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Stabilization of Sub-Grade Material Using Quarry Dust

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Abstract

For pavements and other constructions to be stable and long-lasting, subgrade soil stabilization is essential in civil engineering. The application of quarry dust as an economical and environmentally friendly way to improve the qualities of sub-grade materials is the main topic of this study. It has been demonstrated that using quarry dust, which is a byproduct of the crushing process in quarries, as a stabilizing agent increases the strength and load-bearing capacity of soil. It has been noted that adding quarry dust to sub-grade soil improves compaction, lowers plasticity, and raises the California Bearing Ratio (CBR), all of which improve performance and workability under load construction. In this study, a sub-grade soil were collected for testing test. Compaction, CBR, and Atterberg limits test were among the laboratory studies used to evaluate how quarry dust affected the characteristics of the sub grade soil. The findings suggested quarry dust as a potential stabilizer for road building and other infrastructure projects since they showed a high degree of improvements in strength properties and decreased susceptibility to water. This technique offers a low-cost way to improve soil strength and lessen the environmental impact of conventional stabilizers, in addition making quarry dust waste a sustainable purpose.

Keyword: Compaction, Stabilization, Sub grade, Quarry dust, Liquid limit, California bearing ratio, Plasticity, Grading, Load bearing capacity, Improvement, Testing, Durability , Construction

Introduction

In order to guarantee a solid and long-lasting foundation, sub-grade material stabilization is vital for road and building projects (Prabhakar, 2020). The soil layer beneath the pavement layers, known as the sub-grade, gives the layers on top structural support (Emeka, 2018). Stabilization is often needed for sub-grade soils which are generally weak, such as clay soils, in order to increase its engineering property, decrease compressibility, and increase load-bearing capacity (Nweke, 2017). While there are many different stabilization methods, quarry dust has been the subject of more recent study and use (Etim, 2021). An eco-friendly and cost-effective substitute for conventional stabilizing materials like cement or lime is quarry dust, which is a by-product of the crushing process (Amadi, 2018). Particles of rock make up the majority of this fine aggregate, which has characteristics comparable to those of natural sand and a stable, interlocking particle structure (Indiramma, 2017). Quarry dust can improve particle dispersion, fill up cavities, and boost the soil's carrying capacity and shear strength when combined with sub-grade soil (Arun, 2014). Quarry dust also improves stability by increasing particle friction due to its rough and angular texture (Onyelowe, 2018). By reusing quarry dust, minimizing waste disposal problems, and lessening the environmental impact, this stabilizing technique not only enhances the sub-grade soil's technical qualities but also supports sustainable building methods in this present generation (Manjuladevi, 2021).

Statement of the problem

The purpose of this study is to use quarry dust as a stabilizing agent to increase the performance and stability of road infrastructure. A cheap and possibly useful alternative is quarry dust, a byproduct of crushing stones. Its efficacy in enhancing geotechnical characteristics and ideal mixing ratios is unclear. The goal of the study is to create a stabilization technique that is both economical and sustainable using quarry dust.

Objectives of the Study

i. Assess the Effectiveness of Quarry Dust: To ascertain whether quarry dust can stabilize sub-grade soils and how it can enhance soil characteristics such as compressibility, shear strength, and bearing capacity.

ii. Evaluate sub grade Soil-Quarry Dust Mix Ratios: Using mechanical characteristics like CBR (California Bearing Ratio)

iii. Analyze the Durability and Environmental Impact: To determine how long stabilized subgrade soil lasts under different environmental conditions or circumstances and assess the advantages of employing quarry dust for the environment, such as waste reduction and possible pollution control.

Methodology

Stabilizing of sub-grade material with quarry dust is a common method to enhance the load-bearing capacity and durability of weak sub grade soil layers, often used in road construction, building foundations, and other civil engineering projects. Here's a methodology to guide this process:

Sample collection and Preparation

The following samples were collected in Lafia Nasarawa state and allow to dry under sun for about two to three days.

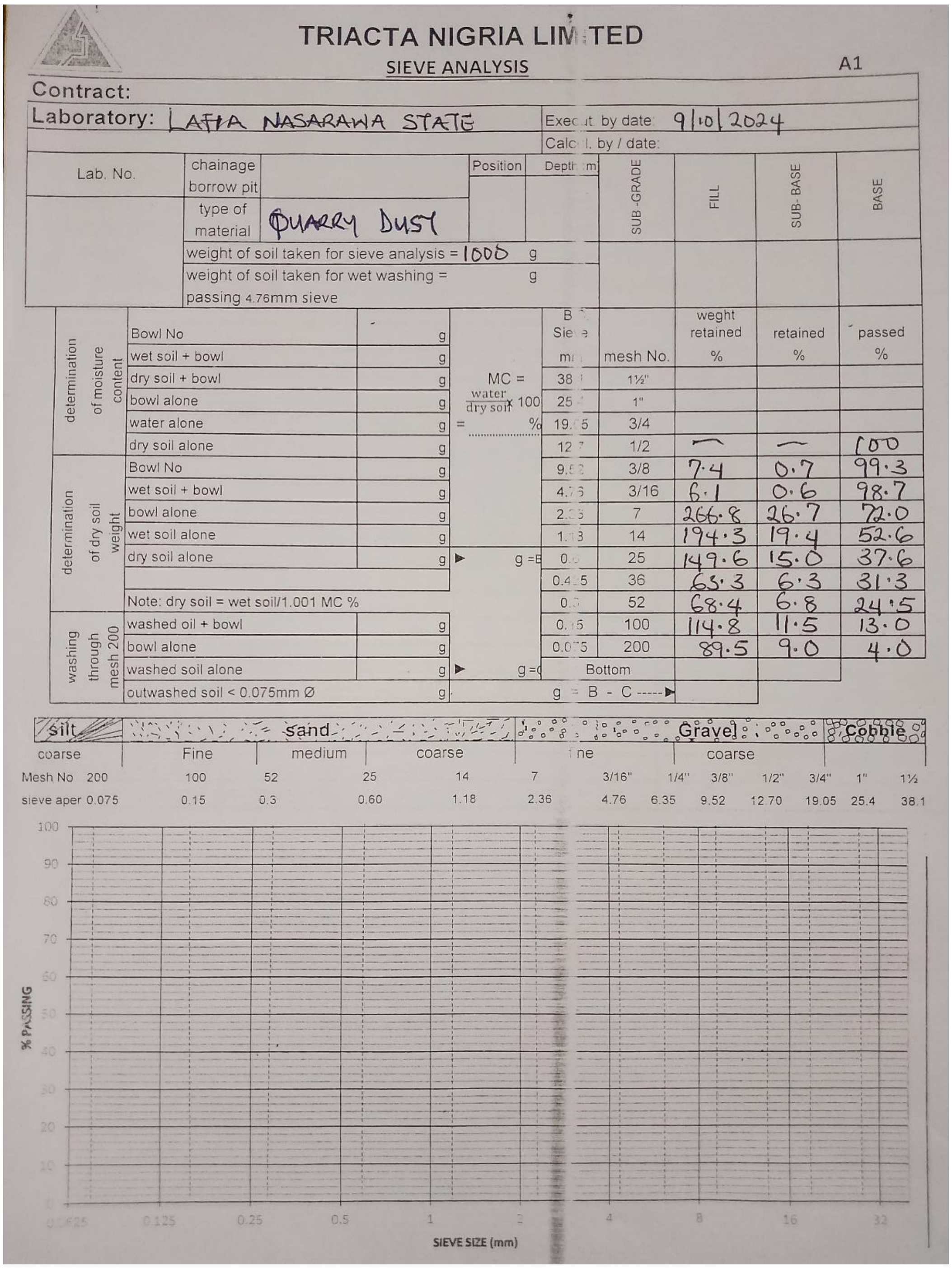
Quarry Dust: Quarry dust which is a by-product of crushed stone with particles ranging from fine to middle sand

Sub-grade Soil: The sub-grade materials were collected at NTA borrow pit for laboratory testing.

