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APPLICATION OF DYNAMIC CONE PENETRATION (DCP) TESTING TO EVALUATING THE RESILIENCE OF CLAYCRETE PAVEMENT ON IDUOMWINNA - AZURE POWER PLANT ACCESS ROAD, BENIN CITY.

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Abstract

This paper presents the findings and conclusions derived from the Dynamic Cone Penetration (DCP) test conducted on the Iduomwinna - Azura power plant road in Uhunmwonde Local Government Area of Edo State. The earth road, measuring 7.3m in width and spanning 2.4km, was slated for stabilization using Claycrete, an innovative road stabilization initiative in the region. The Claycrete stabilization was designated for a 1.5km stretch, with the possibility of incorporating additional asphalt layers contingent on the achievement of a minimum CBR value of 50% within a 7-day timeframe for the stabilized earth road. In the field, test points were chosen based on the specifications outlined in BS 1377-9:1990. The DCP equipment was strategically positioned at designated test points, and the testing was conducted. The test spacing was 300m interval for five points. These points covered an area of 1.5 kilometres that had already undergone treatment with Claycrete, as well as an additional 900 meters that remained untreated with Claycrete. The results indicate that in the treated sections, the subgrade CBR values for the DCP test range from 83 to 167%, giving an indication of suitable load-bearing capacity and enhanced resistance to deformation. Conversely, in the untreated sections, subgrade CBR values varied from 20 to 22%, signalling a lower load-bearing capacity and raising concerns about pavement strength. These findings affirm that the current Claycrete road surpasses the Road Note 31 (Transport Research Laboratory) recommendation of a minimum CBR of 15-30% for subgrade. The results advocate for the application of an Asphalt layer on the existing Claycrete surface as a continuation of the road construction endeavours premised on a properly stabilized subgrade with claycrete materials.

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1.0 Introduction

Claycrete is a construction material primarily composed of naturally occurring clay and stabilizers, forms the core subject of investigation. Its composition varies, with prevalent stabilizers such as lime, cement, or chemical additives. These stabilizers serve a crucial role in elevating the engineering properties of clay, thereby improving its strength, durability, and workability (Skempton, 1963, Rolt and Parkman, 2000).

The clay component, being a fine-grained soil, constitutes the fundamental structure of Claycrete. Through proper treatment and stabilization, it transforms into a solid and dependable foundation for road construction. Lime and cement, widely employed stabilizers, engage in reactions with clay minerals, yielding pozzolanic compounds and forming a cementitious matrix. These reactions contribute significantly to the hardening and stabilization of the clay, rendering it suitable for bearing substantial loads.

The historical use of stabilized clay for road construction spans centuries, with local materials employed in various global regions for infrastructure development. Contemporary interest in sustainable and cost-effective construction methods has prompted the exploration of alternative materials like Claycrete. Its utilization represents a modern approach to leverage the intrinsic properties of clay through stabilizer application, fostering ongoing research and innovative construction projects(MacNeil and Steele, 2002).

Claycrete emerges as a cost-effective alternative in road construction, benefiting from local availability and a simplified manufacturing process that reduces project costs. Despite its swift construction, a maturation period of four months is required, posing a limitation in urgent construction scenarios. The material's load-bearing capacity may be lower compared to some traditional pavement materials, necessitating careful consideration of expected traffic and load conditions. The strength of Claycrete, relative to materials such as asphalt and concrete, hinges on factors like soil composition, stabilizer content, and construction techniques. Although it may exhibit lower initial strength, proper application and curing can yield a road surface with suitable strength for moderate traffic conditions (MacNeil and Steele, 2002, Garg, 2009).

The use of Claycrete in road construction entails a nuanced balance of advantages and disadvantages, contingent upon project requirements, local conditions, and a willingness to navigate specific limitations for economic and environmental benefits. Thoughtful consideration of factors like load requirements, maturation time, and weather conditions is imperative for informed decision-making in road construction projects. Consequently, the Dynamic Cone Penetrometer (DCP) emerges as a crucial tool for assessing the strength and condition of Claycrete road pavement. By measuring the penetration rate of a cone driven into the pavement under standard impact, the DCP provides partially non-destructive insights into pavement thickness and condition. Changes in penetration rate serve as indicators of material strength variations, enabling identification and determination of the thickness and strength of each pavement layer (Done and Samuel, 2004).

This study focuses on the application of Claycrete for the enhancement of Iduomwinna - Azura power plant access road project in Uhunmwonde LGA of Edo State. The Claycrete Road, spanning 2.4km in length and 7.3m in width, stands as a unique initiative within the state. Currently, 1.5km of this road has been treated with Claycrete, and there is consideration by the authority to introduce an asphalt layer to further strengthen the road. This has prompted the need to assess the road's strength using Dynamic Cone Penetrometer (DCP) tests to determine its capacity to support the proposed asphaltic layer and traffic loads.

