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EVALUATION OF ROAD PAVEMENT FAILURE: A CASE STUDY OF FEDERAL MEDICAL CENTER ROAD, JABI, ABUJA

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ABSTRACT: ***Background of Study:*** *In Nigeria, roads frequently degrade soon after construction, especially if the work is not done properly. However, some roads last for a long time before they deteriorate. This current study examined the factors that contribute to road collapse along the Federal Medical Centre road, Abuja and proposed optimal solutions.*

Methods: *Sufficient soil samples were obtained at the road's collapsed segment. However, a traffic volume study was conducted together with laboratory investigation such as natural moisture content determination, sieve analysis, atterberg limit testing, compaction test and california bearing ratio analysis using (BS 1377) to better understand the factors causing the road failure.*

Results*: The result from natural moisture content shows that the soil sample obtained contained an amount of water for each sample, while sieve analysis shows that the samples have satisfied the requirements. In addition, the atterberg limit test indicates that the earth's samples are good and excellent for use in building roads, while for compaction, the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) values obtained have also satisfied the requirements. More so, the California bearing ratio test also shows that the sub-base materials are good, which makes the layers of good strength. A traffic volume study was done by counting the number of vehicles going and coming out from various organizations surrounding the road in the morning and Afternoon hours.*

Conclusion*: The construction materials of the road are good and excellent and have all complied with the requirements. Hence, by visual observation, the road's drainage system could be better, and the road surface needs to be cambered to the direction of the drainage to drain off water, especially during the rainy season. Water poses a lot of threat to roads, gradually creating void and allowing water infiltration, causing severe damage to the subsoil and pavement. Therefore, it is recommended that the drainage system should be properly built while cambering the road to either direction for proper running off of water.*

KEYWORDS: Road, Pavement, Failure, Concentration.

INTRODUCTION

A road is a long piece of hard ground constructed between two locations to facilitate travel by vehicle, whether it is a rural or urban route (Collins, 2022). It is essential for reducing unemployment, enhancing economic conditions, and bridging the development gap between underdeveloped and developed regions (Fred & Maxwell, 2022). It is believed that traditional modes of transport, particularly road networks, are of the utmost importance to a country's economic affairs. Since its extensive road network serves as its main source of transportation, Nigeria is not an exception. According to Aghamelu et al. (2011), one factor that has contributed to the sector's economic backwardness is the challenge of building and maintaining efficient road and highway networks in diverse parts of the world (i.e., developing countries like Nigeria). Aghamelu et al. (2011) claim that the lack of construction supplies and subpar building practices are to blame for damaged roads. According to research by Akudo et al. (2022), there is a significant link between a nation's economic development and the caliber of its highway network. In order to successfully employ the worth of the general people and the economic satisfactory support, a country's highway system must be developed and modeled competently and attractively.

Numerous tragedies, involving human deaths and asset losses worth fortunes, are being relocated as a result of vehicle accidents due to the degraded road systems. The primary reasons of road collapse, such as geotechnical, geomorphological, geological, roadway use, flaws in plans and models, and insufficient upkeep considerations, were looked into and assessed by Mohd et al. (2019). Nevertheless, Okogbue et al. (2010) and Aghamelu et al. (2011) pointed out that roadway concepts along with other engineering/civil constructions had collapsed and suffered serious damage shortly after the building process had been accomplished as a result of the poor foundation that the concept was built on, and steady maintenance of designs that are susceptible to this failure is extremely expensive. The road is a crucial engineering structure made possible by adaptable pavement designs and subsurface layers (i.e., subgrade, subbase, and foundation course). The basis soil, which serves as the subgrade soil, was created by in-situ weathering of the basement rock in the Basement Complex environment. Therefore, it is a result of the environment's geology and climatic factors. Geological factors are regrettably frequently not taken into consideration despite the fact that the soil underneath(subgrade) is a result of geology during the design and restoration of various highways in Nigeria (Obasaju et al., 2022). As a result, these elements—particularly climate and geology, which have an impact on the outlook and long-term durability of the road—must be incorporated into the highway model. Naturally, a location's geology is what ultimately determines how long any road building will last. Before any road construction is constructed, the qualities of the subgrade (in-situ soil) of that specific location must be thoroughly investigated because it acts as the foundation for building roads and, if it is not adequate, cannot hold the load above it. This is due to the fact that many of the difficulties faced by contractors when building roads are directly tied to the subgrade's potential. If this is the case, road failure after construction is inevitable (Gungat et al., 2013). Roadway pavement standards are influenced by the geology of the area, the building materials picked, and the features of the on-site natural subgrade, as stated by Maduka et al. (2017).

