



**GEOPHYSICAL AND GEOTECHNICAL ASSESSMENT OF SUB-GRADE
CONDITION ALONG PROPOSED ROADS AT LAGOS STATE UNIVERSITY OF
SCIENCE AND TECHNOLOGY, IKORODU, SOUTH-WEST NIGERIA**

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ABSTRACT: *In most parts of the world, road failure has contributed to major problems leading to the death of so many people, causing traffic hazards, accidents and also increasing the rate of damage to vehicles. This research is to assess the geophysical and geotechnical conditions of proposed roads to be constructed in the Lagos State University of Science and Technology, Ikorodu, South-West, Nigeria. To achieve this, Electrical resistivity tomography (ERT) at 5 m spacing and Dynamic Cone Penetration Test (DCPT) at intervals of 50 m were deployed on five (5) profiles of 250 m each. The results show that the California Bearing Ratio (CBR) values calculated from DCPT range from 1.67% to 98.71% revealing very poor to excellent base/sub-grade material while the electrical resistivity tomography shows that the resistivity values ranges from 113.5 to 1266 Ωm revealing subsurface signatures of incompetent sandy clay, fairly competent sandy clay, fairly competent clayey sand and competent sand/dry sand materials. The areas of incompetence can be evacuated and compacted to facilitate better and more durable road constructions in the study area.*

KEYWORDS: California Bearing Ratio (CBR), Road failure, Sub-grade condition, Traffic hazard.



INTRODUCTION

Nigerian roads have often been characterized by different types of cracks, potholes and other pavement defects. These have posed a serious challenge and disaster, such that Nigerians can hardly travel a kilometer without coming across long cracks and potholes. These challenges have resulted in a spike in the number of road accidents and a plunge in the nation's economic development.

Most of the roads built are often known to have a stipulated design life, but roads oftentimes fail long before the expiration of the design life; some fail after flooding or environmental disaster, some immediately after construction while others last to their entire life expectancy with appropriate maintenance (Emmanuel et al., 2021). Some factors are considered to be the cause of these road failures and they are said to be poor construction materials, poor drainage networks, abandoned river channels and geological factors. There is a need to carry out pre-construction geophysical investigation before road design and construction. The investigations are deployed in the determination of the layout, road pavement thickness, and properties of individual layouts below the terrain surface in which the construction of a specific structure is planned (Amosun et al., 2018).

Geotechnical investigation is a process in which the physical qualities of a site are evaluated to determine if the site's soil is suitable and safe for the purpose it is intended for. It includes surface exploration and subsurface exploration and it is also the study of properties of the near-surface geological units, collected, tested, evaluated, and mapped.

Ogungbe et al. (2020) carried out geophysical investigations of road failure using Two-dimensional (2D) electrical resistivity imaging along the Lagos –Badagry expressway, Lagos State, Nigeria, to determine the subsurface geological structures that may pose a danger to the highway. They identified the possible causes of the expressway failure in the study area to include poor sub-graded materials and waterlogged sand, which resulted in major cracks and were unable to withstand heavy traffic plying the highway. They posited that other factors, like poor drainage patterns for runoff at both sides of the road pavement, could have also contributed to the failure.

The engineering geological properties of the sub-soil that make up the sub-grade materials along the Supare – Emure road were investigated by Oyeshomo (2023) for the purpose of determining the causes of the failure of pavement along the rickety sections. He determined the natural moisture content, plasticity index, grain size, Atterberg limits and linear shrinkage. His results revealed that the bedrock clayey nature and chemistry of sub-grade soils are responsible for the failure of some sections of the road examined.

Olufemi et al. (2024) applied the Geophysical method – electrical resistivity method to differentiate the subsurface target of interest from the surrounding strata along the Ago-Iwoye/Ilishan road in South-western Nigeria. Vertical Electrical Sounding (VES) and 2-D resistivity imaging involving the Dipole-Dipole profiling technique were adopted in the sedimentary segment. From a geotechnical view, subgrade materials underlying the SB and TZ segments can be adjudged competent to sand and clayey sand units with minor occurrences of incompetent clay and sandy clay lenses. The occurrence of subsurface discontinuities at the BC end of the TZ of the road would adversely affect the pavement stability.

This work is based on geophysical and geotechnical assessment of ground conditions for the construction of good roads devoid of road failures, thereby saving lives and properties on the road and prevents unnecessary spending on road repairs, thereby increasing the application of limited available resources to other pressing needs.

