitivity problems. These results confirm the conclusions of Winterkorn [34] on the need to respect a continuous particle size curve to optimize compactness.

The results of the mixture of 40% crushed granite+60% silty sand of Tohouè are recorded in Table 9.

From the analysis of Table 9, it appears that the value of the CBR index is 32.40% and the dry density is 2.06 g/cm3. This drop in the CBR index and the dry density show a particle size imbalance where the excess of coarse grains impairs the homogeneity and the quality of the coarse grains in the mixture in high proportion. These values are unacceptable according to the standards referenced above. The increase in VBS (up to 0.44%) suggests a contribution of crushed clay fines, exacerbating water sensitivity problems. These results confirm the conclusions of Winterkorn [34] on the need to respect a continuous particle size curve to optimize compactness.

The results of the mixture of 45% crushed granite+55% silty sand of Tohouè are recorded in Table 10.

From the analysis of Table 10, it appears that the value of the CBR index is 39.40% and the dry density is 2.07 g/cm3. This drop in the CBR index and the dry density show a particle size imbalance where the excess of coarse ngrains impairs the homogeneity and the quality of the coarse grains in the mixture in high proportion. These values are unacceptable according to the standards referenced above. The increase in VBS (up to 0.47%)

suggests a contribution of crushed clay fines, exacerbating water sensitivity problems. These results confirm the conclusions of Winterkorn [34] on the need to respect a continuous particle size curve to optimize compactness.

Table 3. Geotechnical Characteristics of the Mixture 10% Crushed+ 90% Silty Sand

N °	Granulometric analysis			Measuring methylene blue values	Organic matter	Optimum Modified Proctor		CBR load-bearing indices	
	Dmax (mm)	2mm (%)	0,08mm (%)			W_{OPM} (%)	γ_{OPM} (g/cm3)	95% OPM	100% OPM
Sample 1	31,5	90	13	0,331	0,35	5,8	1,95	58	76
Sample 2	31,5	88	13	0,328	0,35	5,8	1,93	55	72
Mean	31,5	89	13	0,330	0,350	5,8	1,94	56,5	74
Standard deviation	0	1	0	0,00	0,00	0,00	0,01	1,50	2,00

Table 4. Geotechnical characteristics of the mixture 15% Crushed + 85% Silty Sand

N °	Granulometric analysis			Measuring methylene blue values	Organic matter	Optimum Modified Proctor		CBR load-bearing indices	
	Dmax (mm)	2mm (%)	0,08mm (%)			W_{OPM} (%)	γ_{OPM} (g/cm^3)	95% OPM	100% OPM
Sample 1	31,5	90	13	0,331	0,34	7,8	1,95	54,6	75,6
Sample 2	31,5	88	12	0,332	0,36	7,9	1,96	56,8	74,7
Mean	31,5	89	12,5	0,332	0,350	7,85	1,955	55,7	75,15
Standard deviation	0,00	1,00	1,00	0,00	0,02	0,05	0,01	1,10	0,45

Table 5. Geotechnical characteristics of the mixture 20% Crushed + 80% Silty Sand of Tohouè

N °	Granulometric analysis			Measuring methylene blue values	Organic matter	Optimum Modified Proctor		CBR load-bearing indices	
	Dmax (mm)	2mm (%)	0,08mm (%)			W_{OPM} (%)	γ_{OPM} (g/cm^3)	95% OPM	100% OPM
Sample 1	31,5	88	13,5	0,33	0,31	7,5	1,98	57,6	66,6
Sample 2	31,5	86	11,5	0,32	0,32	7,9	2,05	59,2	70,5
Mean	31,50	87,00	12,50	0,33	0,32	7,70	2,02	58,40	68,55
Standard deviation	0,00	1,41	1,41	0,01	0,01	0,28	0,05	1,13	2,76

Table 6. Geotechnical characteristics of the mixture 25% Crushed granite + 75% Silty sand of Tohouè

N °	Granulometric analysis			Measuring methylene blue values	Organic matter	Optimum Modified Proctor		CBR load-bearing indices	
	Dmax (mm)	2mm (%)	0,08mm (%)			W_{OPM} (%)	γ_{OPM} (g/cm3)	95% OPM	100% OPM
Sample 1	31,5	89	13,5	0,372	0,32	7,5	2,03	64,8	85,8
Sample 2	31,5	87	11,5	0,364	0,27	7,8	2,02	62,5	81,6
Mean	31,50	88,00	12,50	0,37	0,30	7,65	2,03	63,65	83,70
Standard deviation	0,00	1,41	1,41	0,01	0,04	0,21	0,01	1,63	2,97