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METHODOLOGY

Study Area

This study was conducted from the junction of the Federal Medical Center to the Emeritus Umaru Shehu Road section, which is 1.1 km long. The road is linked with several roads, such as Emeritus Umaru Shehu Road, Kado-Galadima Road and Body of Benchers Nigeria Road.

The study area started at a latitude and longitude of 9°00’59.09”N and 7°24’43.81” E, respectively, with an elevation between 1379 ft and 1817 ft. above the sea level. The study area ends at Emeritus Umaru Shehu Road at a latitude and longitude of 9°00’37.15”N and 7°24’15.53”, correspondingly, which is located at an altitude of 1363 ft beyond sea level.

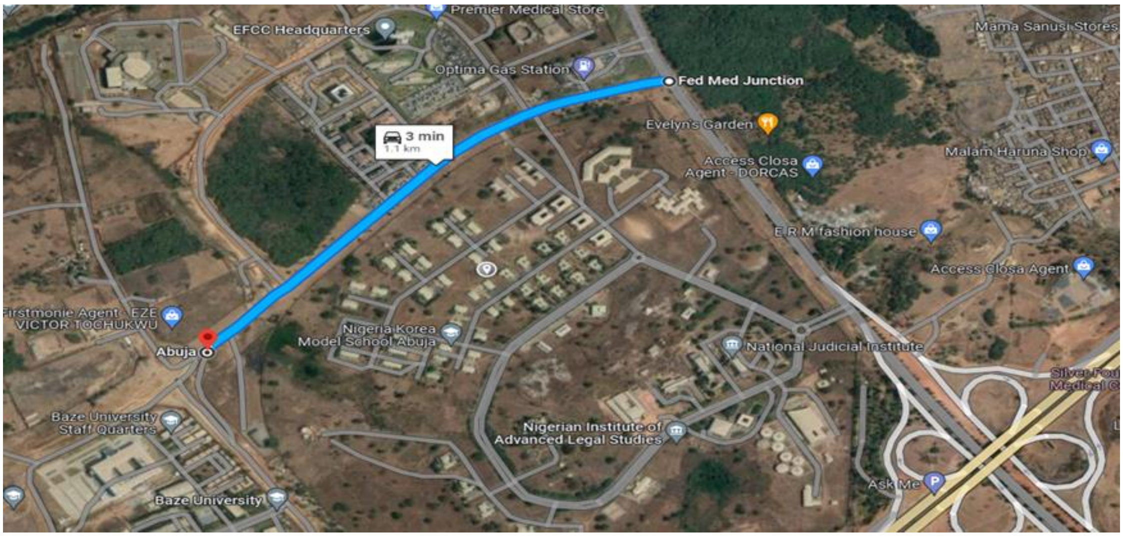

Figure 1.0: Aerial Map of the Specific Road

Data Analysis

Data can be divided into two categories: quantitative and qualitative. This study collects its data and analyzes it in the form of Quantitative and Qualitative data

1. Quantitative data: It deals with numerical data that can be converted into numbers (Sheard, 2018).
2. Qualitative data: Qualitative data is non-numerical information that involves written words, moving pictures, still images, or audio recordings. This kind of information can be gathered by record counts or assessments, and it can be evaluated using a grounded approach or the analysis of themes. (Saul, 2019).

Study Design

This aspect consists of an experimental design study that is utilized to accomplish the objectives of this study and aids the creation of the best possible solutions. The experimental design consists of two tasks: laboratory tests and traffic volume study laboratory testing provides extra information on the engineering qualities of the soil used to build the road, while traffic volume study gives details on the types and number of vehicles accessing the road daily and weekly. Material samples for laboratory tests were obtained from the study area at the

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failed section of the road to measure the soil's strength and physical properties of the soil and mitigate the occurrence of defects on the flexible pavement.