Laboratory testing for sub grade soil and quarry dust

Since my interest is to use quarry dust to stabilized sub grade material the following laboratory test were carried out on each of the material before mixing it together

Gradation Analysis: In order to check the particle size distribution of quarry dust and that of sub-grade material before mixing it together. Figure 1a and 1b below shows the grading of quarry dust and sub grade soil



TRIACTA NIGRIA LIM TED

SIEVE ANALYSIS

A1

Contract:

Laboratory: LAFIA NASARAWA STATE | Exec ut. by date: 9|10|2024

Calc l. by / date:

Lab. No. | chainage borrow pit | Position | Depth m

type of material: QUARRY DUST

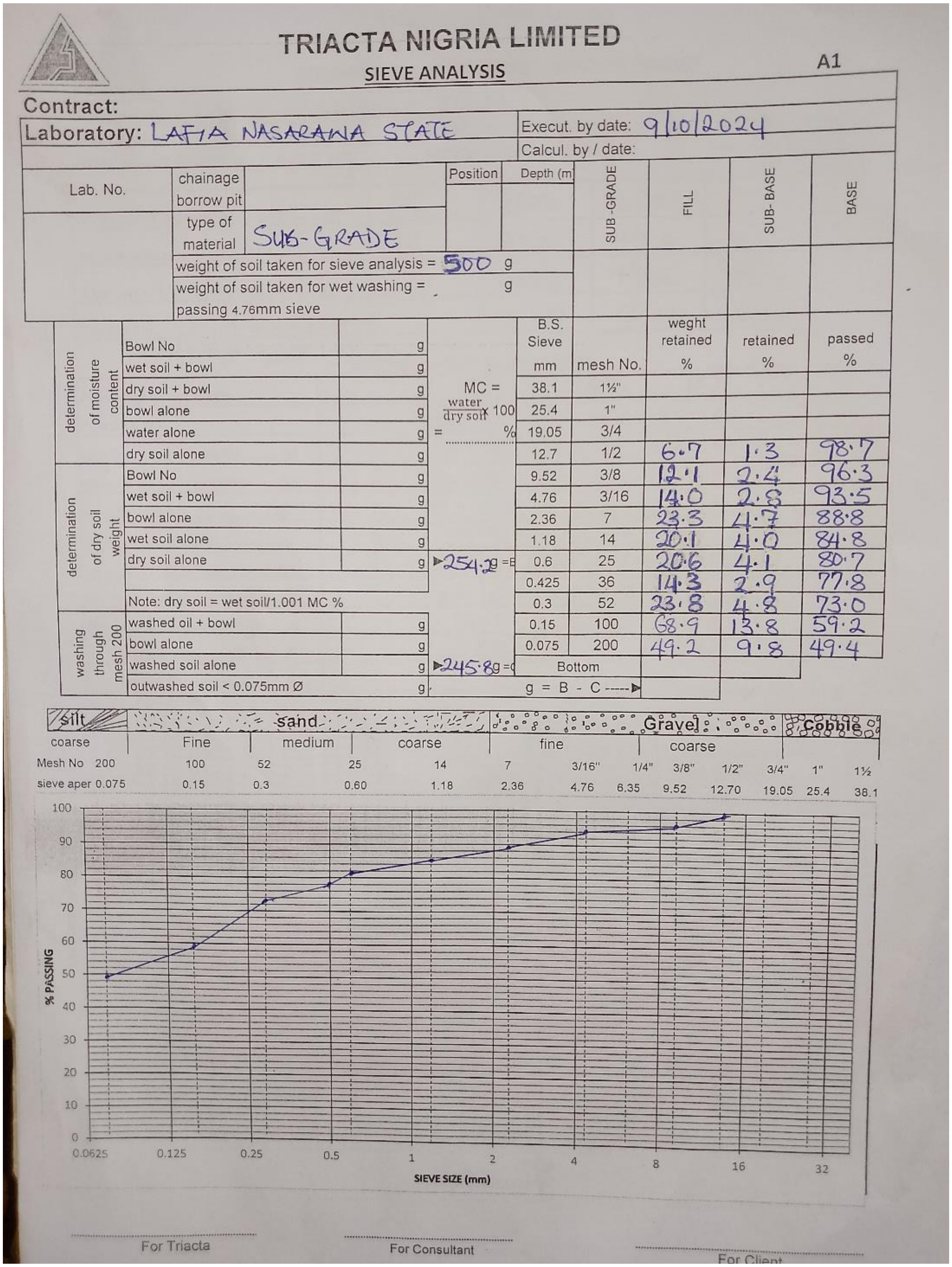
weight of soil taken for sieve analysis = 1000 g

weight of soil taken for wet washing = g

passing 4.76mm sieve

Sieve mm	mesh No.	weght retained %	retained %	passed %
38	1½"			
25	1"			
19.5	3/4			
12	1/2	–	–	100
9.5	3/8	7.4	0.7	99.3
4.7	3/16	6.1	0.6	98.7
2.	7	266.8	26.7	72.0
1.3	14	194.3	19.4	52.6
0.	25	149.6	15.0	37.6
0.4 5	36	63.3	6.3	31.3
0.	52	68.4	6.8	24.5
0. 5	100	114.8	11.5	13.0
0.0 5	200	89.5	9.0	4.0
Bottom				

Figure 1a: Result for Quarry dust



TRIACTA NIGRIA LIMITED

SIEVE ANALYSIS

A1

Contract:

Laboratory: LAFIA NASARAWA STATE

Execut. by date: 9/10/2024

Calcul. by / date:

Lab. No. | chainage | borrow pit | Position | Depth (m) | SUB-GRADE | FILL | SUB-BASE | BASE

type of material: SUB-GRADE

weight of soil taken for sieve analysis = 500 g

weight of soil taken for wet washing = g

passing 4.76mm sieve

B.S. Sieve mm	mesh No.	weght retained %	retained %	passed %
38.1	1½"			
25.4	1"			
19.05	3/4			
12.7	1/2	6.7	1.3	98.7
9.52	3/8	12.1	2.4	96.3
4.76	3/16	14.0	2.8	93.5
2.36	7	23.3	4.7	88.8
1.18	14	20.1	4.0	84.8
0.6	25	20.6	4.1	80.7
0.425	36	14.3	2.9	77.8
0.3	52	23.8	4.8	73.0
0.15	100	68.9	13.8	59.2
0.075	200	49.2	9.8	49.4
Bottom				

determination of moisture content: Bowl No g; wet soil + bowl g; dry soil + bowl g; bowl alone g; water alone g; dry soil alone g

$MC = \frac{water}{dry\ soil} \times 100 = \%$

determination of dry soil weight: Bowl No g; wet soil + bowl g; bowl alone g; wet soil alone g; dry soil alone g ▶254.2g =