2.0 Methodology

The Dynamic Cone Penetration Apparatus (shown in Figure 1) is a widely used apparatus for assessing the strength and compaction characteristics of soil. It comprises of the following (Kleyn and Savage, 1982, Pratt, 1983, Jones and Rolt, 1991)

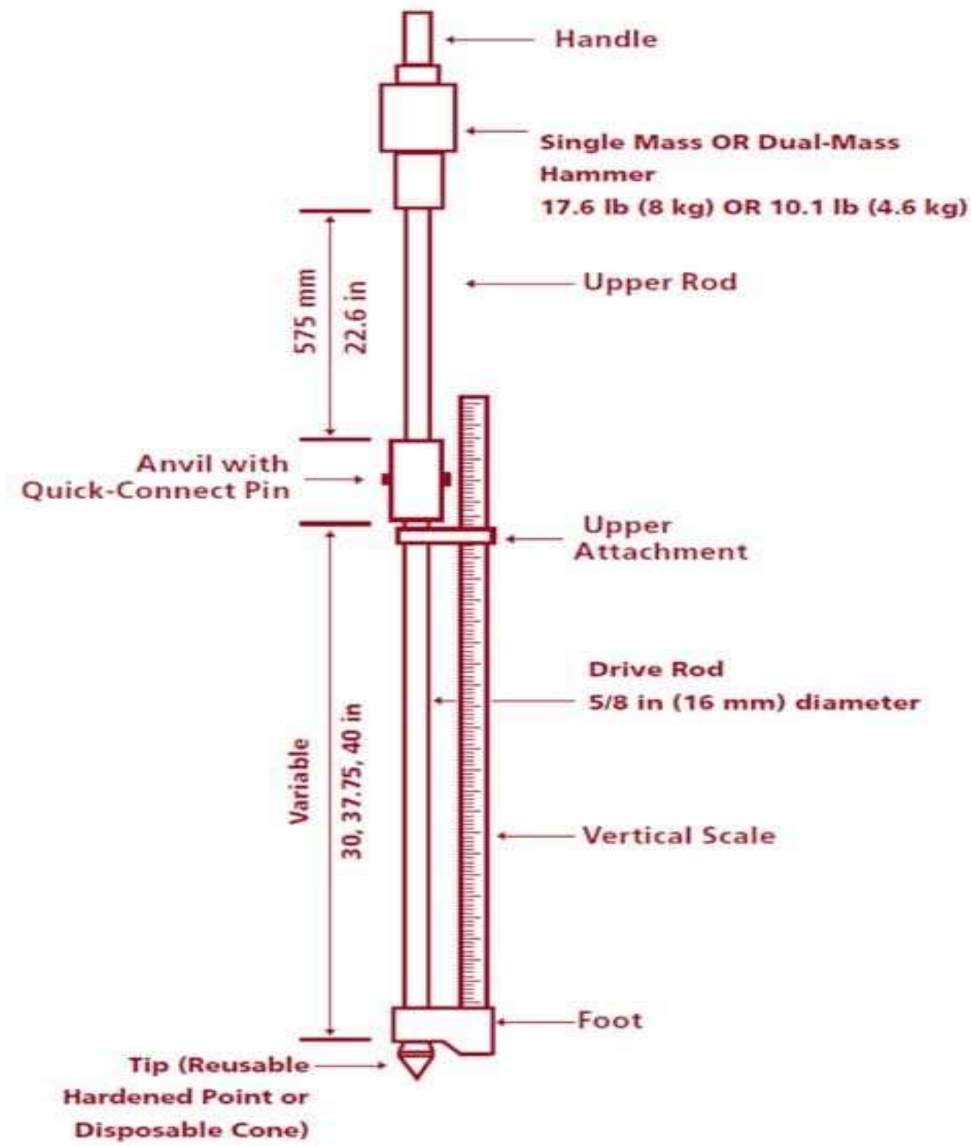

Figure 1: Dynamic Cone Penetration Apparatus (British Standards Institution, 1990)

a) Cone Penetration Rod

This is a long, slender rod that is inserted into the ground during testing. It typically has markings to measure penetration depth.

b) Cone Tip

The cone-shaped tip at the end of the penetration rod is designed to penetrate the soil. It may have a standard angle and area to ensure consistency in testing.

c) Hammer or Mass

The hammer or mass is used to provide the necessary energy for driving the cone into the soil. The mass is typically lifted to a specific height and then released to strike the anvil, resulting in a blow to the cone.

d) Anvil

The anvil is a sturdy surface against which the falling mass strikes. It is designed to transmit the energy efficiently to the cone.

