THE EFFECT OF VEHICLE TYPE ON THE QUANTITY OF MATERIAL LOST FROM AN UNPAVED ROAD SURFACE

BY

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REG. NO: PGD/CIVIL ENG/2008/025

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BEING FINAL YEAR PROJECT SUBMITTED TO THE DEPARTMENT OF CIVIL ENGINEERING IN PARTIAL FULFILMENT FOR THE AWARD OF POST GRADUATE DIPLOMA (PGD)
IN CIVIL ENGINEERING,
FEERAL UNIVERSITY OF TECHNOLOGY, MINNA.

FEBRUARY, 2011

DECLARATION

I, OCHIGBO IDU CLEMENT (ADMISSION NO:PGD/CE/08/025 A CANDIDATE of Civil Engineering Department, Federal University of Technology, Minna hereby declare that the project titled "Effect of Vehicle Type on the Quantity of Material lost from an unpaved surface" carried out by me is my original work. All sources of information have been duely acknowledged.

-- 24-02-2011
Ochigbo Iduh Clement | Date
Reg. No. PGD/CE/08/025

CERTIFICATION

This is to certify that this project "Effect of vehicle type on the Quantity of Material Lost From an Unpaved Road Surface" was carried out wholly by him under supervision and submitted to the Department of civil Engineering, federal University of Technology, Minna for the award of PGD in Civil Engineering.

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Prof. S Zubaine Dean S.P.G.	Date

DEDICATION

This entire project work is dedicated to my understanding and caring family members. Cecilia O. Ochigbo my lovely wife and Agnes, Doris, Dorathy, Anne, Clementina who supported me with their prayer to God Almighty for the success of this program. I love you all.

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TABLE OF CONTENTS

		Page
Title Page		i
Declaration		ii
Certification		iii
Dedication		iv
Acknowledgements		v
Abstract		vi
Table Of Content		vii
List of Table		ix
List of Figures		x
List of Plates		xi
CHAPTER ONE:	INTRODUCTION	
1.1	Background	1
1.2	Problem Statement	2
1.3	Aim and Objectives	3
1.4	Scope of Study	3
CHAPTER TWO:	LITERATURE REVIEW	4
2.1	Unpaved Roads	4
2.2	Material Loss	6
2.3	Vehicular effect	7
2.4	Road Dust. Its Generation Mechanism And Impact	12

ABSTRACT

Five different test vehicles of differing sizes and weights subjected to the same conditions generated varying amounts of road dust per vehicle pass ranging from 24. 47g – 214 20g on 100m section of road leading to Shintaku in Basssa Local government area, Kogi state. To generate this dust, the five vehicles were individually made to run across the marked road section at varying speeds while other factors were constant. Results from suitable road/soil test and analysis showed that the bulk sample of the road bed material gave a silt fraction of 11.60% (which is a measure of the mass of particles less than 75µm in diameter) and a moisture content of 0.32%. The experiment showed that dust emission rates depend highly on the fine particle content of the road (silt content) and on the vehicle characteristics such as weight, clearance and speed. Suggested solutions for remedial treatment include use of Chemical suppressants (which may be either wetting or binding agents), use of bituminous seals, coating with hygroscopic and deliquescent chemicals (like Calcium Chloride and Sodium chloride) and use of organic Binders. The ultimate solution to material loss from unpaved road is paving.

CHAPTER THREE: MATERIALS AND METHODS 16

3.1 Project Site 16

3.2 Materials Used 17

3.3 Vehicle characteristics 18

3.4 Experimental Methods 19

CHAPTER FOUR: RESULTS AND DISCUSSION 22

4.1 Results 22

4.2 Discussion Of Results

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS 41

5.1 Conclusion 41

5.2 Recommendations 41

5.3 References 43 - 47

LIST OF TABLES

Table	Title	Page
Table 3.1	Environmental Conditions at the site	17
Table 3.2	Characteristics of Test Vehicles Used	19
Table 3.3	Test Vehicles Used And Their Variable Speed Limits	20
Table 4.1	Quantity of Road dust Collected at each Test speed per Test vehicle Used	22
Table 4.2	Amount Of Road dust generated by Tractor at varying Speeds	23
Table 4.3	Amount Of Road dust Generated by Toyota Dyna Truck at varying speeds	24
Table 4.4	Amount Of Road dust Generated by Nissan Blue Bird Wagon varying speeds.	25
Table 4.5	Amount Of Road dust Generated by Toyota Liteace Bus at varying speeds.	26
Table 4.6	Amount Of Road dust Generated By Peugeot 504 at varying speeds	27
Table 4.7	Exponents of the speed value for the different test vehicles in relation to their emissions	28
Table 4.8	Results of Particle Size Analysis of Road dust Emissions	31

LIST OF FIGURES.

Figure

Figure	Title/description	Page
Figure 4.1	Amount of Dust Collected Against Tractor speed.	23
Figure 4.2	Amount of Dust Collected Against Toyota Dyna Truck speed.	24
Figure 4.3	Amount of Dust Collected Against Nissan Blue Bird Wagon speed.	25
Figure 4.4	Amount of Dust Collected Against Toyota Liteace Bus speed.	26
Figure 4.5	Amount of Dust Collected Against Peugeot 504 speed.	27
Figure 4.6	Particle size analysis of road dust emissions.	28
Figure 4.7	Particle size analysis of sample road bed material.	32

LIST OF PLATES

Plates	Title/description	Plates
Plate I	Map showing Project site.	
Plate II	Pictures of Tractors showing dust emission during the experiment.	16
Plate III	Pictures of Nissan Blue Bird Wagon showing dust emission during the experiment.	29
Plate IV	Pictures of sample road dust emitted by a test vehicle during the experiment.	30

CHAPTER ONE

INTRODUCTION

1. 1 Background to the Study

There is a growing concern by most national governments, regulatory agencies, industry, stakeholders and the public worldwide on the Impacts of material lost from unpaved road surface due to vehicular traffic on these roads, .Particles suspended by vehicles running through unpaved roads constitute road wear and tear and contributes to road dust. This affects different aspects of a nations economy and livelihood of its populace in the areas of health, agriculture and above all , environmental hazards

In developing countries like Nigeria, farm/ market roads, feeder road and rural roads constitute a reasonable percentage of unpaved roads

Majority of these unpaved roads lead to localities where food, agricultural raw materials and others industrial raw materials are being produced. While these roads carry a small portion of the country's traffic , they provide a vital first link in the country's economy. However, these routes are being neglected and as such are associated with traffic accidents, dust and high cost of vehicle maintenance. It is thus imperative to give serious thought and consideration to unpaved roads and hazards associated with them in order to improve on the agriculture and industrial production and equally avoid environmental pollution.

1.2 problems statement.

One major and obvious problem associated with all unpaved roads is dust. To residents living along unpaved roads the airborne dust can penetrate their homes causing a nuisance and health problems such as hay fevers and allergies. Dust can also be a conveyor of other diseases the fine suspended dust particles contribute significantly to the particulate loading in the atmosphere making road dust one major source of air pollution. The dust cloud formed when vehicle use these roads can impair visibility and cause a hazard to motorist . The fine abrasive particles can also greatly increase the wear and tears on the moving parts of vehicles. The dust can also pollute nearby surface water and stunt crop growth by shading and clogging the pores of the plants.

Besides polluting the environment , the generation of dust means the loss of fines, which act as road surface binders. This represents a significant material and economic loss. The severity of the dust problem is determined primarily and by the speed of vehicles, the abrasive resistance of the road aggregates and the amount of fines in the initial aggregate mix.

The volumes of traffic and the climatic condition of the region can also aggravate the road dustiness. The loss of fines from the road surface as dust leads to the coarser aggregates becoming loose and therefore can be throw or washed away from the road surface. The resulting road is one that is

CHAPTER TWO

LITERATURE REVIEW

2.1 Unpaved Roads

Unpaved roads comprises of the major part of most road networks, amounting for example to 81% of all road in a major survey of developing countries but varying with the per capital income and population density from about 90% in Africa and Latin America down to about 70% in Asia, Europe and Middle East (World Bank 1997).

Over 70 percent of the local roads in Nigeria are unpaved. They can be found in agricultural areas and forest; and even in many cities and villages. The proportion of the total traffic carried on these roads varies widely ranging from a few vehicles to up to several hundred vehicles per day, but the economic importance of these is often appreciable since many provide the farm to market access in rural areas. While they can only carry a small proportion of a nation's traffic, they are vital first link in the local economy.

A variety of definitions have been used to classify unpaved roads onto gravel and earth roads. The term " earth road" is sometimes used to denote a track as opposed to an engineered road. In Kenya study of road deteriotion, "earth road" described all unpaved engineered roads for which the surfacing material was outside the material gradation specification for gravels of the Kenya ministry of works (Hodges, et al, 1975) In the Brazil study, "earth road" denoted those roads having a surface of predominantly fine soil materials with more than 35% finer than 0.075 mm particle size (Geipot, 1982) in the present study, this last definition has been adopted because of it simple physical definition.