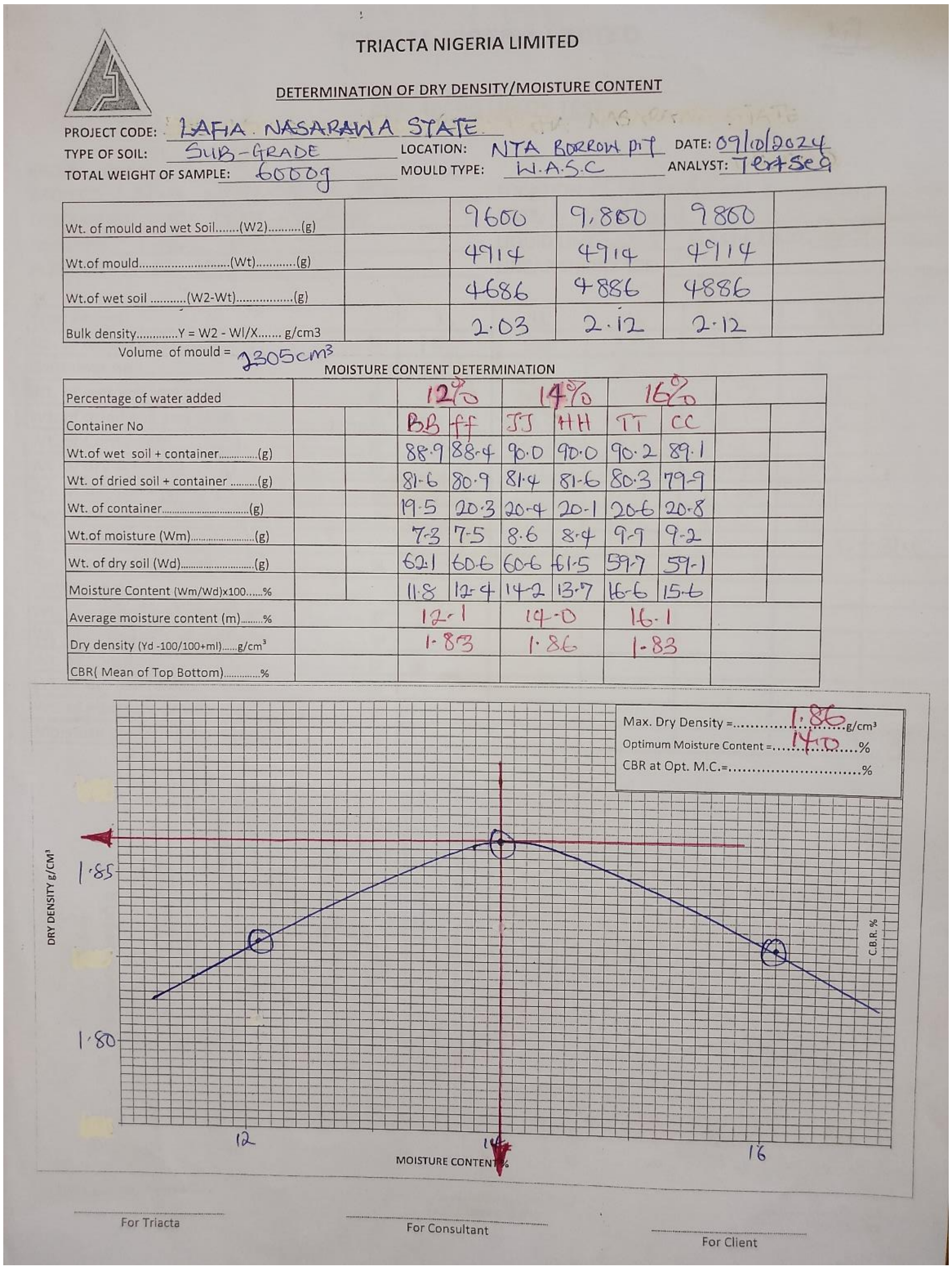
Note: dry soil = wet soil/1.001 MC %

washing through mesh 200: washed oil + bowl g; bowl alone g; washed soil alone g ▶245.8g =; outwashed soil < 0.075mm Ø g

g = B - C ----▶

Figure 1b: Result of Sub-grade material

Compaction tests: A compaction test was carried out on the sub-grade soil and the following result was obtained as showed in figure 2 below



TRIACTA NIGERIA LIMITED

DETERMINATION OF DRY DENSITY/MOISTURE CONTENT

PROJECT CODE: LAFIA NASARAWA STATE
TYPE OF SOIL: SUB-GRADE LOCATION: NTA BORROW PIT DATE: 09/10/2024
TOTAL WEIGHT OF SAMPLE: 6000g MOULD TYPE: W.A.S.C ANALYST: Tertseg

Wt. of mould and wet Soil.......(W2)..........(g)		9600	9,880	9880	
Wt.of mould...........................(Wt)............(g)		4914	4914	4914	
Wt.of wet soil ....(W2-Wt).................(g)		4686	4886	4886	
Bulk density.............Y = W2 - Wl/X....... g/cm3		2.03	2.12	2.12	

Volume of mould = 2305cm³

MOISTURE CONTENT DETERMINATION

Percentage of water added			12%		14%		16%			
Container No			BB	ff	JJ	HH	TT	CC		
Wt.of wet soil + container..............(g)			88.9	88.4	90.0	90.0	90.2	89.1		
Wt. of dried soil + container ....(g)			81.6	80.9	81.4	81.6	80.3	79.9		
Wt. of container...............................(g)			19.5	20.3	20.4	20.1	20.6	20.8		
Wt.of moisture (Wm)......................(g)			7.3	7.5	8.6	8.4	9.9	9.2		
Wt. of dry soil (Wd).........................(g)			62.1	60.6	60.6	61.5	59.7	59.1		
Moisture Content (Wm/Wd)x100......%			11.8	12.4	14.2	13.7	16.6	15.6		
Average moisture content (m).......%			12.1		14.0		16.1			
Dry density (Yd -100/100+ml)......g/cm³			1.83		1.86		1.83			
CBR(Mean of Top Bottom).............%										