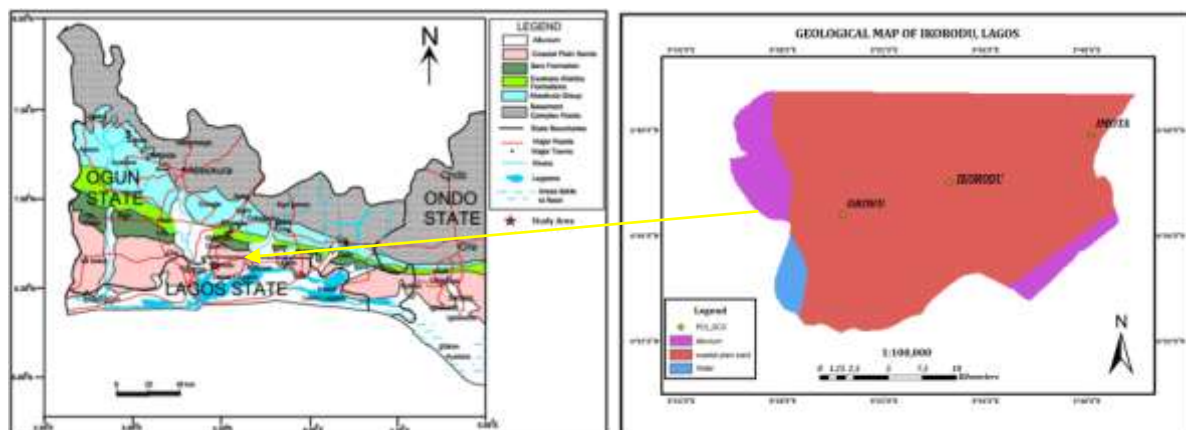
Geological settings of the study area

Ikorodu is a city and local government Area in Lagos state, Nigeria, located along Lagos lagoon, it shares a boundary with Ogun state. Geographically located between Latitude $6^{\circ}31'N$ and $6^{\circ}41'N$ and Longitudes $3^{\circ}26'E$ and $3^{\circ}42'E$ (Epuh et al., 2020). Figure 1 shows the map of the study area.

The study area is located at Lagos State University of Science and Technology (LASUSTECH), Ikorodu campus. The campus is in the generally low-lying, coastal terrain of Lagos State, characterized by extensive water bodies (lagoons, rivers, creeks) and fertile soil, meaning its campus likely features flatter areas, possibly some wetlands, and is near significant water features, typical of the Ikorodu region. The topography is not mountainous but rather a mix of built-up areas and natural plains, influenced by the proximity to the Ogun River and lagoon systems.

LASUSTECH reflects the broader Lagos environment, characterized by coastal plain sands, clays, and sandstone, situated within the Dahomey Basin, which is the Eastern part of the Sedimentary Basin that extends from the Volta Delta state in Ghana to the Okitipupa ridge in Nigeria (Coker, 2015). The soil and rock mechanics (geotechnics) of these sand and clay formations directly impact construction and infrastructure development on campus.

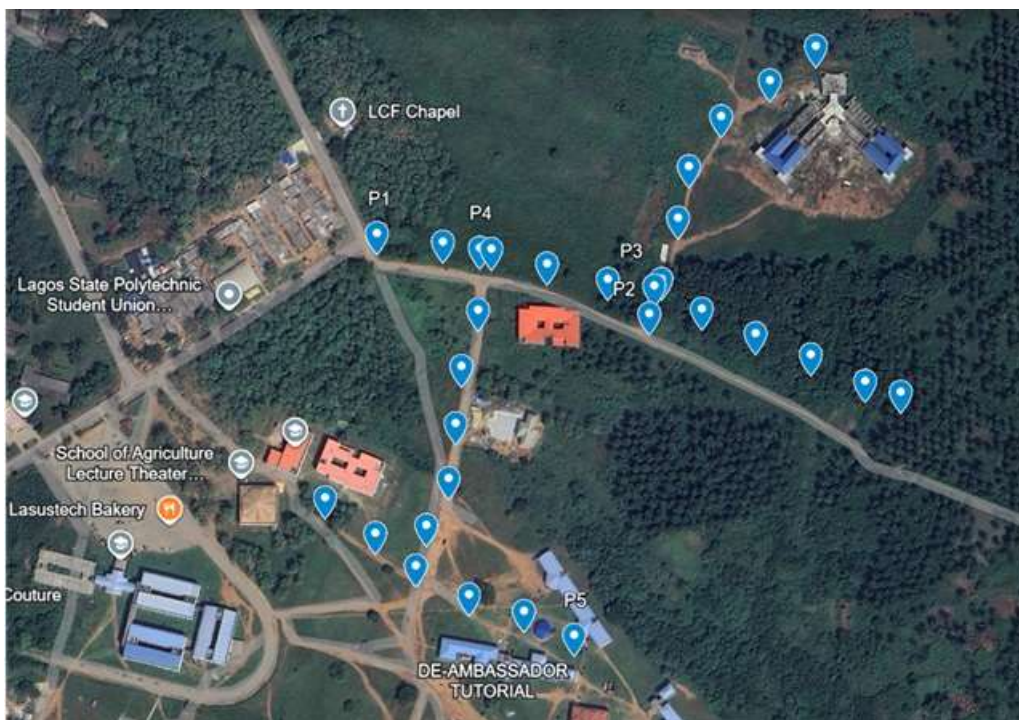
Figure 1: Modified geologic map of the study area (Epuh et al., 2020)