The dust generation potential of a given unpaved road is dependent on several factors including climatic effect of wind and rainfall, nature of surface (gravel or dirt) and traffic volume especially during the dry season of the year. The source of dust from unpaved surface is largely from roadbase material. For instances where the road is narrow and ineffectively curbed, the unpaved shoulders can be another significant source (U.S.EPA1998).

Traffic on unpaved roads produce about 35% of atmospheric pollution worldwide. Of this 28% is from dust while 7% is from exhaust fames (U.S. EPA1998). In addition to polluting the air, dust can be a health problem for nearby residents. It also settles on plants around the road side, slowing their growth and reducing crop yields. The dust generated from these road surfaces equally reduces visibility and vehicle efficiency (Noss, 1999). During the wet season, these roads are prone to erosion, which makes them slippery and quite risky to travel by. Accidents on this roads could lead to damage of agricultural produce, industrial raw materials and finally economic instability (U.S Federal Highway Administration 1998).

2.2 Material Loss

Materials lost from unpaved road surface are in the form of road dust.

Table 4.9	Results of Particle Size Analysis of Sample Road bed material.	32
Table 4.10	Vehicular Traffic On Market days.	33
Table 4.11	Vehicular Traffic On Ordinary days.	34

Road dust is defined as road aggregate that become airborne as a result of the abrasive action of traffic. The particle size distribution of dust from unpaved roadways depends on the type of road surface. Road dusts emitted into the atmosphere may be categorized according to dust particle size into"

i. Particulate matter less than or equal to 2.5 µm (PM^{10})'

ii. Particulate matter less than or equal to 10 µm (PM2 5);

iii. Particulate matter less than or equal to 39 µm (PM 30)

iv. Particulate matter less than or equal to 75 µm (silt fraction).(U.S. EPA 1998)

The loss of material from unpaved road surface is mainly as a result of soil particles not binding together with the dust constituent on the road surface and also as well as the non-redistribution of applied vehicle load,. This leads to a loose and less cohesive road material structure.

When these particles are lost as road dust, it damages the gravel surface and exposes the larger aggregate pieces. These are then scattered by vehicles or washed away. The unstable road surface becomes rough, developing potholes and tyre tracking. These hold water, which infiltrates and damages the base. In addition, this leads to higher surface irregularities that in turn give rise to increase in vehicle operating costs, environmental hazardous effects and traffic accidents (U.S) Federal Highways Administration 1988).

Field investigations have shown that emissions depend on the associated vehicle traffic and source parameters that characterize the condition of a particular road like it's silt content and moisture content (U.S EPA 2003)

2.2.1 **Silt Content Of The Road Surface**

Open field measurements show that the proportion of particles that are in Suspension is approximately equal to the proportion of particles less than 75 microns present in the soil on road surface (Monsanto Research Corporation, 1979). Studies have found that dust emission rates depend on the fine particle content of the road (Cowherd et al, 1990; MRI 2001). Reducing the silt or fine content of the top layer of the road surface will significantly reduce the amount of dust that will be kicked up into the air.

2.2.2 **Soil Moisture Content**

As the moisture content of road surface aggregates increase, the cohesive force between the soil particles increases and the rate of road dust generation decrease (Mansanto Research Corporation, 1979, Nicholson et al, 1989)

2.3 Vehicular Effect

When a vehicle travels on an unpaved road the force of the vehicle on the road surface breaks the surface material into fine particles. Tests have shown that fine particles are continually removed by traffic through re-entrainment to the atmosphere, leaving a higher percentage of coarse particles on the road surface (USEPA, 1998). These fine particles are lifted by and dropped from the rolling wheels of vehicles, and the road surface is exposed to strong air currents in turbulent shear with the surface. The turbulent wake that is left behind the vehicle continues to act on the road surface after the vehicle has passed, resulting in further particulate loss. The volume of this particulate loss depends on vehicle weight, speed, number of wheels, tyre type, size and contact area, if all other factors are constant.

The total weight of the vehicle determines the total pressure or force per unit area acting on the road surface. Based on soil characteristics, the road surfaces respond differently at each different section to the different weight exerted by the vehicles. Hence, the higher or greater the weight, the greater the pressure and soil breaking force leading to high emission of particles. The reverse is the case when the weight is low.

On the other hand, the vehicles speed forms and creates the velocity known as thresh-old velocity, which is responsible for the initiation of particulate movement. The greater the speeds of the vehicles traveling over an unpaved road, the greater the amounts of dust that will be generated. Therefore, reducing the speed of vehicles on an unpaved road will reduce the amount of dust kicked up into the air . Emission of particles less than 2 microns in size is proportional to the vehicle speed, while those less than 10 million microns in diameter are proportional to the square of vehicle speed (Monsanto Research Corporation, 1979; Nicholson et al.; 1989). The tyre contact area with the road surface varies with tyre size, the greater the contact area, the greater the particle of the soil being broken. Research by Roberts et al (1975) in the USA stated that, on gravel roads each vehicle-kilometer run at a traffic speed of 32km/hr contributed 2kg of fine material to the air. This is equivalent to 73 tons per kilometer per year. In both cases, the emission of dust from the road varied as an exponent of speed.

In a study done by Jones in Kenya (1981) to quantify the amount of dust removed by traffic and to identify the effect of traffic speeds, he found out that about 25 tons could be lost annually per kilometer on unpaved roads carrying 100 vehicles per day and traveling at 75km/hr.

In 1983, USDA Forest Service reported that, a single vehicle traveling an unpaved road once a day for a year will produce 1 ton of dust per mile, this translates to losing 100 tons of fine particles a year for each mile of road with an average of 100 vehicles a day. It also showed that the amount of dust produced is related to vehicle speed, cutting average vehicle speeds from 40 mph to 35 mph will reduce dust emissions by 40%.

Reckard, (1983), succarieh (1992), and Bennett (1994) have proven that other factors including; road condition, road length, traffic characteristics (volume, type weight, number of wheels, speed, tires width etc.) number of vehicle passes, the silt and moisture content of the road surface material being disturbed, particle size distribution, and climatic conditions affect the quantity of emissions from unpaved roads.

Individual studies in the past, by Nicholson et al, (1989), Cowherd et al, (1990), U.S. EPA,(1996, 2003) and MRI, (2001) have found that dust emission rates depend on the fine particle content of the road, soil moisture content, vehicle speed, and vehicle weight MRI further reported that for unpaved roadways, Another report by Zachel (1986), summarizing dust data collected as part of ongoing annual monitoring activities along the West Road at Prudhoe Bay, USA showed similar dispersal results to earlier studies. Fallout decreased rapidly as distance from the road increased.

Again, in 1997, it was reported that road dust settles up to 500 feet (about 152m) from the road edge (Wisconsin Transportation Bulletin No.13). Further more, (Watson and Chow, 2000; Countess, 2001) observed that dust particles emitted from unpaved roads can deposit to an appreciable extent within several hundred meters downwind of the road, though the fraction of particles removed varies greatly based on setting and atmospheric stability.

Apparently there have been various attempts by different people to develop devices and procedures that would measure road dust. Also, several studies have proposed mathematical models for generation and distribution of particulate emissions from various sources (Robinson. et al., 1971), and (Becker, 1978), Becker, (1978), examined a Gaussian plane model applied to dust generated from unpaved roads lowa and Kansas. Included were limited field measurements, using a high volumetric sampler and mechanical analysis of collected particulate.

Notable among the devices and procedures that would measure road dust were those of Wellman and Barraclough (1972), Hoover et al. (1973), Schultz (1983), Langdon (1984) and Irwin et al. (1986) to name a few. Some of the measuring techniques used stationary devices, which characterize road dustiness at a particular point while others used moving devices, which provided dust measurements that describe a section of road. The dust quantification method common among all the previous works was either the weighing of the collected dust or the measurement of air opacity using visible light.

Another type of static dust monitoring device records the amount of interference between an infrared transmitter and receiver (Jones, 1999). This infrared devices is triggered when a vehicle passes the measuring station; however not all infrared wavelengths from 88907 sunlight can be filtered out under some circumstances this affects the accuracy of these measurements.

The accuracy of measuring dust at a points along the road has been challenged and in recent years new method for estimating road dust emissions have been developed. The TRAKER (Testing Re –entrained Aerosol Kinetic Emissions from Roads) allows for measurement of PM10 and PM2.5 emissions. The concentration of airborne particles in a specific size range is monitored with particle sensors are influenced by the road dust generated from the interaction of the vehicle tire and the road. Tests by Kuhns et al, in 2001 indicated that the TAKER signal increases as the cube of the speed for a given road dust loading,

2.4 Road dust, its generation mechanism and impact

Road dust consists of inorganic material in the size range of silt and clay particles along with some organic matter. Quantitatively, the dust contains about 8% (by weight) of particles less than 5μm, 24% less than 30μm and 68% greater than 30μm (Orlemann et al., 1983).