e) Rod Couplings

If the rod needs to be extended for deeper penetration, rod couplings are used to connect additional sections of the rod securely.

f) Measuring Scale

The rod usually has a measuring scale marked in centimetres or inches. This scale is used to measure the penetration depth of the cone into the soil after each blow.

g) Pre-test

During the initial phase of the project, a thorough inspection of the Dynamic Cone Penetrometer (DCP) equipment was conducted to ensure its optimal condition. The cone, rod, and weight were meticulously checked and securely attached to guarantee reliable test results. Simultaneously, suitable test locations were identified based on project requirements, taking into account accessibility and safety considerations. Numerous standards and guidelines play a crucial role in the execution of Dynamic Cone Penetration (DCP) testing. These standards delineate specific requirements and methodologies for conducting DCP tests aimed at evaluating the strength, CBR (California Bearing Ratio), and compaction characteristics of soils. In this study, BS 1377-9:1990 was employed as the primary standard.

2.1 Test Setup

The assembly of the DCP equipment was carried out with precision in mind, ensuring a secure connection between the cone and the vertical rod. The stability of the coupling was verified to prevent any discrepancies during testing. Calibration procedures were meticulously followed according to the manufacturer's specifications, with special attention given to the accuracy of the vertical scale. Test spacing adhered to the project requirements specified by the department of road and bridges in Edo State, Nigeria specifying 5 points at 300m intervals, covering the area of 1.5km already treated with Claycrete and 900m of untreated area of the earth road.

2.2 Field Testing

In the field, the Dynamic Cone Penetrometer (DCP) was strategically positioned at assigned test points, and the testing process was seamlessly executed. The weight was consistently lifted and dropped onto the coupling, propelling the cone into the pavement, and the penetration per blow was meticulously recorded using the vertical scale. Test spacing adhered to project requirements, specifying 5 points at 300m intervals, covering the area of 1.5km already treated with Claycrete. Adjustments were made based on variations in pavement conditions. The data collection during field testing included the precise recording of penetration rates for each blow, coupled with detailed observations of visual indicators such as layer transitions or alterations in resistance. Adjustments were implemented to account for variations in pavement conditions.

2.3 CBR Calculation

The strengths of Test layers are calculated by converting the penetration rate (mm per blow) to a California Bearing Ratio (CBR) value and then from the CBR value to a strength coefficient and finally to a Structural Number. A number of relationships between penetration rate and CBR value have been derived and are given in Table 1. The TRL relationship for a 60° cone (Transport and Road Research Laboratory, 1990) shown in Table 1 was adopted in this study.

Table 1: Penetration Rate – CBR Relationships

Cone angle	Name of relationship	Relationship
60 ⁰ cone	TRL[(1)]	$Log_{10}(CBR) = 2.48 - 1.057\ Log_{10}(pen\ rate)$
	Kleyn[(2)] (pen rate > 2 mm/blow)	$CBR = 410\ (pen\ rate)^{-1.27}$
	Kleyn[(3)] (pen rate = 2 mm/blow)	$CBR = 66.66\ (pen\ rate)^2 - 330\ (pen\ rate) + 563.33$
	Expansive Clay Method[(4)]	$Log_{10}(CBR) = 2.315 - 0.858\ Log_{10}(pen\ rate)$
	100% Planings[(5)]	$Log_{10}(CBR) = 1.83 - 0.95\ Log_{10}(pen\ rate)$

50% Planings	$Log_{10}(CBR) = 2.51 - 1.38\ Log_{10}(pen\ rate)$
User-Defined	$Log_{10}(CBR)$ = [constant] – [coefficient] $Log_{10}(pen\ rate)$ Constant and Coefficient can be defined by the user

The results obtained was compared to Road Note 31 requirements for CBR for standard traffic classes and Subgrade Classes. Extract from the Road Note is shown in Table 2.

Table 2: Road Note 31 CBR for Traffic and Subgrade Classes(Rolt et al., 2022)

Traffic Classes	CBR (%) Lowest 10th percentile CBR%
S1	< 3
S2	3, 4
S3	5 - 7
S4	8 - 14
S5	15 - 30

The results as shown in Table 2 gives the minimum CBR percentage for S5 traffic classes in the range of 15 - 30

3.0 Results and Discussion

Tables 3 and 4 presents the results from the conducted Dynamic Cone Penetration (DCP) test at five selected positions along the Iduomwinna road - Azura power plant access road in Uhunmwonde Local Government Area of Edo State. Graphical presentation of the results was provided in Figure 2. The outcomes of the DCP test suggest that the current Claycrete road surpasses the minimum California Bearing Ratio (CBR) value of 50%, as specified by the Edo State Government guidelines for subgrade CBR, which notably exceeds the minimum CBR of 15-30% for subgrade outlined in Rolt *et al.* (2022). Despite the inherent maturation period of Claycrete of about four months, significant variations were observed between treated areas (positions 1, 2 and 3) and untreated areas (positions 4 and 5) as shown in Table 4 and Figure 3. The lowest CBR was found in position 4 while the highest was found in position 1. Based on these findings, it is recommended that to enhance the road strength and durability, there is need to apply an additional asphalt layer on top of the existing Claycrete layer which aligns with the proposed measures of the current administration of the Edo State Government.