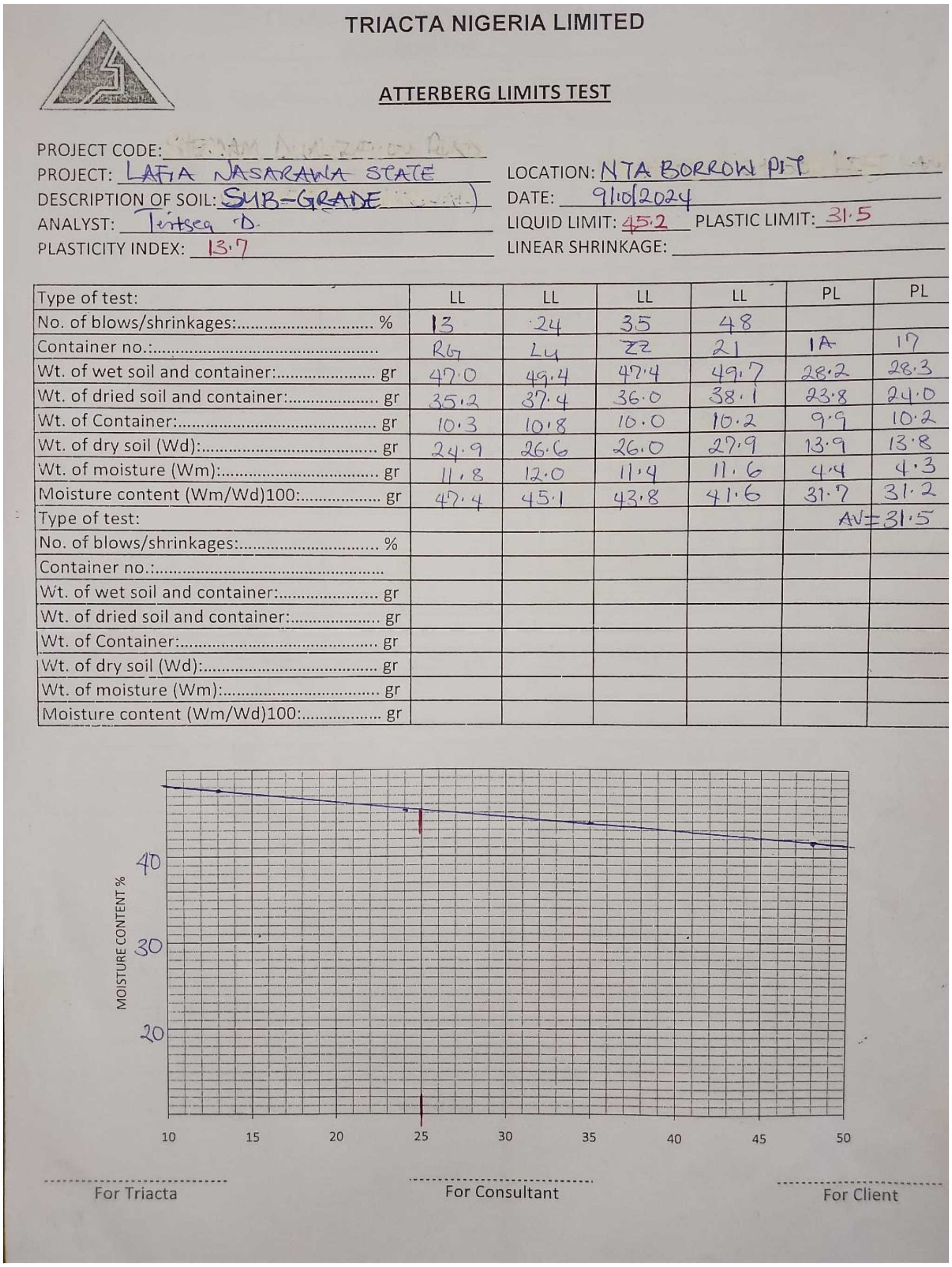
For Triacta

For Consultant

For Client

Figure 2: Compaction test for Sub-grade soil

Atterberg Limits: An Atterberg limit test (plastic and liquid limits) was carried out on the sub-grade soil and the following results were obtained as showed in figure 3



TRIACTA NIGERIA LIMITED

ATTERBERG LIMITS TEST

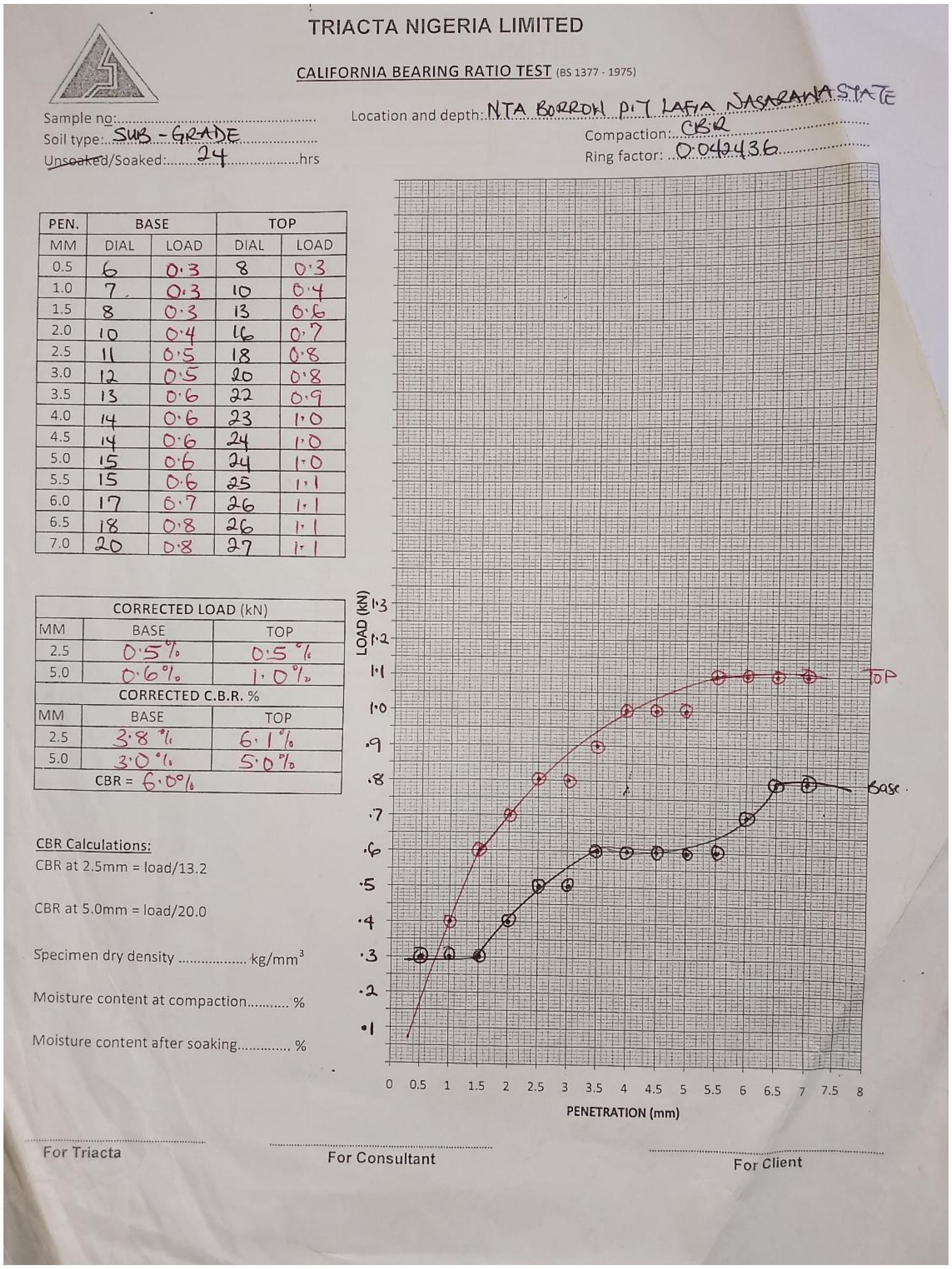
PROJECT CODE:
PROJECT: LAFIA NASARAWA STATE
LOCATION: NTA BORROW PIT
DESCRIPTION OF SOIL: SUB-GRADE
DATE: 9/10/2024
ANALYST: Tertsea D.
LIQUID LIMIT: 45.2
PLASTIC LIMIT: 31.5
PLASTICITY INDEX: 13.7
LINEAR SHRINKAGE:

Type of test:	LL	LL	LL	LL	PL	PL
No. of blows/shrinkages:............................. %	13	24	35	48		
Container no.:...	R6	L4	ZZ	21	1A	17
Wt. of wet soil and container:...................... gr	47.0	49.4	47.4	49.7	28.2	28.3
Wt. of dried soil and container:.................... gr	35.2	37.4	36.0	38.1	23.8	24.0
Wt. of Container:... gr	10.3	10.8	10.0	10.2	9.9	10.2
Wt. of dry soil (Wd):...................................... gr	24.9	26.6	26.0	27.9	13.9	13.8
Wt. of moisture (Wm):.................................. gr	11.8	12.0	11.4	11.6	4.4	4.3
Moisture content (Wm/Wd)100:.................. gr	47.4	45.1	43.8	41.6	31.7	31.2
Type of test:					AV= 31.5	
No. of blows/shrinkages:............................. %						
Container no.:...						
Wt. of wet soil and container:...................... gr						
Wt. of dried soil and container:.................... gr						
Wt. of Container:... gr						
Wt. of dry soil (Wd):...................................... gr						
Wt. of moisture (Wm):.................................. gr						
Moisture content (Wm/Wd)100:.................. gr						

For Triacta
For Consultant
For Client

Figure 3: Atterberg limit test for Sub-grade soil

California Bearing Ratio (CBR) Test: A CBR test was performed to determine the load-bearing capacity of the sub-grade soil and the following results were obtained as showed in figure 4 below



TRIACTA NIGERIA LIMITED

CALIFORNIA BEARING RATIO TEST (BS 1377 - 1975)

Sample no:......

Soil type: SUB - GRADE

~~Unsoaked~~/Soaked: 24 hrs

Location and depth: NTA BORROW PIT LAFIA NASARAWA STATE

Compaction: CBR

Ring factor: 0.042436

PEN.	BASE		TOP	
MM	DIAL	LOAD	DIAL	LOAD
0.5	6	0.3	8	0.3
1.0	7	0.3	10	0.4
1.5	8	0.3	13	0.6
2.0	10	0.4	16	0.7
2.5	11	0.5	18	0.8
3.0	12	0.5	20	0.8
3.5	13	0.6	22	0.9
4.0	14	0.6	23	1.0
4.5	14	0.6	24	1.0
5.0	15	0.6	24	1.0
5.5	15	0.6	25	1.1
6.0	17	0.7	26	1.1
6.5	18	0.8	26	1.1
7.0	20	0.8	27	1.1

CORRECTED LOAD (kN)		
MM	BASE	TOP
2.5	0.5%	0.5%
5.0	0.6%	1.0%
CORRECTED C.B.R. %		
MM	BASE	TOP
2.5	3.8%	6.1%
5.0	3.0%	5.0%
CBR = 6.0%		

CBR Calculations:

CBR at 2.5mm = load/13.2

CBR at 5.0mm = load/20.0

Specimen dry density .... kg/mm³

Moisture content at compaction.......... %

Moisture content after soaking............. %

For Triacta

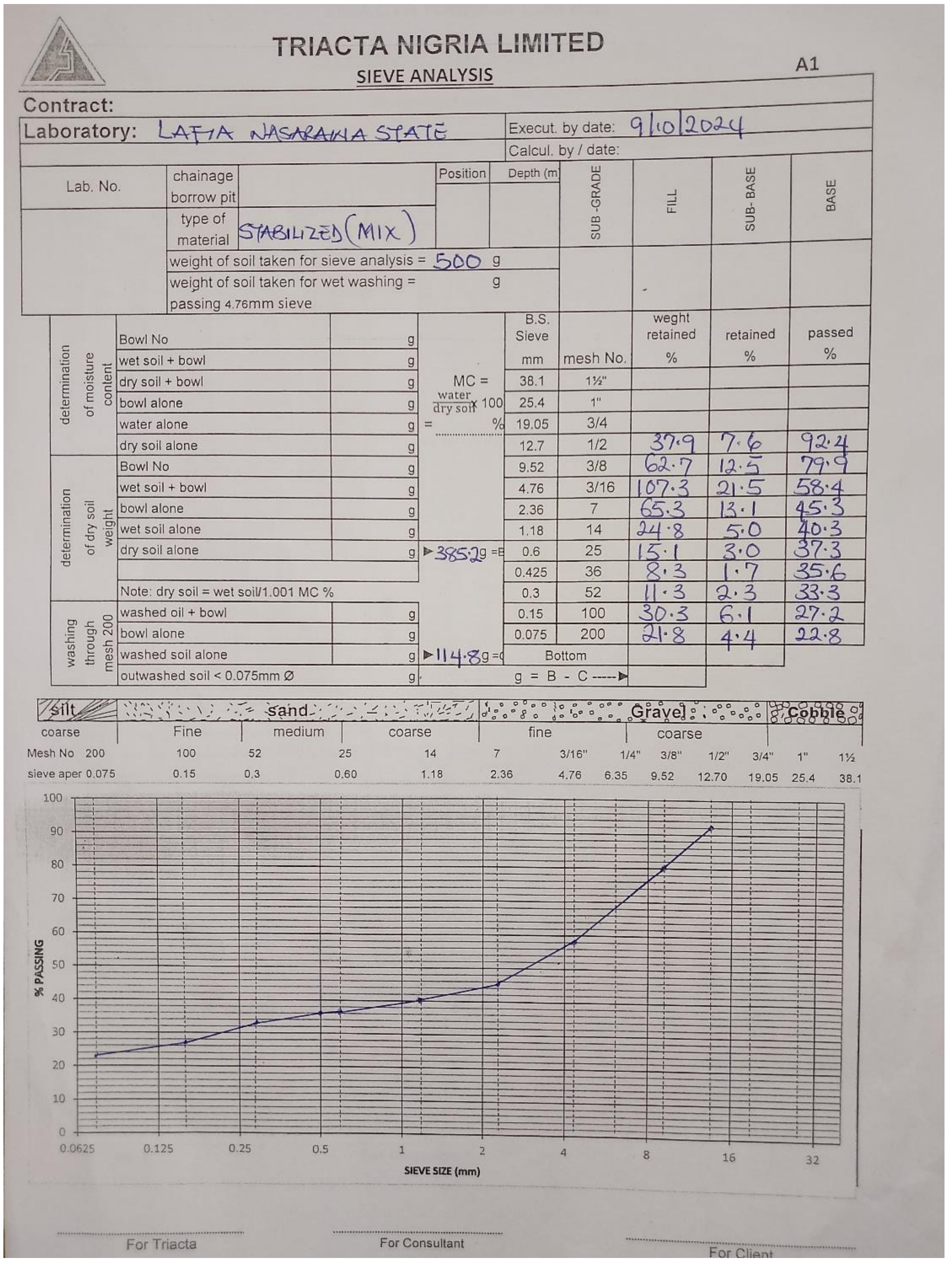
For Consultant

For Client

Figure 4: CBR test for Sub-grade soil

After the quarry dust was mixed with the sub grade material the same test is repeated to check if there are changes to the result and the following result was obtained.