Road dust is related to dryness. Fines absorb moisture that increases their particles, which could lead to damage to windshields. Also, when a particle bounces at the road surface, it could hit smaller particles getting them into suspension. Creep involves the slow movement of the road surface caused mainly by the direct impact of saltation grains that are too heavy to be dislodged into the air.

The impact of road dust as identified and examined by this experimental study includes impact on: health, safety, aesthetics, vegetation, soils and aquatic sources (Techman Engineering Limited, 1982).

2.44 Impact of road dust on health

Unpaved roads are the largest source of particulate air pollution in the country. According to the Environmental Protection Agency, unpaved roads produce almost five times as much particulate matter as construction activities and wind erosion (the next two largest sources) combined. In addition to polluting the air, dust can be a health problem for nearby residents. Health reviews have shown that particulate matter as construction activities and wind erosion (the next two largest sources) combined. In addition to polluting the air, dust can be a health problem for nearby residents. Health reviews have shown particles greater than 10 µm primarily lodge in the oral and nasal passages. The particles are largely eliminated by natural body processes and do not penetrate further into the respiratory tract (Battigelli, 1969; united Nations, 1979). Particles smaller than 10 am often called PM-10 can travel deep in to the respiratory tract and may lodge in the lungs. These PM-10 particles have been shown to cause respiratory aliments in the young and the elderly. The PM-10 particles also can trigger asthmatic attacks in the sensitive segment of the population (Weisskopf , 1991).

2.45. Impact of road dust on safety.

Accident potential is greater on unpaved road as oppose to paved surfaces. This increase in accident potential is due to loss of visibility, skidding Swaying of vehicles, less positive steering response, longer stopping distance, and broken windshields from flying aggregates (Hoover, 1971).. Studies have shown that about 230 percent more people are killed on unpaved road per vehicle kilometer as compared to paved road in the United states and this is due to visibility and skidding (U. S federal Highway Administration !998).

In Nigeria, about 155 persons die yearly and about 153 are injured as a result of slipperiness of unpaved roads in the wet season, poor Geometric standard of unpaved roads, and reduced visibility in the dry Seasons. (Federal Road Safety commission 2001).

2.46 Impact of road dust on aesthetics

Dust generated by unpaved roads produces an immediate visual Impact, which effects the residents living adjacent to these roads (Techman Engineering Limited, 1982).

2.47 Impact of road dust on vegetation

During hot weather, a coating of dust on leaves could increase solar Heat absorption and decrease transpiration causing a heat build –up in these leaves. This could result in reduction in leaf water content, Chlorophyll content and carbon uptake as well as an increase in plant water temperature, mineral ion concentration and p^H, thereby slowing down growth and reducing crop yields (succarieh 1992) emissions vary with speed raised to a power typically between 1 and 1.5. they suggested that physical characteristics of the vehicles such as shape and number of tires and tread pattern may have only a minor influence on the emissions.

The US Environmental Protection Agency's *Compilation of Air Pollutant Emission Factors* for unpaved roads (AP-42, Section 13.2.2) indicates that dust emissions from unpaved roads vary linearly with the volume of traffic traveling along the road (USEPA 1998). EPA also provided an equation for estimating dust emissions factor for unpaved roads (USEPA 2003 emission model).

A study of particulate emission rates for un paved shoulders conducted by Hoosmuller et al (1998) looked at developing an empirical estimate of particle emissions. The study focused on developing a measurement methodology, identifying the mechanisms that suspend dust, and qualifying PM10 emissions in an emission rate. Observations indicated that large vehicles (traveling over 50 mph) generated significant dust entrainment. In another study that looked at highway runoff in Washington State (Wick et al 1980), the authors theorized that solids adhering to vehicles traveling on unpaved roads can be released on highways, providing a source of dust.

Few studies reviewed looked at dust dispersal. As part of a study to identify the major impacts of the West Roads at Prudhoe Bay in USA, Klinger et al (1983) conducted a dust study to measure the quantity and quality of dust falling on experimental plots. The study found that the main dust impact occurred within 30m of the road.

weight substantially and holds them down. When the moisture evaporates, because of an arid climate or a dry season the fines become lighter and are prone to be stirred up and blown away. It's impossible for fines to be an effective binder when they have dried completely because they lose their binding ability.

The process of dust /generation begins as the surface crusts dries out and start breaking up. As more of the surface material is exposed to the drying effects, tyre abrasion separates coarse from fine particles and soon lifts up the accumulated dried fines as dust. The possible mechanisms for dust generation under these conditions are vortex entrainment, slippage entrainment, and saltation and creep. These mechanisms are discussed briefly below (Techman Engineering Limited, 1982).

2.41 Vortex Entrainment

Dust is pumped into the air as a compression and expansion caused by the passage of a vehicle over unpaved roads. This constitutes a very small percentage of generated dust on unpaved roads.

2.42 Slippage Entrainment

Slippage between the tyre and road is the largest contributor to road dust generation. This mechanism of road dust generation is known as slippage entrainment and is responsible for about 90% of traffic generated dust.

2.43 Saltation and Creep

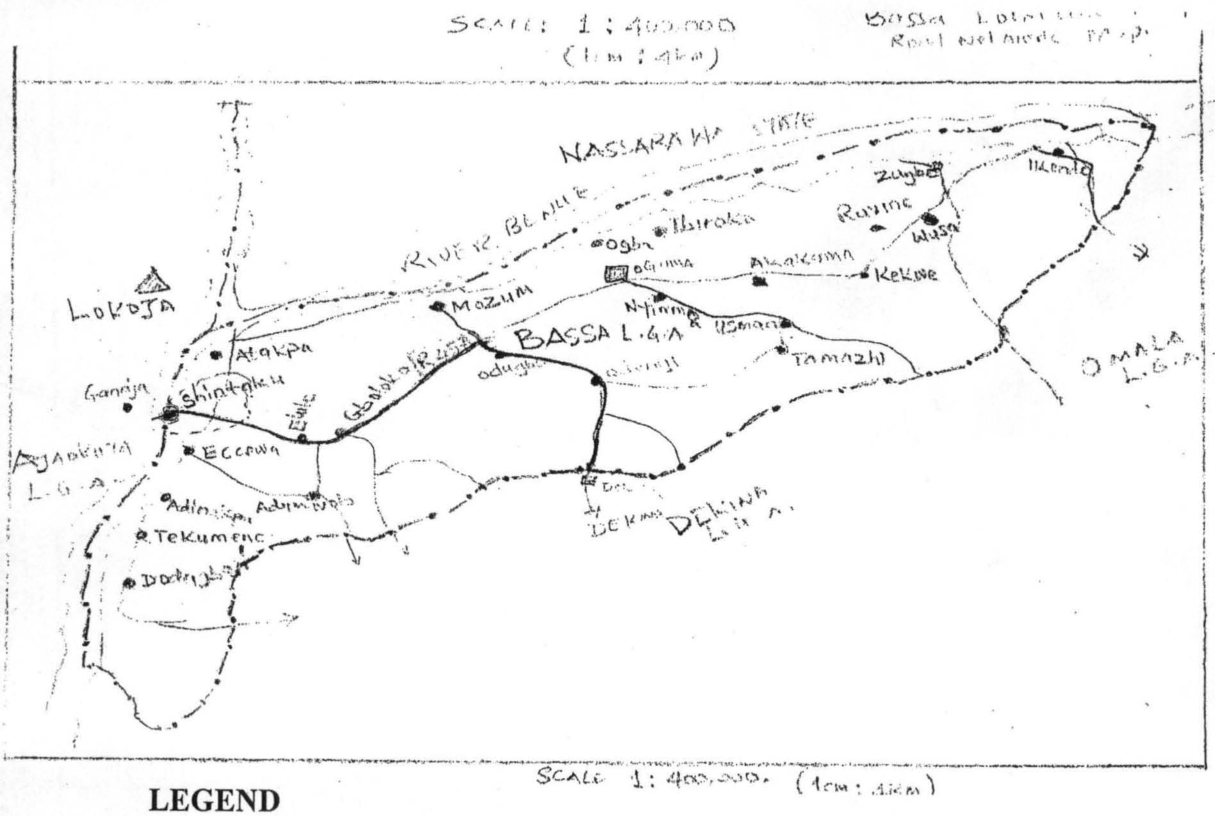
Aggregates of large size (>10 microns) may become suspended via saltation and surface creep (Cannessa, 1977). Saltation involves the bouncing of

CHAPTER THREE

MATERIALS AND METHODS

3.1 Project Site

The experiment was conducted on a section of an unpaved road leading to Shintaku Village Bassa Local Government in Kogi State. Length of the road is 12km,(Gboloko-Shintaku), a 100m section was chosen in a fairly straight portion along this length b/t k71 + 000 – km 71 + 100. This section of the road chosen depicts the nature of farm, rural and feeder roads network in the district.