Reasons for Selection Approach

The soil investigations consist of determination of natural moisture content, sieve testing, California bearing rate test, atterberg limit assessment, compaction testing, and traffic volume study. Listed below are the reasons why each test is selected for the investigation:

I. **Natural moist concentration:** The inherent moisture content affects how much weight a soil can support and how much it will settle. An idea of the soil's condition in the field will be provided by its natural moisture content**.**
II. **Sieve analysis:** This aims at calculating the proportion of various grain sizes present in the soil. The qualities of the soil are influenced by the grain size, creating problems like air voids which allow infiltration of water during the rainy season.
III. **Atterberg limit:** This is done in order to understand the behavior of the soil at which it transits from the solid, semi-solid, plastic, and liquid states.
IV. **Compaction test:** The reason behind selecting the compaction test is to thoroughly understand the compaction characteristics of the soil, the value of maximum density achieved during the construction and the soil's density.
V. **California bearing proportion:** To ascertain the durability of the base course materials and subgrade soil, this test was selected.
VI. **Traffic volume study:** It is done in a bid to evaluate the traffic flow characteristics and types of vehicles accessing the road pavement, e.g. heavy-duty vehicles, private cars, buses and so on. Heavy-duty vehicles tend to give more stress and deflection on the pavement, causing deterioration and problems on the road surface.

Laboratory Test

A sufficient number of samples were gathered from the failed portion of the flexible pavement/roadway study area and sealed in an air-tight sack to prevent natural air from tampering with the soil sample. The sample obtained is from three failed sections of the road categorized as Sample A, Sample B and Sample C. The materials were transported to the laboratory of Baze University. These tests were performed according to AASHTO following the BS 1377 method, part 2: 1990. The results will be compared to the Federal Ministry of Works, Housing and Transport of Nigeria's General specifications (Roads and Bridge). Below are some failure types on the road sections with the Samples Obtained.


Figure 2.0: Showing Crack Types Damaged and Their Sample

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Figure 2.1: Showing Potholes Type Damaged and Their Sample


Figure 2.2: Showing of Distress Damaged and Their Sample

Data Collection

a. **Sieve Testing/Evaluation:** This was done to determine the particle size distribution of the soil. The 500g soil sample was weighed and steeped in water for 24 hours. After being rinsed and dried in the oven, soil samples were utilized for the test. The BS 200 sieve was used to wash the sample, and the amount that remained on the sieve was dried and used for the sieve analysis procedure. The sieve analysis was performed by hand with a set of sieves.

b. **Atterberg's Limit Test (LL and PL):** The Atterberg limit analysis is used to measure the plasticity, strength, and settling properties of soil samples by determining their percentage of clay in terms of its liquid limit, elastic limit, and plasticity index. To determine the liquid limit, a 200 g soil sample was passed through a 425-micron BS mesh and mixed with water to form a thick homogeneous paste. The mixture was placed within Casagrande's apparatus, a grove was formed, and the number of strokes required to close the gap was noted. To determine the plastic limit, a 200-g soil sample was obtained from the material, passed through a 425-micron BS sieve, and blended with water until homogeneous. The soil was rolled on a glass plate until the thread broke at roughly a 3-millimeter diameter. To find the plastic limit, the 3 mm diameter piece of the rolled soil was heated to 105°C in an oven.

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c. **Compaction Testing:** BS 1377's test technique for compaction was used to conduct the sub-base compaction tests. When soil is mechanically compacted, the proportion of horizontal practical size to vertical effective stress increases as a result of packing the soil granules into a more compact configuration. The dry weight determines how much compaction there is which raises the road foundations bearing capacity, stabilizes slopes, regulates unwanted volume changes and also prevents unwelcome structural settlement. A 4.5kg rammer was used to compact the soil in 5 layers.