MATERIALS AND METHODS

This research starts with a reconnaissance survey for field assessment of the roads earmarked for construction within the study area. The profiles to be occupied were marked out. This was followed by a geophysical survey by electrical resistivity measurement along the road. The Wenner array was adopted to determine the electrical resistivity imaging (ERI) of the subsurface to the depth of 15.4 m. A total of five (5) profiles of 250 m spread at 5 m spacing Wenner electrical resistivity surveys were carried out in the area covering major parts of the proposed road. The Wenner profiling technique adopted on the proposed road is used to map the vertical subsurface of the study area along each profile. The field data were inverted to a 2-D resistivity structure using RES2DINVx64 Version 4.04 software. Lithologic variations depicted on the 2-D inverted resistivity structures were inferentially delineated with the aid of the resistivity contour colorations, but the interpretations assigned to a colouration depend on the observed electrical resistivity distribution on the structure. This is generally uneven within the probed subgrade due to its varied lithologic composition.

Figure 2: Base map of the study area showing the profiles and DCPT points



Furthermore, thirty (30) in situ Dynamic Cone Penetration tests (6 on each profile) were also carried out to a depth of 3 m. The numbers of blows were recorded at every 100 mm depth penetration and the results obtained were used to calculate the California Bearing Ratio (CBR). The CBR values were compared with the standards rating of soil material (Table 1) for soil type classifications.

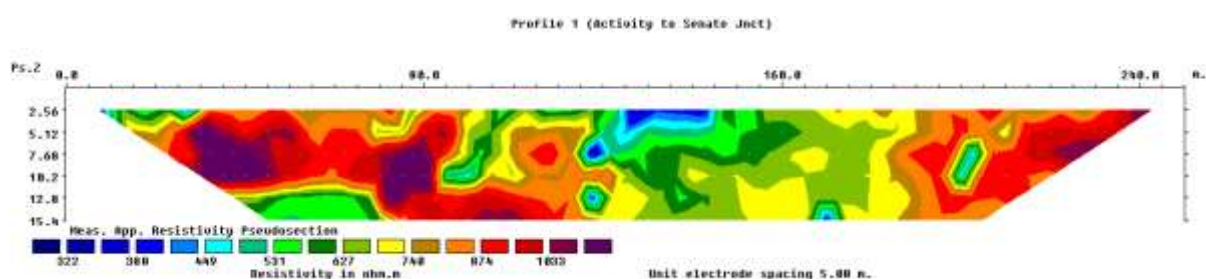
Table 1: General rating of soil materials using CBR values (Atilade et al., 2024)

CBR Value	Classification	Uses	Classification System
0-3	Very poor	Sub-grade	Organic high plasticity, Clay high plasticity, Silt high plasticity, organic low plasticity
3-7	Poor-fair	Sub-grade	Organic high plasticity, Clay high plasticity, Silt high plasticity, organic low plasticity
7-20	Fair	Sub-grade	Organic low plasticity, Clay low plasticity, Silt low plasticity, sand clay, Sand silt, Sand poorly graded
20-50	Good	Base, Sub-grade	Gravel silt, Gravel clay, Sand well graded, Sand silt, Sand poorly graded, Gravel poorly graded
>50	Excellent	Base	Gravel well graded, Gravel silt