LEGEND

Local Government Boundary	- - - - - - - - - - -
Local Government Headquarters	■
Towns And Villages	●
Federal Roads	━━━━
Stare/Local Government	────
Rivers	═══

PLATE 1: Map showing Project sites.

The Length of the road section in consideration, $L = 100m$

The Width of the road section, $W = 7.3m$

The Area of the road section, $A = 730_{m}^{2}$

Table 3.1 below contains the average value of the project sites

Environmental conditions recorded during the days the experiment was conducted

Table 3.1 Environmental conditions at the Site

Environmental Conditions	**Average Value**
Temperature	35.75°C
Solar Radiation	
Relative Humidity	**24.5%**
Wind Speed	**7.3km/hr**
Latitude	**North East**
Wind Direction	**10°N**

3.2 Materials Used

Major equipment and instruments used during the experimentation period include:

(1) ***measuring tape***

Name of Manufacturer: Tricle Ltd, Shanghai China

Length: 50 meters

Type: long fibre ramie yarn

(2) Potentiometer winds vane (AY77)

Name of Manufacturer: Vector Instrument, England

Type W200P

Serial No: 5878

(3) Digital Measuring Instrument for Temperature and Humidity

Name of Manufacturer: Alder UK

Serial No: 00507

(4) APEX AT size Thick papers

Name of Manufacturer Square Ltd. China

Type: Metallic

(5) Thumb Tacks

Name of Manufacturer: Square Ltd, China

Type: Metallic

(6) **5 Test Vehicles** (a detailed description is contained in paragraph 3.21)

(7) Switching Anemometer

Name of Manufacturer: Vector Instrument, North Wales England

Type: A100R

Serial No: 4895 1984 series

(8) Sun radiation Measuring Equipment

Name of Manufacturer: H.H.P (T) LTD LONDON

Type: Gun blanner

Serial No: RHAI 037

(The values for the wind speed and sun radiation were measured from the equipment named in 7 and 8 above respectively located in Kogi state University, Geography department, K.S.U., Anyigba.

1.1 Vehicle Characteristics

A mix of 5 test vehicles covering a substantial range of weights, length and width dimensions were used for the experimentation. As can be seen from Table 3.2 they include a Tractor (Fiat 666 model), Nissan Blue Bird Wagon (SLX model), Toyota Truck, Toyota Liteace Bus, and Peugeot 504 car Wagon.

Table 3.2: Characteristics of Test Vehicles Used

Vehicle type	Weight (kg)	Tyre treading	Tyre pressure (kg/cm^2	Clearance (m)	Exhaust pipe position
TRACTOR Fiat 666 Model	4200	Zig-Zag	Fron 40 Rear 15	0.52	Vertically Upward on Left side
NISSAN Blue Bird Wagon SXL model	969	Zig-Zag	Fron 40 Rear 37	0.23	Horizontally Backward on Right side
TOYOTA Dyna Truck	1778	Zig-Zag	Front 50 Rear 46	0.40	Horizontally Backward On left side
TOYOTA Liteace Bus	1600	Zig-Zag	Fron 44 Rear 42	0.34	Horizontally backward on right side
PEUGEOT 504 car	1350	Zig-Zag	Front 40 Rear 36	0.25	Horizontal Backward on Right side

1.2 Experimental methods

A 100m fairly straight section of the unpaved road leading to Shintaku was used for this experiment .this road section was marked and was closed to traffic during the experiment.

The thermometer, hydrometer, and wind vane and anemometer were fixed 3m from the road edge on one side of the road to determine the atmospheric condition at the experimental site.

Thick papers of A1 size were placed and pinned down 2m away from the edge of the road covering a width of 2m on either side of the marked road section for the collection of fine material dislodge from the road during the experiment.

5 different test vehicles (described in paragraph 3.3e above) were made to run one after the other at varying speed on its own 100m section. Each test vehicle was made to go through 8 passes at the same speed starting from the lowest, after which the speed was increased incrementally to the maximum . samples of the airborne fine materials dislodged from the road at each speed were collected and weighed in accordance with the vehicle and speed generating it.

The tape was used to measure the clearance and the tyre width for each of the test vehicles used. Also the trye pressure, threading as well as exhaust pipe position of the 5 vehicles was noted. varying speed ranges were adopted for the different test vehicles used. Table 3.3 below shows this in detail.

Table 3.3 Test vehicles used and their variable speed limits

Test Vehicle Speed km/hr	Tractor (fiat 666 model	Nissan Blue bird wagon	Toyota Truck	Toyota Liteace Bus	Peugeot 504 car
1st speed (km/hr	10	10	10	10	10
2nd speed (km/hr	15	15	15	15	15
3rd speed (km/hr	20	20	20	20	20
4th speed (km/hr	25	-	-	25	25
5th speed (km/hr	30	30	30	30	30
6th speed (km/hr	-	40	40	40	40
7th speed (km/hr	-	50	50	50	50
8th speed (km/hr	-	60	60	60	60
9th speed (km/hr	-	70	70	70	70

Mean that the was no vehicle run at this speed"

The speed adopted for the Tractor were function of capability of the Vehicle and not an experimental limit.

At the experiment, all materials, equipments and test Vehicles used were removed from the road and the road opened to traffic.

All the dust samples collected were weighed in the Laboratory and an average was calculated for the 8, passes for each speed and vehicle. Subsequently, their particle size distribution, moisture content and Plasticity were determined.

Traffic count

Traffic count was conducted for a period of one week. The purpose of the traffic count is to identify the intensity of vehicular traffic on the road and hence help us in determining / calculating the quantity of road base material lost to this traffic. The count is grouped into two :that market days and non- market days.

On market days , which are Wednesdays and Saturdays, the traffic on the road is usually high as compared to non- market days where the vehicular traffic is usually low. The result of the count is presented in chapter four.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Results

4.1.1 Dust Generated

The table below contains the average quantity of road dust collected for each speed per vehicle

Table 4.1: Quantity of Road dust Collected at each Test Speed per Test vehicle Used (vehicle weight remaining constant).

Quantity of road dust collected at each speed/test vehicle (g) speed					
Test Peed (km/hr)	Tractor (Fiat 666 model)	Toyota Truck	Toyota Liteace Bus	Nissan Blue Bird Wagon	Peugeot 504 car
10	24.47	30.10	31.00	31.27	32.10
15	40.90	56.20	58.80	59.90	61.00
20	65.70	75.30	77.50	78.60	80.10
25	67.90	N.R	78.10	N.R	81.40
30	74.20	77.40	79.70	80.70	82.70
40	N.R	80.40	83.60	85.40	88.90
50	N.R	119.60	123.70	126.60	129.90
60	N.R	162.50	168.30	175.65	176.70
70	N.R	193.70	199.00	207.72	214.20

* N.R.* indicates that there was no vehicle run at that speed and hen no dust collected

The table 4.2 below contains the average road dust collected on each side of the road, the total weight of dust collected, and the normalized total weight of dust (obtained by linear regression) against each Tractor speed

Table 4.2: Amount Of Road dust generated by TRACTOR at varying speeds

Speed (km/Hr)	Dust collected On Left side of road (g)	Dust collected on Right side of road (g)	Total weight of dust collected (g)	Normalized Total weight of dust (g)
10	15.30	9.27	24.47	29.34
15	21.70	19.20	40.90	41.99
20	36.20	29.50	65.70	54.63
25	38.58	31.10	67.90	67.28
30	38.50	35.70	74.20	79.93