Table 3: Cumulative Blow and Penetration Depth

Position / Chainage			**CH 0+100**	**CH 0+500**	**CH 1+500**	**CH 1+800**	**CH 2+400**
No.	**Blows**	**Cumulative Blows**	**Penetration Depth (mm)**				
1	0	0	55	60	60	50	62
2	5	5	60	63	85	98	107
3	5	10	65	81	93	118	130
4	5	15	70	86	102	128	150
5	5	20	75	87	108	146	168
6	5	25	80	88	112	158	182
7	5	30	85	93	122	170	192
8	5	35	90	94	132	185	202
9	5	40	95	98	140	201	213
10	5	45	100	99	148	213	222
11	5	50	105	100	158	228	232
12	5	55	110		169	245	242
13	5	60	115		180	260	260
14	5	65	120		190		270
15	5	70	125		200		285
16	5	75	130		210		299
17	5	80	135				311
							322

Table 4: CBR % for Test positions

Position	**Penetration Rate (mm/blow)**	**Thickness (mm)**	**Depth to layer bottom (mm)**	**Layer**	**Strength Coefficient**	**SN**	**SNC**	**SNP**	**CBR %**
1	1	125	125	Subgrade	0.14	0.71	0.71	0.71	167
2	1.73	76	76		0.14	0.41	0.41	0.41	91
3	2	200	200		0.13	1.03	1.03	1.03	83
4	6.8	108	108		0.05	0.23	0.23	0.23	22
5	5.3	158	158		0.07	0.43	0.43	0.43	29

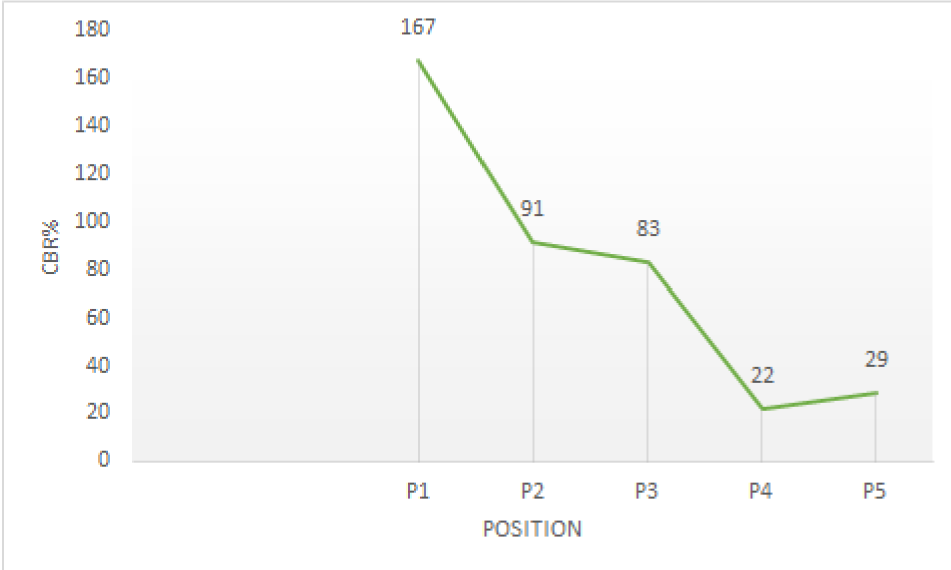

Figure 2: CBR Values for Test Positions

4.0 Conclusion and Recommendation

The outcomes of the Dynamic Cone Penetration (DCP) tests conducted on the Iduomwinna - Azura power plant access road in Uhunmwonde Local Government Area of Edo State offer valuable insights into the performance and robustness of the Claycrete-stabilized earth road. This pioneering initiative of the existing road spanning 2.4Km length and 7.3m in width had 1.5Km of the road stabilized with Claycrete. The findings of the DCP test revealed that the current Claycrete road surpasses the standard subgrade CBR value of 50%, stipulated by the Edo State Government and 15 -30% CBR stipulated in Road Note 31 document.

It is therefore recommended that the application of asphalt layer on the existing Claycrete surface proceed as proposed which will further enhance the road strength and durability to fostering a resilient and sustainable infrastructure in the region. The findings in this study offer valuable insights that underscores the importance of CBR as a useful parameter for the evaluation of the strength of subgrade when treated with Claycrete material.

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