Gradation Analysis: A mixed sample (sub-grade and quarry dust) were subjected to a grading to check the particle size distribution of quarry dust and that of sub grade soil .and the following result was obtained as showed in figure 5



TRIACTA NIGRIA LIMITED

SIEVE ANALYSIS

A1

Contract:

Laboratory: LAFIA NASARAWA STATE

Execut. by date: 9/10/2024

Calcul. by / date:

Lab. No. | chainage borrow pit | Position | Depth (m) | SUB-GRADE | FILL | SUB-BASE | BASE

type of material: STABILIZED (MIX)

weight of soil taken for sieve analysis = 500 g

weight of soil taken for wet washing = g

passing 4.76mm sieve

determination of moisture content: Bowl No g; wet soil + bowl g; dry soil + bowl g; bowl alone g; water alone g; dry soil alone g

MC = water/dry soil x 100 = %

determination of dry soil weight: Bowl No g; wet soil + bowl g; bowl alone g; wet soil alone g; dry soil alone g ▶ 385.2 g =B

Note: dry soil = wet soil/1.001 MC %

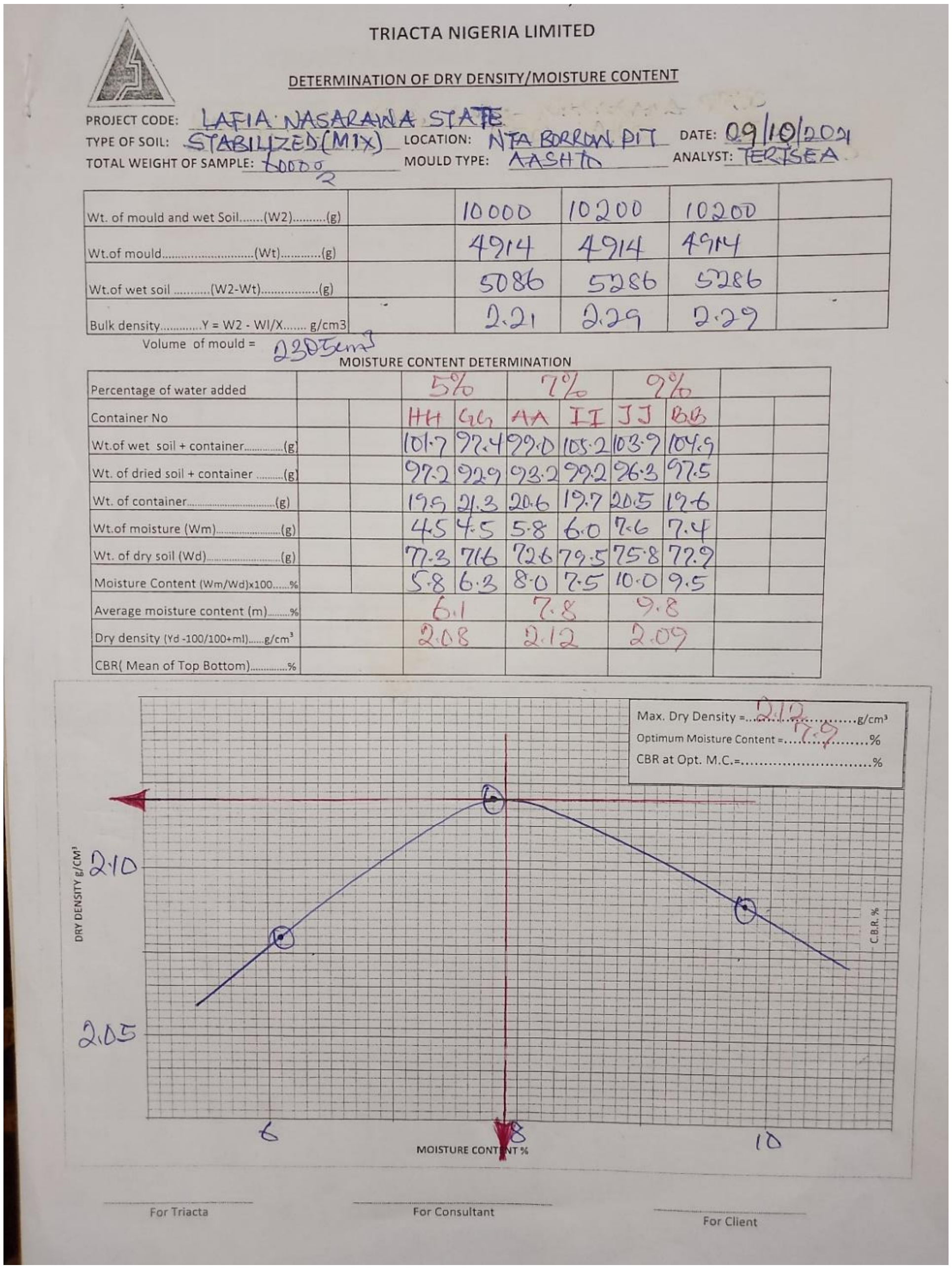
washing through mesh 200: washed oil + bowl g; bowl alone g; washed soil alone g ▶ 114.8 g =C; outwashed soil < 0.075mm Ø g = B - C

B.S. Sieve mm	mesh No.	weght retained %	retained %	passed %
38.1	1½"			
25.4	1"			
19.05	3/4			
12.7	1/2	37.9	7.6	92.4
9.52	3/8	62.7	12.5	79.9
4.76	3/16	107.3	21.5	58.4
2.36	7	65.3	13.1	45.3
1.18	14	24.8	5.0	40.3
0.6	25	15.1	3.0	37.3
0.425	36	8.3	1.7	35.6
0.3	52	11.3	2.3	33.3
0.15	100	30.3	6.1	27.2
0.075	200	21.8	4.4	22.8
Bottom				

Figure 5: Grading for mixed material

The above result shows an in improvement into the property of the material as interpreted in the result above

Compaction tests: A compaction test was carried out on the mixed material (sub-grade and quarry dust) to determine the optimal moisture content and maximum dry density of the material and the result obtained is showed in figure 6



TRIACTA NIGERIA LIMITED

DETERMINATION OF DRY DENSITY/MOISTURE CONTENT

PROJECT CODE: LAFIA NASARAWA STATE
TYPE OF SOIL: STABILIZED (MIX) LOCATION: NTA BORROW PIT DATE: 09/10/2021
TOTAL WEIGHT OF SAMPLE: 6000 MOULD TYPE: AASHTO ANALYST: TERISEA

Wt. of mould and wet Soil.......(W2)..........(g)		10000	10200	10200	
Wt.of mould...........................(Wt)............(g)		4914	4914	4914	
Wt.of wet soil ....(W2-Wt).................(g)		5086	5286	5286	
Bulk density.............Y = W2 - WI/X....... g/cm3		2.21	2.29	2.29	