Direction of wind: Right to Left

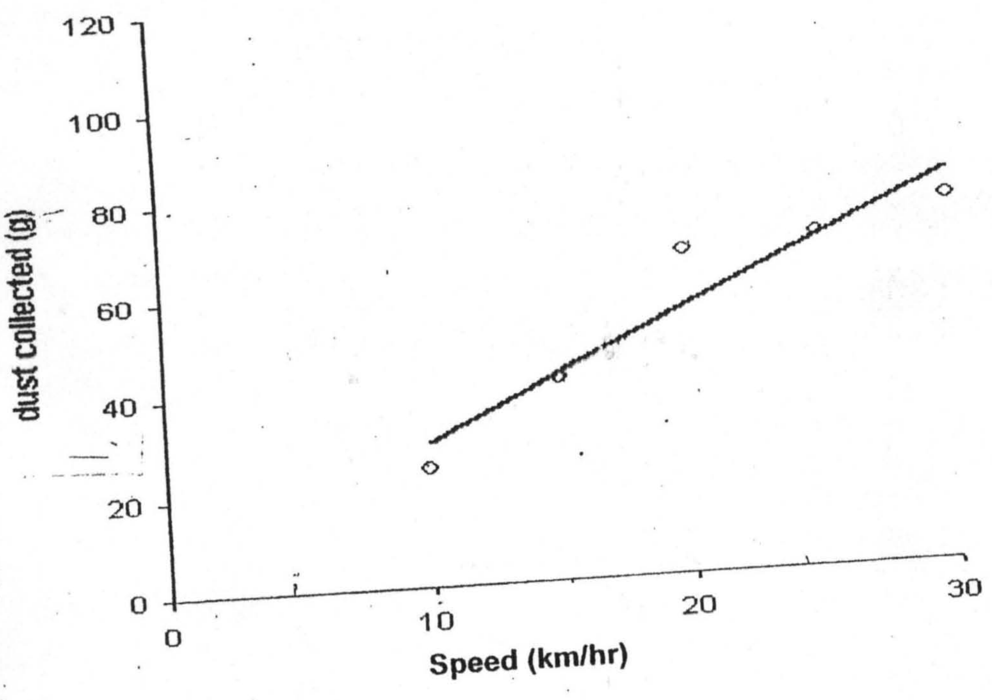


FIG. 4.1 Graph: Amount of Dust Collected Against Tractor speed

The Table 4.3 below contains the average road dust collected on each side of the road, the total weight of dust collected, and the normalized total weight of dust (obtained by linear regression) against each Truck speed

Table 4.3: Amount Of Road dust Generated by TOYOTA DYNA TRUCK at varying speeds.

Speed (Km/Hr)	Dust collect4ed on Left side of road (g)	Dust collected on Right side of road (g)	Total weight of dust collected (g)	Normalized Total weight of dust (g)
10	11.40	18.70	30.10	33.92
15	26.90	29.30	56.20	46.11
20	33.70	41.60	75.30	58.29
30	34.60	42.80	77.40	82.65
40	36.30	44.10	80.40	107.01
50	57.90	61.70	119.60	131.38
60	79.20	83.30	162.5	155.74
70	95.20	96.50	193.70	180.10

Direction of wind: Left to Right

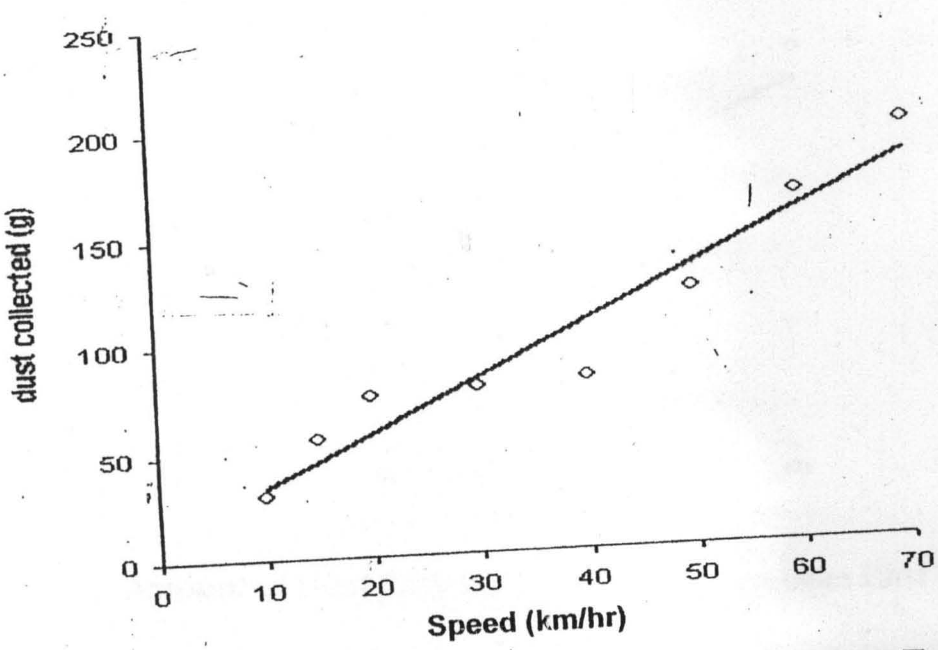


Fig. 4.2 Graph: Amount of Dust Collected Against Toyota Dyna

The Table 4.6 below contains the average road dust collected on each side of the road, the total weight of dust collected, and he normalized total weight of dust (obtained by linear regression) against each speed

Table 4.6: Amount of Road dust Generated by PEUGEOT 504 at varying speeds

Speed (km/hr)	Dust collected on Left side of road (g)	Dust collected on Right side of road (g)	Total weigh of dust collected (g)	Normalized To weight of dust
10	19.80	12.30	32.10	36.40
15	32.10	28.90	61.00	49.80
20	44.10	36.00	80.10	63.24
25	44.90	36.50	81.40	76.66
30	45.60	37.10	82.70	90.09
40	47.90	39.00	86.90	116.93
50	66.90	63.00	129.90	143.77
60	89.40	87.30	176.70	170.62
70	110.50	103.70	214.20	197.46

Direction of wind: Right to left

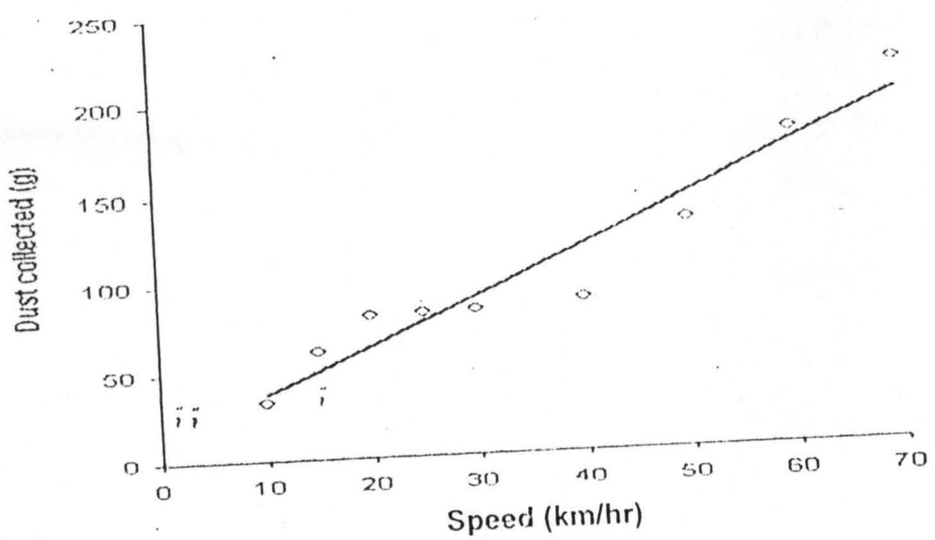


Fig. 4.5 Graph: Amount of Dust Collected Against Peugeot 504

The Table 4.4 below contains the average road dust collected on each side of the road, the total weight of dust collected, and the normalized total weight of dust (obtained by linear regression) against each Wagon speed.

Table 4.4: Amount of Road dust Generated by NISSAN BLUE BIRD WAGON at varying speeds.

Speed (km/hr)	Dust collected on Left side of road	Dust collected on right side of road (g)	Total weight of dust collected (g)	Normalized Total weight of dust (g)
10	11.97	11.35	31.27	34.75
15	28.20	31.70	59.90	47.96
20	35.00	43.60	78.60	61.16
30	36.20	44.50	80.70	87.51
40	38.30	47.10	85.40	113.98
50	61.26	65.40	126.60	140.39
60	88.30	87.35	175.65	166.80
70	101.60	106.12	207.72	193.21

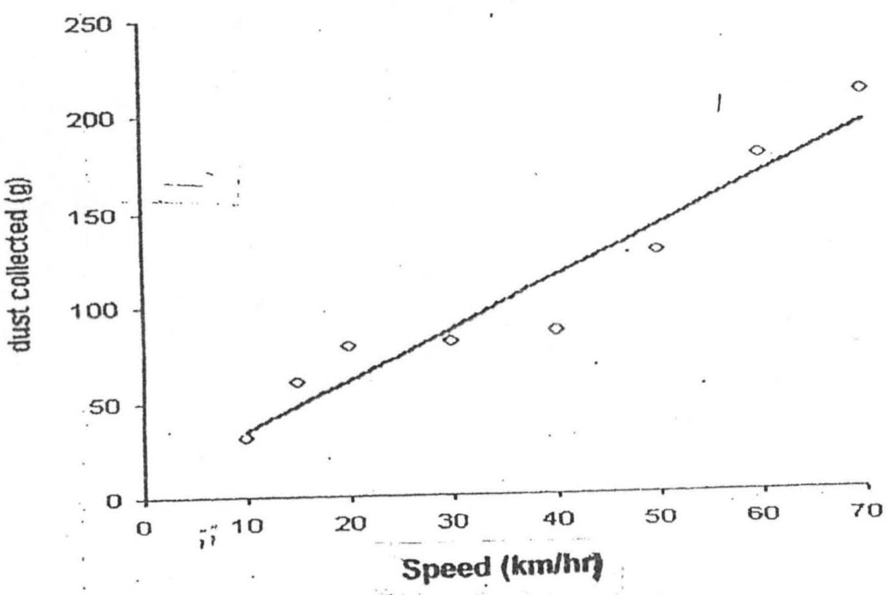


Fig.4.3 Graph: Amount of Dust Collected Against Nissan Blue Bird Wagon

The Table 4.5 below contains the average road dust collected on each side of the road, the total weight of dust collected, and the normalized total weight of dust (obtained by linear regression against each Bus speed.