d. **California Bearing Ratio (CBR):** This penetration test, also known as the California Bearing Ratio (CBR) test, measures the mechanical integrity of soil materials used as base course, sub-base, and subgrade pavement levels. The CBR soaking technique was applied for a full day. Similar methods were used for the Compaction test, which involved compacting the soil in five layers with 65 blows each using a 4.5 kg hammer, at the ideal moisture level. A load was applied after the compacted mold soil was put underneath the CBR machine. At a penetration of 0.0, 0.25, 0.50, 0.75, 1.00, 1.25, 1.50, 1.75, 2.00, 2.25, 2.50, 2.75, 3.00, 3.50, 4.00, 4.50, 5.00, 5.50 and 6.00, the load was recorded.

e. **Traffic Volume Study:** Data for the traffic volume research was collected at three different points along the road section. The vehicle entry and exit records were taken in the evening from 4:30 to 5:30, while the traffic count was conducted in the morning from 9:00 to 11:00. These hours were perfectly selected because they are the peak hours having the heaviest traffic volume, and this will give accurate data for vehicles. The volume of vehicular traffic was calculated as Average Daily Traffic (ADT), which is equal to the sum of the daily traffic volumes for a particular period (defined as a time period greater than or equal to one day but less than one year) divided by the number of days in that period. The Passenger Car Unit (PCU), which is the correction factor for each vehicle, was computed by summing up each class of a vehicle and multiplying it by the PCU.

RESULTS

***Table 3.1**: Laboratory Results*

	Natural Moisture Content (%)	Particle size Analysis (%) passing	Atterberg Limit			Compaction test		California Bearing Ratio test
			LL	PL	PI	OMC %	MDD mg/m^3	
A	24.81	35.4	29.1	21	8	7.8	2.13	50
B	25.10	33.4	36.1	28	8	10.7	2.01	54
C	26.70	37.6	36.0	31	5	9.0	2.027	69

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***Table 3.2** Results analysis as compared with Federal Ministry of Works & Housing (1997) specification for Roads and bridges and AASTHO*

Samples	**A**	**B**	**C**
Sieve Analysis	35.4 Pass	33.3 Pass	37.6 Fail
LL	29.1 Pass	36.1 Pass	36.0 Pass
PL	21 Pass	28 Pass	31 Pass
PI	8 Pass	8 Pass	5 Pass
OMC	7.8 Pass	10.7 Pass	9.0 Pass
MDD	2.13 Pass	2.01 Pass	2.027 Pass
CBR	50 Pass	54 Pass	69 Pass

***Table 3.3**: Data for Vehicles Going to EFCC & FMC Hospital*

EFCC						FMC Hospital				
Time (am)	**Private Cars**	**Motorcycle**	**Bus/ Mini van**	**Truck/ Pickup**	**Tricycle**	**Private Cars**	**Motorcycle**	**Bus/ Mini van**	**Truck /Pick up**	**Tricycle**
9:00 - 9:10	43	2	1	0	0	24	8	1	0	0
9:10-9: 20	43	2	1	0	1	29	12	3	0	1
9:20-9:30	32	4	3	0	1	43	15	0	1	0
9:30 - 9:40	27	2	3	0	0	17	1	2	0	0
9:40 - 9:50	31	3	0	0	1	22	5	1	1	1
9:50-10:00	36	2	2	0	0	16	6	3	1	0
10:00-10:10	33	1	3	0	0	30	5	0	0	0
10:10-10:20	26	3	2	0	0	22	9	0	0	0
10:10-10:30	22	0	2	1	0	22	4	1	0	1
Total	293	19	17	1	3	225	65	11	3	3
PCU	1	0.5	2.3	3	0.5	1	0.5	2.3	3	0.5
Volume of Traffic (Total × PCU)	293	9.5	39.1	3	1.5	225	32.5	25.3	9	1.5

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Table 3.4: *Data for Vehicles Going to and Coming out from Baze University*