Volume of mould = 2305cm³

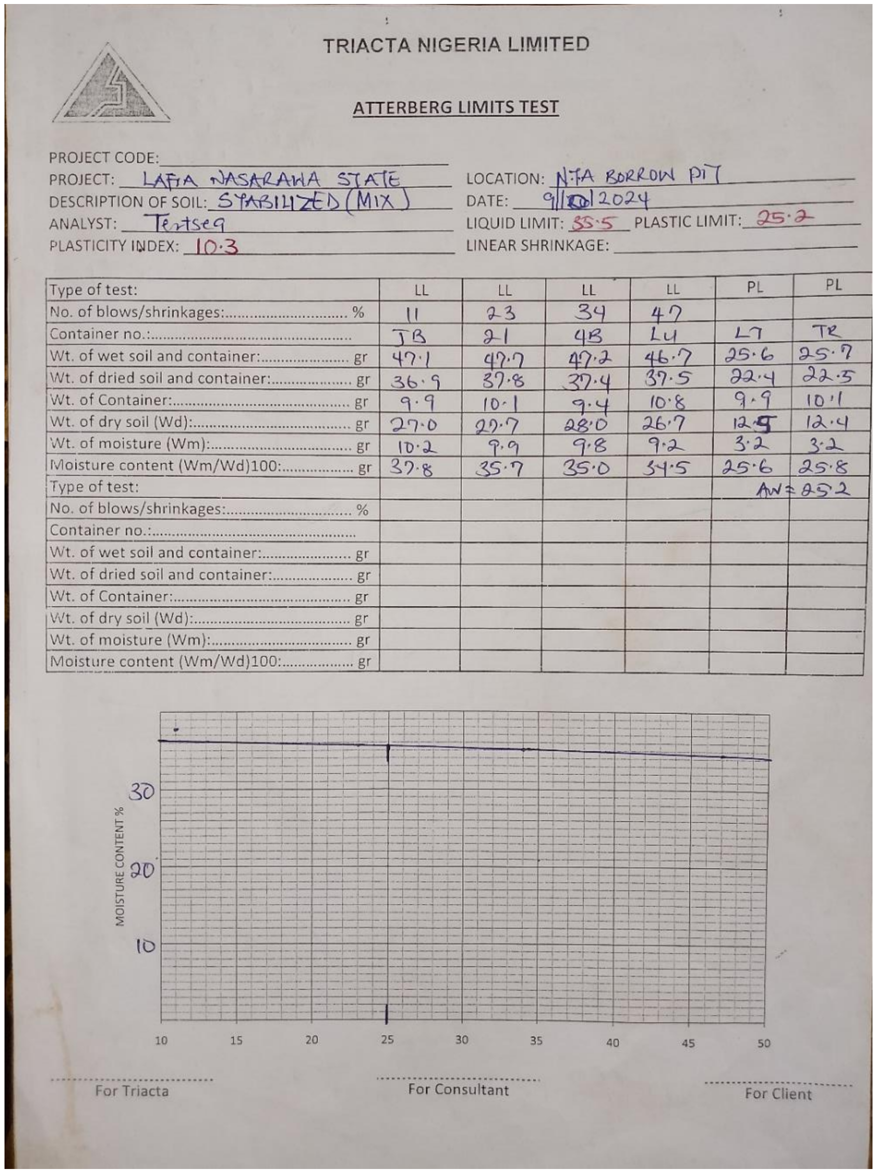
MOISTURE CONTENT DETERMINATION

Percentage of water added	5%		7%		9%	
Container No	HH	GG	AA	II	JJ	BB
Wt.of wet soil + container.............(g)	101.7	97.4	99.0	105.2	103.9	104.9
Wt. of dried soil + container ....(g)	97.2	92.9	93.2	99.2	96.3	97.5
Wt. of container...............................(g)	19.9	21.3	20.6	19.7	20.5	19.6
Wt.of moisture (Wm).......................(g)	4.5	4.5	5.8	6.0	7.6	7.4
Wt. of dry soil (Wd)..........................(g)	77.3	71.6	72.6	79.5	75.8	77.9
Moisture Content (Wm/Wd)x100......%	5.8	6.3	8.0	7.5	10.0	9.5
Average moisture content (m).........%	6.1		7.8		9.8	
Dry density (Yd -100/100+ml)......g/cm³	2.08		2.12		2.09	
CBR(Mean of Top Bottom).............%						

Figure 6: Compaction test for mixed material

A progressive result is obtained as the material is compacted, showing a reduce optimum moisture content and an increase in the maximum dry density of the material

Atterberg Limits: After proper mixing of sub-grade and quarry dust, Atterberg limit (plastic and liquid limits) was carried out on the soil mixtures to assess the plasticity and workability.an improvements was observe due to the addition of quarry dust, and the following result was obtained as showed in figure 7



TRIACTA NIGERIA LIMITED

ATTERBERG LIMITS TEST

PROJECT CODE:

PROJECT: LAFIA NASARAWA STATE

LOCATION: NTA BORROW PIT

DESCRIPTION OF SOIL: STABILIZED (MIX)

DATE: 9/[illegible]/2024

ANALYST: Tertseg

LIQUID LIMIT: 35.5 PLASTIC LIMIT: 25.2

PLASTICITY INDEX: 10.3

LINEAR SHRINKAGE:

Type of test:	LL	LL	LL	LL	PL	PL
No. of blows/shrinkages:.............................. %	11	23	34	47		
Container no.:..	JB	21	4B	L4	L7	TR
Wt. of wet soil and container:...................... gr	47.1	47.7	47.2	46.7	25.6	25.7
Wt. of dried soil and container:.................... gr	36.9	37.8	37.4	37.5	22.4	22.5
Wt. of Container:... gr	9.9	10.1	9.4	10.8	9.9	10.1
Wt. of dry soil (Wd):..................................... gr	27.0	27.7	28.0	26.7	12.5	12.4
Wt. of moisture (Wm):.................................. gr	10.2	9.9	9.8	9.2	3.2	3.2
Moisture content (Wm/Wd)100:................. gr	37.8	35.7	35.0	34.5	25.6	25.8
Type of test:						AW = 25.2
No. of blows/shrinkages:.............................. %						
Container no.:..						
Wt. of wet soil and container:...................... gr						
Wt. of dried soil and container:.................... gr						
Wt. of Container:... gr						
Wt. of dry soil (Wd):..................................... gr						
Wt. of moisture (Wm):.................................. gr						
Moisture content (Wm/Wd)100:................. gr						