Table 4.5: Amount of Road dust Generated by TOYOTAL LITEACE BUS at varying speeds

Speed (km/hr)	Dust collected on Left side of road (g)	Dust collected on right side of road (g)	Total weight of dust collected (g)	Normalized Total weight of dust (g)
10	19.20	11.80	31.00	36.28
15	31.00	27.80	58.80	48.74
20	43.00	34.50	77.50	61.20
25	43.30	34.80	78.10	73.66
30	43.90	35.80	79.70	86.12
40	46.00	37.60	83.60	111.04
50	64.20	59.50	123.70	135.96
60	85.50	82.80	168.30	160.88
70	102.00	97.00	199.00	185.81

Direction of wind: Right to left

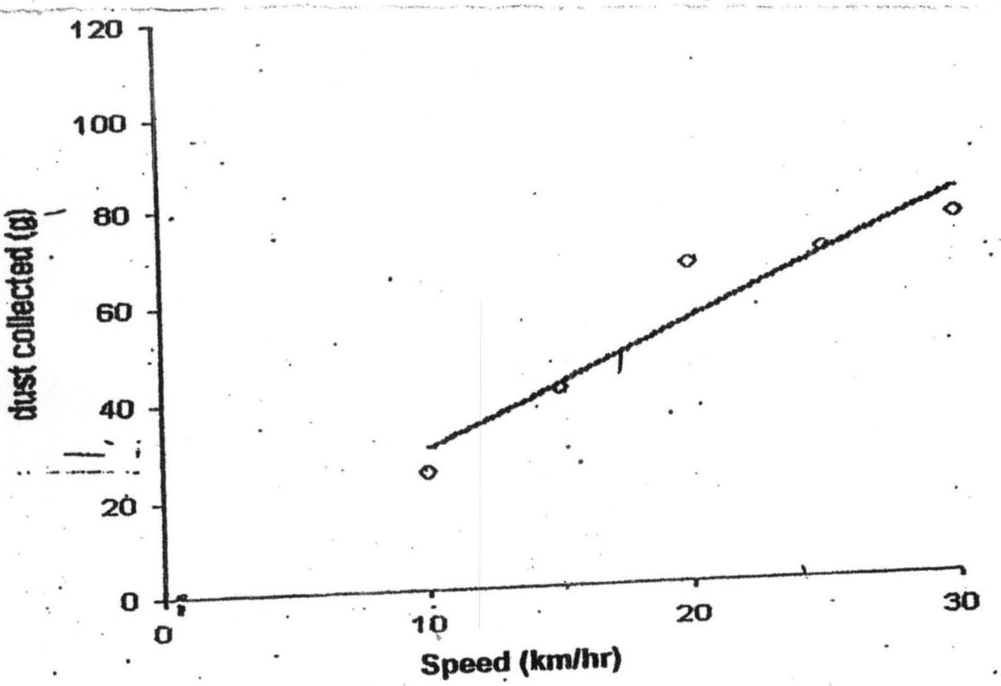


FIG. 4.4 Amount of Dust Collected Against Toyota Liteace Bus speed

The Table 4.6 below contains the average road dust collected on each side of the road, the total weight of dust collected, and he normalized total weight of dust (obtained by linear regression) against each speed

Table 4.6: Amount of Road dust Generated by PEUGEOT 504 at varying speeds

Speed (km/hr)	Dust collected on Left side of road (g)	Dust collected on Right side of road (g)	Total weigh of dust collected (g)	Normalized To weight of dust
10	19.80	12.30	32.10	36.40
15	32.10	28.90	61.00	49.80
20	44.10	36.00	80.10	63.24
25	44.90	36.50	81.40	76.66
30	45.60	37.10	82.70	90.09
40	47.90	39.00	86.90	116.93
50	66.90	63.00	129.90	143.77
60	89.40	87.30	176.70	170.62
70	110.50	103.70	214.20	197.46

Direction of wind: Right to left

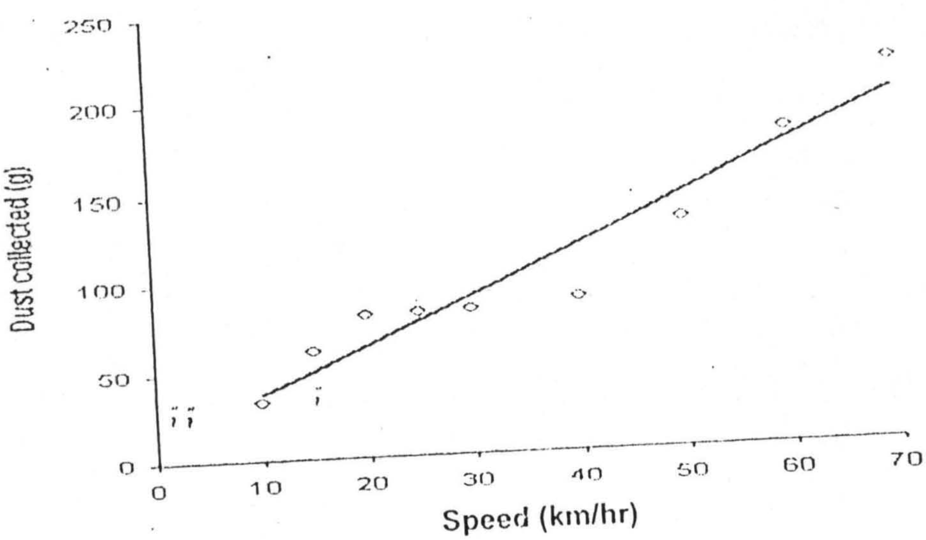


Fig. 4.5 Graph: Amount of Dust Collected Against Peugeot 504

A study from MRI, from unpaved roadways, shows that emissions vary with speed raised to a power typically between 1 and 1.5. The table below contains the values of exponents of speed for the different test vehicle used during our experiment in relation to their emissions at that particular speed.

Table 4.7: Exponents of the speed value for the different test vehicles in

Relation to their emissions a that particular speed

Exponents of the speed value for the different test vehicle					
Speed (km/hr)	Tractor	Toyota Truck	Toyota Bus	Nissan Blue Bird	Peugeot 504
10	1.3886	1.4785	1.4914	1.4951	1.5065
15	1.3704	1.4876	1.5045	1.5113	1.5180
20	1.3971	1.4425	1.4522	1.4569	1.4631
25	1.3104	-	1.3539	-	1.3667
30	-	1.2787	1.2873	1.2909	1.2981
40	-	1.1892	1.1998	1.2056	1.2103
50	-	1.2229	1.2316	1.2375	1.240
60	-	1.2433	1.2519	1.2623	1.2638
70	-	1.2395	1.2459	1.2560	1.2633

The emission varied with speed raised to a power of between 1.19 – 1.52 (mea 1.34). this values correspond with those of MRI.

PLATE II: Picture of Tractor (with the highest clearance and weight) showing dust emission during the experiment.