RESULTS AND DISCUSSION

Table 2: CBR minimum, maximum and average values along profile 1

CBR Values of Profile 1						
	0 m	50 m	100 m	150 m	200 m	250 m
AVE	19.94%	48.07%	37.69%	51.94%	50.17%	56.32%
MIN	7.93%	14.84%	7.93%	17.24%	12.49%	17.24%
MAX	59.00%	78.58%	95.80%	98.71%	95.80%	95.80%

Figure 3: The Electrical Resistivity Tomography of profile 1

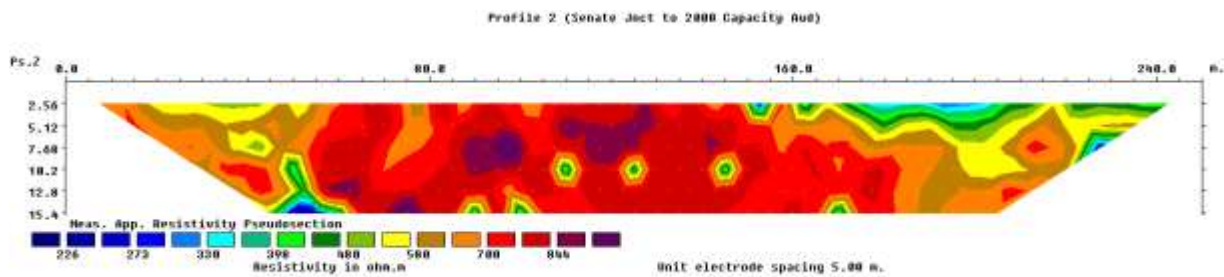
On Profile 1 (Table 2), the CBR values range from 7.93% to 98.71%, depicting poor-fair sub-grade to excellent base materials with average values between 19.43% and 56.32%, which indicates fair sub-grade to excellent base materials.

The electrical resistivity tomography (ERT) resistivity distribution along the sub-grade of profile 1 (Figure 3) ranges from 293 – 1062 Ω m. Areas with pockets of blue/green colouration (293 – 600 Ω m) represent the regions of fairly competent clayey sand, while green/yellow/brown/red/violet coloured areas (600 – 1062 Ω m) are competent sand/dry sand materials.

Table 3: CBR minimum, maximum and average values along profile 2

CBR Values of Profile 2						
	0 m	50 m	100 m	150 m	200 m	250 m
AVE	49.56%	57.78%	47.02%	51.04%	43.64%	40.11%
MIN	12.49%	19.67%	10.18%	10.18%	1.68%	7.93%
MAX	95.80%	98.71%	95.80%	95.80%	90.02%	92.91%

Figure 4: The Electrical Resistivity Tomography of profile 2



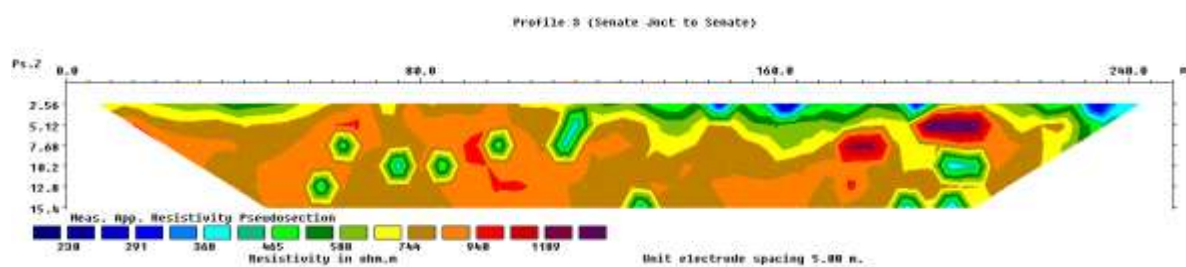
CBR values of profile 2 (Table 3) range from 1.68% to 98.71%, depicting very poor sub-grade to excellent base materials, while the average CBR values are between 40.11% and 57.78%, which indicates good base, sub-grade to excellent base materials.

Figure four shows the electrical resistivity tomography (ERT) resistivity distribution along the sub-grade of profile 2, which ranges from 195.5 – 905 Ω m. Areas with dark blue colour (195.5 – 200 Ω m) represent the region of fairly competent sandy clay, pockets of blue/green/yellow colours represent fairly competent clayey sand and the spread of brown/red/violet colours (600 – 905 Ω m) represent competent sand/dry sand materials.