Morning						**Afternoon**					
Time (am)	**Private Cars**	**Motor cycle**	**Bus/ Mini van**	**Truck/ Pickup**	**Tri cyc le**	**Time (pm)**	**Private Cars**	**Motor cycle**	**Bus/ Miniv an**	**Truck/ Pickup**	**Tri cycl e**
9:00 - 9:10	64	12	3	2	0	**4:00–4:10**	25	11	2	0	0
9:10-9: 20	63	17	8	2	2	**4:10–4:20**	28	5	1	0	0
9:20-9:30	55	21	4	0	0	**4:20–4:30**	31	12	3	0	0
9:30 - 9:40	29	2	0	1	0	**4:30–4:40**	24	6	0	0	0
9:40 - 9:50	49	13	1	1	0	**4:40–4:50**	31	9	0	0	0
9:50-10:00	47	7	2	2	1	**4:50–5:00**	23	6	4	3	0
10:00-10:10	40	5	1	4	0						
10:10-10:20	43	8	4	2	1						
10:10-10:30	44	8	2	3	0						
Total	434	93	25	17	4		162	49	10	3	1
PCU	1	0.5	2.3	3	0.5		1	0.5	2.3	3	0.5
Volume of Traffic (Total × PCU)	434	46.5	57.5	51	2		162	24.5	23	9	0.5

DISCUSSION

Natural Moisture Content Determination

Estimating the soil's natural moisture content provides information on how much water is inside the soil when obtained at that particular period of time. The state of the soil for sample A has a natural moisture content of 24.81%, while the state of the soil for sample B has a Natural moisture content of 25.10%. However, sample C's soil state has a Natural moisture content of 26.70%. This result, therefore, shows that there is much water in the soil obtained; the availability of water in the soil affects the test that are going to be conducted as before conducting the test, all the obtained sample were dried in order to make sure the water content that is going to be used in each test were highly maintained by following the BS procedures.

Sieve Evaluation

The variety of particle sizes present in the soil is displayed by the particle size distribution study. The size of the soil particles can create voids and allow water penetration through the soil, which tends to cause damage by gradually creating small holes which later develop into

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potholes and other kinds of distresses on the road. For a sample to be utilized for road construction, it must pass the No. 200 sieves with a percentage by weight of less than but not more than 35%, as specified by the Federal Ministry of Work and Housing. In light of the aforementioned findings, the samples under examination were good samples, since with the exception of soil sample C, the percentage of soil by weight passing sieve No. 200 is no more than 35%. The outcome of this test therefore shows that the soil is suitable for building roads because it complies with the requirements.

Atterberg Limit Test (LL & PL)

This test helps understand the behavior of soil at which it transits from solid, semi-solid, plastic and liquid states when loads are applied. The soil classification for sample A is A-2-4, indicating that the soil sample is silt or clay-like gravel and sand that is exceptional and appropriate for construction, whereas the soil classification for sample B is A-2-4, indicating that the soil sample is silty or clayey gravel and sand that is excellent and useful for construction. In addition, the soil classification for sample C is A-4. The soil sample is silty soil which is fair to poor and partially fair for construction. More so, these results show that the materials used for the construction are suitable for road construction as they can withstand applied loads without transiting to the poorest state.

Compaction Test

This test establishes soil's dry density/moisture content relationship under controlled conditions. According to O'Flaherty (1988), the following ranges of data can be expected when utilizing typical proctor testing procedures: for clay, optimal moisture content (OMC) could vary between 20-30% and MDD may fall within 1.44-1.685mg/m3. Silty clay had an OMC of 15-25% and a Maximum dry density (MDD) of 1.6-1.845mg/m3. Sandy Clay has an OMC of 8 to 15% and an MDD of 1.76-2.165mg/m3. As a result, the result from Sample A indicates that the soil material is sandy clay, the result from Sample B indicates that the soil material is sandy clay, and the result from Sample C indicates that the soil material is sandy clay as well.

Furthermore, the results for compaction gave the idea of the percentage of water used in order to maintain the strength of the soil, thereby decreasing the porosity also by maintaining the percentage of water gotten from the test, it tends to provide the total number of compaction to be employed in road construction while in situ test is done after the compaction to check whether the value gotten from the test of dry density is maintained in order to ensure that the road is stabilized and it has attended its maximum strength.

California Bearing Ratio Test

The California bearing ratio analysis evaluates the subgrade and subbase material's strength. According to the Federal Ministry of Works and Housing (1997), sub-base material must have a minimum CBR value of 30% after soaking for 24 hours. All three samples agreed with the Federal Ministry of Works and Housing value based on these standards. The test yielded a CBR value of 50% for Sample A, 54% for Sample B, and 69% for Sample C respectively. Thus, the soil materials are suitable for road construction.