PLATE III: Picture of Nissan Blue bird wagon (with the lowest clearance and weight) showing dust emission during the experiment

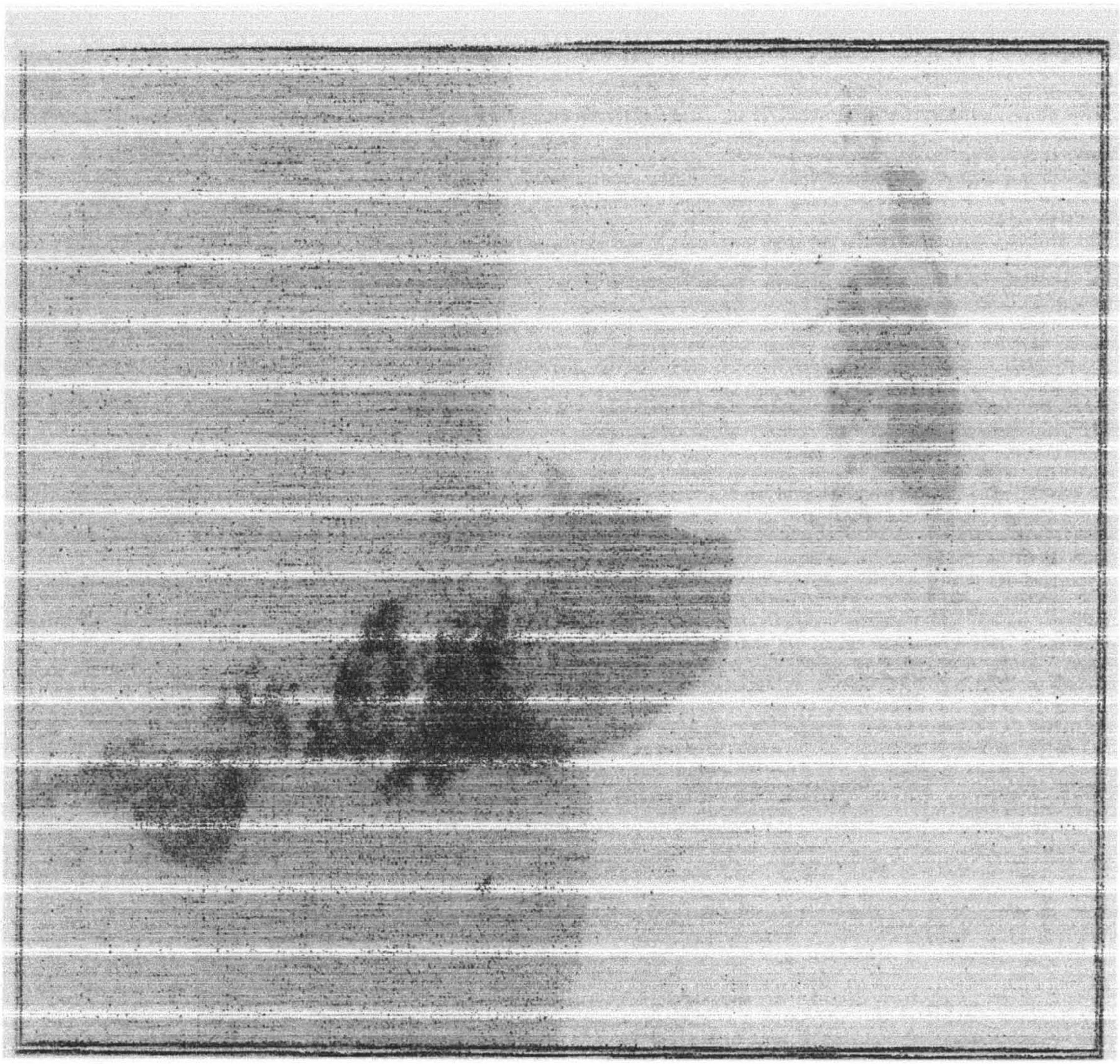


PLATE IV: Picture of sample dust emitted by one of the test vehicles during the experiment

4.1.2 Particle Size Analysis

The result of the Particle Size analysis performed on road dust collected and on road base material are contained in Table 4.8 and Table 4.9 below

Table 4.8: Result of Particle Size Analysis of Road dust Emission
Total mass of sample = (716.63g)

BS sleeve (um)	Mass of empty sieve (g)	Mass of sieve and retained soil (G)	Mass of retained soil particles (g)	Percentage retained on sieve	Percentage passing
850	358.62	525.81	167.19	23.33	76.67
600	335.84	370.81	34.97	4.88	71.79
425	332.03	379.18	47.13	6.58	65.21
300	316.32	374.38	58.06	8.10	57.11
212	304.29	372.89	68.60	9.58	47.53
150	295.93	371.82	75.89	10.59	36.94
75	308.36	456.06	147.70	20.62	16.32
63	287.80	343.64	55.84	7.79	8.52
Bottom pan	300.64	361.69	61.05	5.52	0.00

Silt loading is a measure of the mass of particles less than 75um in diameter.

From the table above, the silt fraction of the bulk sample emitted is **16.32**

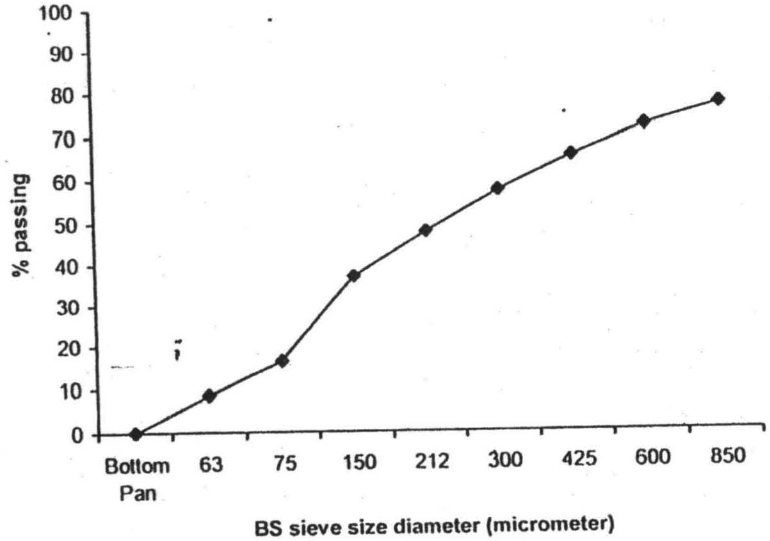


FIG. 4.6 Graph: Particle size analysis of road dust emissions

Table 4.9: result of Particle size Analysis of Sample road base material

BS sleeve (um)	Mass of empty sieve (g)	Mass of sieve and retained soil (G)	Mass of retained soil particles (g)	Percentage retained on sieve	Percentage passing
850	358.62	642.15	283.53	24.27	75.73
600	335.84	453.32	117,48	10.06	65.67
425	332.03	458.23	126.20	10.80	54.87
300	316.32	403.46	87.14	7.46	47.41
212	304.29	383.97	79.68	6.82	40.59
150	295.93	416.62	120.69	10.33	30.26
75	308.36	526.39	218.03	18.66	11.60
63	287.80	352.40	64.60	5.53	6.07
Bottom pan	300.64	371.44	70.80	6.06	0.00

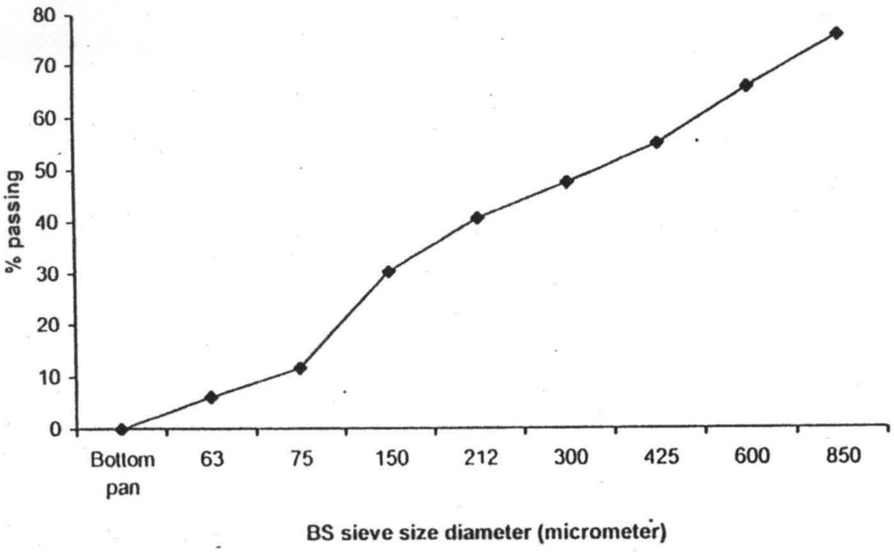


FIG. 4.7 Graph: Particle size analysis of sample road bed material

4.1.3 Moisture content test

Mass of Bulk sample before oven drying 1,171,89g

Mass of Bulk sample after oven drying 1,168.15g

Difference in weight 3.74g

Percentage moisture content of road base material = 3.74g/1171.89

= 0.00318 x 100

= 0.319% = **0.32%**

4.1.4 Atterberg Limit tests

Liquid limit = 45.2%

Plastic limit = 17.5%

Plasticity Index = Liquid limit – Plastic limit

= 27.7%

4.1.5 Table 4.10: Vehicular Traffic On Market days

Traffic	Intensity	Multiplying Factor	Passenger car units (PCU)
Car	23	1	23
Motorcycle	22	0.75	16.5
Pick-up van	10	2	20

Total 59.5 – 60 cars

Table 4.11: Vehicular Traffic On Ordinary days

Traffic	Intensity	Multiplying Factor	Passenger car units (PCU)
Car	3	1	3
Motorcycle	7	0.75	5.25
Pick-up van	4	2	8
Bus	1	3	3
Truck	1	2	2

Total 21.25 – 21 cars

Average speed of passenger cars = 40km/hr say 21 cars

Predominant car during traffic count: Nissan blue Bird (weight 969kg)

Average number of cars using the road per ;day = (60 x 2 + 21 x 5) 7 days

= 225/7

= 32.1 =

say 32 cars

4.1.6 Calculation of Material lost

4.1.6.1 Dust Emission within 2m on both sides of the Road Edge

Base on observation mentioned above and data collected from site, we can now calculate the quantity of material lost within 2m on both sides of the road edge (on the average) thus.