Table 4: CBR minimum, maximum and average values along profile 3

CBR Values of Profile 3						
	0 m	50 m	100 m	150 m	200 m	250 m
AVE	32.43%	68.30%	31.88%	25.63%	19.35%	15.39%
MIN	10.18%	37.46%	10.18%	10.18%	10.18%	3.65%
MAX	95.80%	98.71%	84.28%	67.32%	40.10%	27.14%

Figure 5: The Electrical Resistivity Tomography of profile 3



In profile 3, the CBR values range from 3.65% to 98.71%, interpreted as poor-fair sub-grade to excellent base materials, and the average CBR values range between 15.39% and 68.30%, which indicates good-fair sub-grade to excellent base materials.

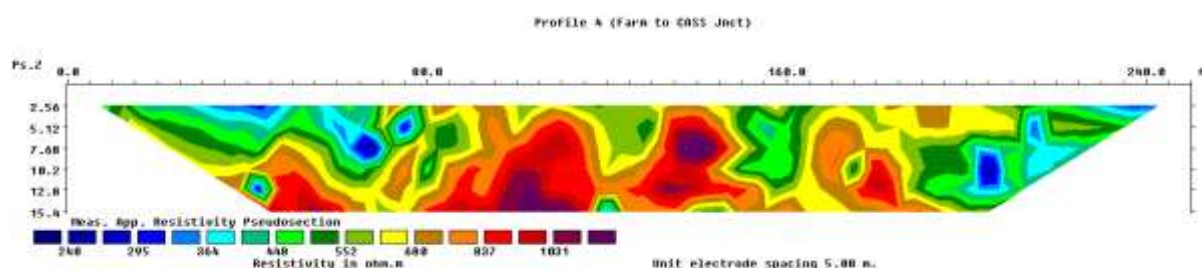
The resistivity distribution along the sub-grade of profile 3 (figure 5) ranges from 199.5 – 1250 Ω m. Areas covered with blue colours (199.5 – 400 Ω m) represent the region of fairly competent sandy clay, pockets of green coloured region represent fairly competent clayey sand and the spread of yellow/brown/red/violet colours (600 – 1250 Ω m) represent competent sand/dry sand materials.

Table 5: CBR minimum, maximum and average values along profile 4

CBR Values of Profile 4

	0 m	50 m	100 m	150 m	200 m	250 m
AVE	33.57%	18.29%	19.19%	19.82%	23.78%	15.18%
MIN	7.93%	7.93%	7.93%	10.18%	5.75%	5.75%
MAX	84.28%	34.85%	37.46%	37.46%	42.75%	61.76%

Figure 6: The Electrical Resistivity Tomography of profile 4



Profile 4 (Table 5) shows that the CBR values range from 5.75% to 84.28%, depicting poor-fair sub-grade to excellent base materials with average values between 15.18% and 33.57%, which indicates fair sub-grade to good base and sub-grade materials.

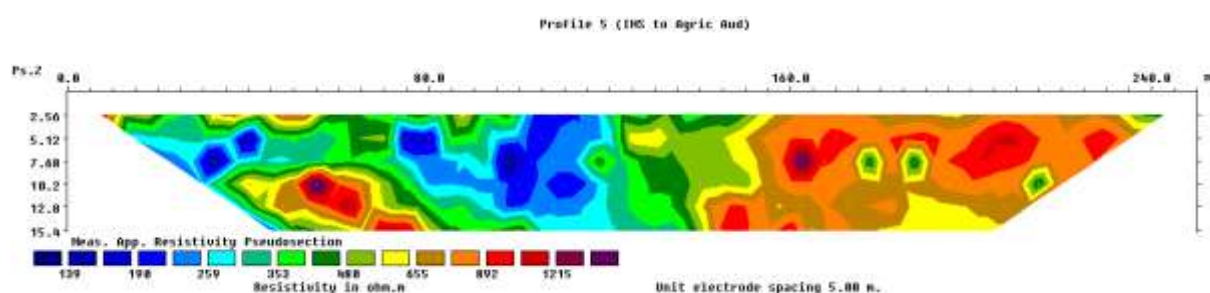
The electrical resistivity tomography (ERT) resistivity distribution along the sub-grade of profile 4 (Figure 6) ranges from 192.5 to 1086 Ω m. Areas with pockets of blue colours (192.5 – 400 Ω m) represent the regions of fairly competent sandy clay units, while the green region

(400 to 600 Ωm) indicates regions of fairly competent clayey sand. The yellow/brown/red/violet coloured areas (600 to 1086 Ωm) represent competent sand/dry sand materials.