Table 7. Geotechnical characteristics of the mixture 30% Granitic crushed + 70% Silty sand of Tohouè

N °	Granulometric analysis			Measuring methylene blue values	Organic matter	Optimum Modified Proctor		CBR load-bearing indices	
	Dmax (mm)	2mm (%)	0,08mm (%)			W_{OPM} (%)	γ_{OPM} (g/cm3)	95% OPM	100% OPM
Sample 1	31,5	87	14	0,34	0,29	7,7	2,03	34,4	66,5
Sample 2	31,5	85	11,8	0,28	0,27	7,5	2,07	36,4	70,65
Mean	31,50	86,00	12,90	0,31	0,28	7,60	2,05	35,40	68,58
Standard deviation	0,00	1,41	1,56	0,04	0,01	0,14	0,03	1,41	2,93

Table 8. Geotechnical characteristics of the mixture 35% Granitic crushed + 65% Silty sand of Tohouè

N °	Granulometric analysis			Measuring methylene blue values	Organic matter	Optimum Modified Proctor		CBR load-bearing indices	
	Dmax (mm)	2mm (%)	0,08mm (%)			W_{OPM} (%)	γ_{OPM} (g/cm3)	95% OPM	100% OPM
Sample 1	31,5	86	16,55	0,41	0,28	7,2	2,03	37	63,56
Sample 2	31,5	88	13,5	0,35	0,25	6,8	2,1	39	75,25
Mean	31,50	87,00	15,03	0,38	0,27	7,00	2,07	38,00	69,41
Standard deviation	0,00	1,41	2,16	0,04	0,02	0,28	0,05	1,41	8,27

Table 9. Geotechnical characteristics of the mixture 40% Granitic crushed + 60% Silty sand of Tohouè

N°	Granulometric analysis			Measuring methylene blue values	Organic matter	Optimum Modified Proctor		CBR load-bearing indices	
	Dmax (mm)	2mm (%)	0,08mm (%)			W_{OPM} (%)	Y_{OPM} (g/cm3)	95% OPM	100% OPM
Sample 1	31,5	77	13	0,46	0,24	5,8	2,05	30,6	50,5
Sample 2	31,5	79	12	0,41	0,26	5,5	2,07	34,2	62,56
Mean	31,50	78,00	12,50	0,44	0,25	5,65	2,06	32,40	56,53
Standard deviation	0,00	1,41	0,71	0,04	0,01	0,21	0,01	2,55	8,53

Table 10. Geotechnical characteristics of the mixture 45% Granitic crushed + 55% Silty sand of Tohouè

N°	Granulometric analysis			Measuring methylene blue values	Organic matter	Optimum Modified Proctor		CBR load-bearing indices	
	Dmax (mm)	2mm (%)	0,08mm (%)			W_{OPM} (%)	Y_{OPM} (g/cm3)	95% OPM	100% OPM
Sample 1	31,5	83	14	0,47	0,23	6,5	2,08	40,4	68,5
Sample 2	31,5	80	12	0,46	0,25	7,5	2,06	38,4	59,6
Mean	31,50	81,50	13,00	0,47	0,24	7,00	2,07	39,40	64,05
Standard deviation	0,00	2,12	1,41	0,01	0,01	0,71	0,01	1,41	6,29

Discussion

Analysis of the various data shows that mixtures of 20 to 25% crushed, comply with the standards [12,13,24]. These formulations allow a saving of 75 to 80% on the purchase of noble materials while guaranteeing satisfactory mechanical performance for the foundation layers. The results are consistent with similar work and offer a sustainable solution for road construction in developing countries. Thus, this formulation represents the best technical-economic compromise for the valorization of local materials.

Conclusion

This study shows that the silty sand of Tohouè, although unsuitable for the raw state, can be efficiently valorized in road construction thanks to a granular stabilization. The addition of 25% Dan 0/31.5 granitic crushed is the optimal formulation, achieving a CBR index of 63.65% and a dry density of 1.995 g/cm³, in accordance with the requirements of the standards in force for foundation layers. Beyond this percentage, the mechanical performance deteriorates due to a particle size imbalance. This solution offers an economical and sustainable alternative, reducing dependence on imported materials and promoting the use of local resources in Benin.

Conflicts of Interest

"The authors declare no conflicts of interest."

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