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Traffic Volume Study

This traffic study gives an idea of the number of vehicles accessing the FMC road. Various organizations are located in the study area, all using the road as access. Therefore, for better accuracy, the vehicles entering and going out of the road, vehicles going to Economic and Financial Crimes Commission (EFCC), Federal Medical Centre Hospital (FMC) Hospital, and Baze University were counted in the morning and afternoon.

Furthermore, from the data obtained and calculated for Average daily traffic (ADT), about 35.65 veh/h of different types of vehicles used to access the Federal Medical Center road during the morning hours while 37.78 veh/h for afternoon. Private cars have the highest number of people accessing the road, followed by motorcycles and truck/pickups. More so, the least amount of value that was obtained is for tricycles from all the organizations, because most people use private cars.

Furthermore, morning entry has the highest number of vehicles accessing the organizations as workers and students resumed to their offices and school at early hours. While evening entry got the least number of vehicles at that hour of counting, which is from 4pm to 5pm, this might be due to some students and staff that might have left around 1pm, 2pm, or 3pm, while most close around 6pm. The study also shows that Baze University has more vehicles going in and coming out from the institution both morning and afternoon compared to EFCC and FMC Hospital, which has the least number of vehicles. From the visual investigation, it has already shown that the end of the road towards Baze University has a severely damaged path; this is also a result of the more gradual movement of vehicles that the investigations show because vehicular loadings are also factors that cause the road to damage and most of the trucks pass through the end path because some major site a located there and also due to severe damaged of the drainage system. In addition, the overall vehicles entering and going out through the roadway are about 125.73 veh/h. This study was conducted at a maximum of 1:30 minutes due to lack of manpower, and the time of counting started at 9:00am, when some vehicles had already accessed the road, consequently limiting the accuracy of the volume studies results.

CONCLUSION

This study aimed to determine the cause of road failure along Federal Medical Center Road and propose optimal solutions. It involved conducting traffic volume studies to determine stresses due to vehicular loadings, conducting laboratory investigations on soil samples, and conducting California Bearing Ratio tests. Traffic volume studies were conducted by counting the number of cars going in and out of the road during early hours and late hours. Natural moisture content was determined by placing the soil sample in cans and oven-drying it for 24 hours. Sieve analysis was performed using various sieve sizes and manual sieving.

Atterberg limit (LL and PL) tests were conducted using a sieve 200mm and Casagrande apparatus. Compaction tests were modified by adding 3% water to the soil and compacting in 5 layers with 65 blows with a 4.5kg rammer. California Bearing Ratio tests were performed using a CBR machine to check soil strength and stability.

The results showed that the soil types for all samples were A-2-4 (silty or clayey gravel and sand), with the exception of a sample classified as A-4 (silty soil). The optimal moisture content

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for all samples was 7.8, 10.7, and 9.0%, while the maximum dry density was 2.13, 2.01, and 2.027 mg/m3. The OMC values were suitable for all samples, and the soaked CBR values were 50, 54, and 69, respectively.

Many studies have evaluated flexible pavement failure using laboratory tests, electrical resistivity imaging (ERI), and software like BISAR software. However, the literature gap lies in terms of location and other parameters, such as weather conditions and temperature variations.

In conclusion, the test findings demonstrated that the soil materials employed along the Federal Medical Centre Road were exceptional, good, and appropriate to support road building/construction. Factors contributing to road failure include bad drainage conditions, poor workmanship, lack of sloping, and improper shoulder treatment.

RECOMMENDATIONS

After the conclusion of the laboratory experiment and traffic volume study, the following suggestions are highly recommended:

a. To extend the life of the, the nearby drainage system needs to be properly repaired or rebuilt.
b. Sloping of the road is strongly advised in order to drain off the water from the surface of the pavement.
c. The damaged road section needs to be correctly repaired using suitable materials.
d. The shoulder of the road should be treated properly.
e. Ensuring the maintenance of any kind of defect on the road is carried out at suitable time.

Generally, this study was carried out to assess the reasons behind pavement failure. The current study carried out a few carefully chosen laboratory tests to examine the soil's material properties and traffic volume studies to ascertain stresses due to vehicular loadings. The study could be expanded to include in-depth laboratory investigations on asphalt.

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