Table 6: CBR minimum, maximum and average values along profile 5

CBR Values of Profile 5						
	0 m	50 m	100 m	150 m	200 m	250 m
AVE	13.71%	13.17%	11.98%	16.35%	10.84%	21.71%
MIN	7.93%	5.75%	5.75%	7.93%	3.65%	3.65%
MAX	29.69%	40.10%	24.62%	67.32%	37.46%	53.52%

Figure 7: The Electrical Resistivity Tomography of profile 5



The CBR values of profile 5 (Table 6) vary from 3.65% to 67.32%, depicting poor-fair sub-grade to excellent base materials. The average values of the CBR are between 10.84% and 21.71%, which indicates fair sub-grade materials.

Figure seven represents the electrical resistivity tomography (ERT) resistivity distribution along the sub-grade of profile 5, which ranges from 113.5 – 1266 Ωm . Areas with dark blue colours (113.5 – 200 Ωm) represents the region of incompetent sandy clay, pockets of blue/green (200 – 400 Ωm) depicts a region of fairly competent sandy clay, the region with resistivity range of 400 – 600 Ωm (dark green/yellow colours) represent fairly competent clayey sand and the areas of brown/red/violet colours (600 – 1266 Ωm) represent competent sand/dry sand materials.

Profiles 1 CBR exhibited a mix of fair sub grade to excellent base materials within the 3 m depth which was confirmed by the range of fairly competent clayey sand and competent sand/dry sand materials revealed by the 2D resistivity imaging pseudosection within the same depth across the profile. This shows high competence with little excavation and fortification of fairly competent areas along the profile.

The CBR values of profile 2 exhibits a blend of good base to excellent base materials on the average within the 3 m depth which was affirmed by the range of fairly competent sandy clay and competent sand/dry sand materials revealed by the 2D resistivity imaging pseudosection within the same depth across the profile. This demonstrates good competence with minimal excavation and fortification of fairly competent areas along profile 2.

In profile 3, the CBR average values are from good-fair subgrade to excellent base materials within the 3 m depth which was similar to the range of fairly competent sandy clay and



competent sand/dry sand materials captured by the 2D resistivity imaging pseudosection within the same depth along the profile. This demonstrates good competency with little excavation and fortification of fairly competent areas along the profile.

Profile 4 CBR average values demonstrate a spread of fair subgrade to good base materials on to the depth of 3 m which was confirmed by the range of fairly competent sandy clay and competent sand/dry sand materials confirmed by the 2D resistivity imaging pseudosection within the same depth across the profile. This shows moderate competence with little excavation and fortification of fairly competent areas i.e. 0 m – 80 m and 200 m – 250 m along the profile.

The average CBR values of Profile 5 exhibited a fair subgrade materials within the 3 m depth which was established by the range of incompetent sandy clay and competent sand/dry sand materials revealed by the 2D resistivity imaging pseudosection within the same depth across the profile. This shows that proper excavation and fortification should be carried out at the incompetent area (0 m – 125 m) along the profile.

CONCLUSION AND RECOMMENDATIONS

Geophysical applications and geotechnical testing have reliably revealed the image of the subsurface for predicting the engineering performance of the subgrade soils. The electrical resistivity method was used as a geophysical tool to image and characterize the shallow subsurface that underlies the selected roads in Lagos State University of Science and Technology, Ikorodu. The 2-D resistivity structures across the area revealed a broad range of resistivity values from 113.5 to 1266 Ωm , while the DCPT values range from 1.67% to 98.71%. These values show the occurrence of a competent dry sand layer and incompetent sandy clay layers across the five profiles. Areas where the road is underlain by incompetent clay/sandy clay and other lithological contacts should be excavated and replaced with a high-quality construction aggregate so as to provide the required stability and durability of the pavement, as well as prevent potential road failure and other associated risks.

Construction of drainage channels on both sides of the road pavement, especially where the road pavement runs parallel to runoff, precipitating high relief is strongly recommended to ensure optimal water management and prevent accumulation.

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Conflict of Interest

The authors declared that there is no conflict of interest in carrying out this research.



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