For Triacta

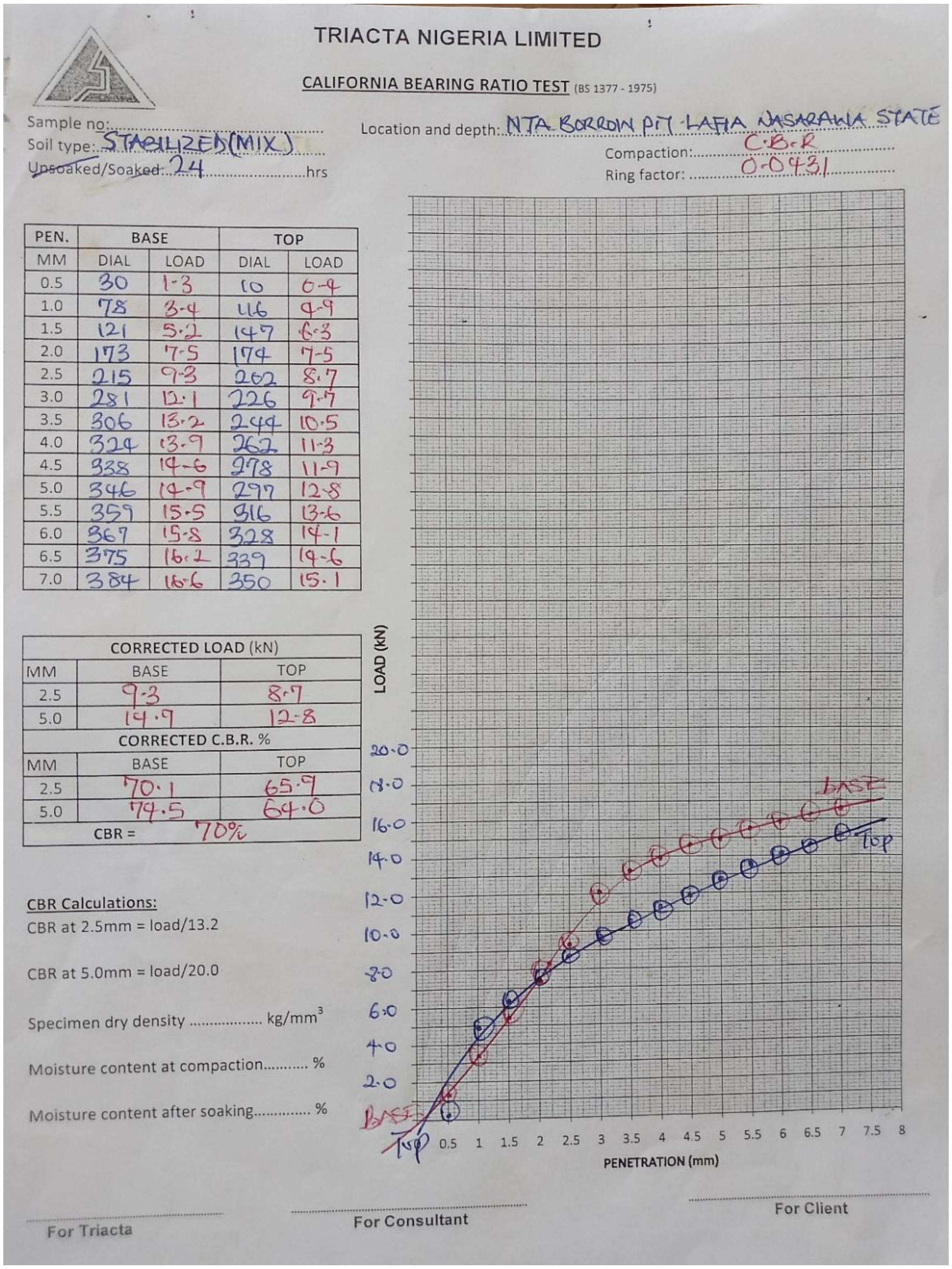
For Consultant

For Client

Figure 7: Atterberg limit test for mixed material

The above data show a reduced liquid limit and plasticity index of the material compare to the value obtain in fig 3 above

California Bearing Ratio (CBR) Test: A CBR test to determine the load-bearing capacity of the mixed material (sub-grade and quarry dust) was performed and the following result was obtained as showed in figure 8



TRIACTA NIGERIA LIMITED

CALIFORNIA BEARING RATIO TEST (BS 1377 - 1975)

Sample no:

Soil type: STABILIZED(MIX)

~~Unsoaked~~/Soaked: 24 hrs

Location and depth: NTA BORROW PIT LAFIA NASARAWA STATE

Compaction: C.B.R

Ring factor: 0.0431

PEN.	BASE		TOP	
MM	DIAL	LOAD	DIAL	LOAD
0.5	30	1.3	10	0.4
1.0	78	3.4	116	4.9
1.5	121	5.2	147	6.3
2.0	173	7.5	174	7.5
2.5	215	9.3	202	8.7
3.0	281	12.1	226	9.7
3.5	306	13.2	244	10.5
4.0	324	13.9	262	11.3
4.5	338	14.6	278	11.9
5.0	346	14.9	297	12.8
5.5	359	15.5	316	13.6
6.0	367	15.8	328	14.1
6.5	375	16.2	339	14.6
7.0	384	16.6	350	15.1

CORRECTED LOAD (kN)		
MM	BASE	TOP
2.5	9.3	8.7
5.0	14.9	12.8
CORRECTED C.B.R. %		
MM	BASE	TOP
2.5	70.1	65.9
5.0	74.5	64.0
CBR =	70%	

CBR Calculations:

CBR at 2.5mm = load/13.2

CBR at 5.0mm = load/20.0

Specimen dry density .... kg/mm^3

Moisture content at compaction........... %

Moisture content after soaking............. %

For Triacta

For Consultant

For Client

Figure 8: CBR test for mixed material

A noticeable improvement in CBR value was observed as quarry dust is mixed to the sub grade material.

Results and Discussion

Using quarry dust to stabilize sub-grade soil is an effective way to improve the load-bearing capacity and durability of soils, especially in areas where naturally occurring materials are inadequate. Here's a comprehensive look at the results and discussion of sub-grade stabilization using quarry dust.

Increased load-bearing capability is indicated by a higher California Bearing Ratio (CBR), which is considerably improved when quarry dust is added to sub-grade materials, according to this studies, depending on the amount of quarry dust injected, the CBR values for clay soils may increase. Decrease in Plasticity Index: Adding quarry dust to subgrade soils frequently lowers their plasticity index, particularly for high-plasticity clays. The coarser quarry dust particles lower the soil's ability to retain water, which results in a decrease in flexibility. Decreased plasticity lessens the possibility of sub-grade layers swelling and shrinking and increases stability under a range of moisture conditions.

Reduced Optimum Moisture Content and Increased Dry Density: The addition of quarry dust progressively raises the maximum dry density (MDD) and lowers the optimum moisture content (OMC) of the material. The soil becomes more compacted and less prone to absorbing water.

The enhancement results from the coarse, dense particles of quarry dust filling vacuum areas and strengthening the soil matrix.

Increased Shear Strength: The addition of quarry dust to the sub-grade materials results in an increase in shear strength, which improves the stability of the pavement or foundation. For road pavements in particular, this is crucial since higher shear strength reduces deformation under load.

Reduced Swelling and Shrinkage: By inhibiting the soil's innate propensity to hold onto water, quarry dust can lessen the swelling potential of expansive soils. This is especially helpful in areas with expansive soils or clay, where pavement degradation can result from cycles of swelling and contraction. Quarry dust improves dimensional stability and lessens pavement structural breaking by lowering the clay percentage.

Mechanisms of Stabilization: Quarry dust serves as a filler, replacing fine particles in the soil, which is primarily responsible for the stabilizing effect. Its angular particles and coarser texture improve soil structure by forming a denser packing pattern. Additionally, quarry dust helps to strengthen particle bonding, which makes the soil more resilient to movement and deformation under stress. In clay and other fine-grained soils, this impact is particularly apparent.

Benefits to the Environment and Economy: Because quarry dust repurposes industrial waste and eliminates the need for natural aggregates, it is an environmentally responsible method of stabilizing soil. This approach promotes sustainable building techniques and reduces the need for new material extraction. For large-scale road and pavement projects, quarry dust is a cost-effective substitute since it is frequently less expensive than other stabilizing agents like cement or lime.

Conclusion and Recommendations

Quarry dust has demonstrated encouraging outcomes when used as a stabilizing agent for sub-grade soil in civil engineering applications such as road and building. The strength, durability, and load-bearing capability of sub-grade material are all improved by quarry dust. When combined with soil, it efficiently fills up spaces and acts as a binder, increasing compaction and decreasing plasticity. A stabilized sub-grade that can withstand deformation under load is the end outcome, extending the life of the pavement structure above and lowering maintenance needs. Additionally, by reusing industrial byproducts and lessening the environmental effect of construction operations, the use of quarry dust encourages sustainability.

The following recommendation are been made from the study:

1. Ideal Mix Proportion: I recommend the use of laboratory tests to ascertain the ideal ratio of quarry dust to sub grade soil mix to achieve good result.
2. Field Testing and Quality Control: Verify laboratory results in the field to guarantee constant performance and quality. Maintaining desirable sub-grade features during construction can be facilitated by routine monitoring.
3. Additional Research: Examine the long-term performance of quarry dust-stabilized sub-grades and the impact of environmental conditions (such as moisture changes), particularly in areas with harsh weather.
4. Quarry dust is a cost-effective and ecologically friendly option for sub-grade stabilization that may increase the longevity of road pavement, save material costs, and encourage environmentally friendly building methods.

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