Quantity of road dust emitted by Nissan blue bird car within 2m of the road edge from road section of the 100m length at a speed of 40km/hr = 85.40g. (see table 4.4)

Quantity of road dust lost from 1km = 85.40 x 10 = 854.0g

Quantity of road dust that would be lost from 1km of the road due to the interaction of 32 cars daily 854.0 x 32 = 27,328g/day

Quantity of road dust that would be lost within 2m of the road edge

From 1km of the road a year 27,328 x 365 = 9.974.720g

= 9.975 tons

This in effect is a reduction of approximately 1.5mm in the thickness of the Wearing course of the 1000m x 7m section of road. This loss is based on the observed average speed on the road, the higher the vehicle speed, the higher the emission.

4.1.6.2 PM_{10} Emission

Using the U.S. EPA (2003) emission model for vehicles

Using the U.S. EPA (2003) emission model for vehicles traveling on publicly accessible roads, dominated by light duty vehicles. The following empirical expressions may be used to estimate the quantity in pounds (lb) of particulate emissions less than or equal to 10 um diameter size from an unpaved road per vehicle mile traveled (VMT)

$E_{pm10} = [1.8(s/12)^{1}(S/30)^{0.5}/(M/O.5)^{0.2}]\text{-}C$

Where

E = PM_{10} emission factor (lb/VMT)

S = surface material sill content (%) = 11.6%

M = surface material moisture content (%) = 0.32%

S = mean vehicle speed (mph) = 40km/hr x 0.62137 = 24.85mph

C = emission factor for 1980\s vehicle fleet exhaust, brake wear and
tire Wear = 0.00047

$E = 1.8\ (11.6/12)^{1}(24.85/30)^{0.5}/(0.32/0.5)^{0.2} - 0.00047$

= 1.731lb/VMT.
But 1 lb?VMT = 261.9 g/VKT

Therefore 1.740lb/VMT = 261.9 x 1.731 = 453.359g/VKT

E = 453.35G/VKT

Quantity of PM_{10} that would be emitted from 1km of the rod in a year
= 455.35 X 32 cars 365 days = 5,295.128
= 5,295 tons

This is a reduction of approximately <u>0.8mm</u> in the thickness of the wearing Course of the 1000m x 7m section of road. This loss is based on the Observed average speed on the road.

4.1.6.3 PM_{30} Emissions

Using the U.S. EPA (2003) emission model for vehicles traveling on Publicly accessible roads, dominated by light duty vehicles. The following empirical expression may be used to estimate the quantity in pounds (lb) of particulate emissions less than or equal to 30 um diameter size from an Unpaved road, per vehicle mile traveled (VMT)

$$E_{pm30} = [6.0(s/12)^{1}(S/30)^{0.3}/(M/O.5)0.3]\text{-}C$$

Where E_{pm30} = PM_{30} emission factor (ib/VMT)

$$E_{pm30} = 6.0(11.6/12)^{1}(24.85/30)^{0.5/(0.32/0.5)}0.3^{-0.00047}$$

6.0336/VMT	(518)(0.910)	- 6.0341
E_{pm30} = 6.266lb/VMT	0.87469	6.0336

$E_{pm30} = 1,580.20g$

Quantity of $PM_{30\ that}$ would be emitted from 1km of the road in a year

= 1,580.20 32 cars   365 days = 18,456.74g

= 18.46 tons (equivalent to TSP)

This is based on the observed average speed on the road. This amounts to a reduction of approximately <u>3mm</u> in the thickness of the wearing course of the 1000m x7m section of the road. These figures may be affected by high moisture content during the wet season.

4.1.6.4 Approximate Quantity of road dust lost:

Quantitatively, dust contains about 24% (by weight) of particles less than 30µm and 68% greater than 30um (orlemann et al; 1983)

Based on this and the data we have already gathered from our study, we

Can calculate for a value that gives us an approximate quantity of road dust

Lost from 1km of Shintaku road/year as follows:

Our calculated value for PM_{30} per year = 18.46 tons

This value represents 24% by weight of the total road dust emitted   Therefore the

Total road dust emited = 18.46 tons/24 x 100

Total road dust emitted = 76.92 tons

This represents an approximate value of the Total quantity of material lost

From 1 km of Shintaku road per year. This amounts to a reduction of approximate <u>12mm</u> in the thickness of the wearing course of the 1000 x 7m section of the road.

4.1.7 Particle size Analysis

The result of the article Size analysis performed on road dust collect and on road bed material are contained in Table 4.8 and Table 4.9 below.

Silt loading is a measure of the mass of particle less than 75 μm in diameter. From the Table above, the silt fraction of the bulk sample emitted is 16.32%

4.2 Discussion of Results

Through this study, it has been established that both vehicle Characteristics, road base material, environmental condition give rise to Loss of material from unpaved road surfaces. Much concentration will be given to the vehicle characteristics since it was the only variable that could be altered during the experimentation exercise.

The results of the study, as illustrated in figures 4.1-4.5 demonstrates that vehicle speed is an important factor with respect to Unpaved roadway emissions for the tested vehicles. The effect of speed on emissions is linear and relatively invariant with vehicle type. Table 4.2-4.6 shows that the amount of dust collected normalized to the fastest speed obtained for each test vehicle indicating that dust emission is dependent on vehicle speed.

Other determining factors to be considered are vehicle weight, clearance and tyre size. These equally affect the quantity of dust emitted by each vehicle for instance Tractor, with the highest clearance of 0.53m emits only 74.20g of dust at 30km/hr while Nissan blue bird wagon with the least clearance of 0.23m emits 80.70g of road dust also at 30km/hr speed.

At a speed of 50km/hr, the Peugeot 504 car gives out 129.90g of dust. The situation here is interesting bearing in mind that since the Peugeot 504 has a higher clearance of 0.25m, it is expected that it will emit less dust than the Nissan blue bird wagon with a lower clearance of 0.23m. This then suggests that speed and clearance alone are not the only factors in play here, the higher weight of the Peugeot 504 car (1305kg) over the Nissan blue bird (969kg) has contributed to higher dust emission alongside other factors like tyre size. It is a well- known fact that the total weight of a vehicle determines the total pressure or force per unit area acting on the road surface. Hence, the greater the weight, the greater the pressure and soil breaking force leading to high emission of particles. The reverse is the case when the weight is low. It can be seen from the graphs in figures 4-1-4.5 that the rate of dust emission varies with speed.

MRI (2001) reported for unpaved roadways, that emissions vary with speed raised to a power typically between 1. and 1.5. This is true for this research study because our calculated emissions varied with speed raised to a power of between 1.19 -1.52 (mean 1.34). This was as a result of the fact that as speed increases, the tyre contact area with the unpaved road surface decreases leading to a reduction of the force dislodging the soil particles, whereas dust movement will be increasing.

From the relationships depicted in tables 4.1-4.6 and figures 4.1-4.5, it is apparent that vehicle speed, weight and clearance play important roles in the magnitude of emissions from unpaved roads. This also suggests that physical characteristics of the vehicles such as shape and number of tyres and tread pattern may have only a minor influence on the emissions.

The percentage road silt content is normally lower than in the surrounding parent soil because fines are continually removed by vehicular traffic, leaving higher percentage of coarse particles. This explains our results In Tables 4.9. it can be seen that the percentage silt content of the sample dust emitted was 16.32% while that of the road base materials was 11.60%. this also corresponds with results obtained from a study done by Lohnes and coree (2002). They observed that the particle size distribution of road dust samples collected at a various distances from the roadway indicated coarser particles on the road and finer particles further away.

Comparing the results obtained by calculating the total road dust emitted from Shintaku road using:

1. the weights of the road dust collected during the experiment and
2. U. S. EPA (2003) emissions models for vehicles traveling on publicly accessible roads, dominated by light duty vehicles,

It can be seen that there is a wide margin between the two results. The result from calculations using the weights of road dust collected during the experiment gave a total emission of 9.975 tons, while that of the U.S EPA (2003) emission model gave a value of 85.969 tons. A study by Klinger (1983) showed that the main dust impact occurred within 100 feet (30.5m) of the road. Zachel in his research in 1986, also reported that dust fallout decreased rapidly as distance from the road increased. Further more, in 1997, it was reported that road dust settles up to 500 feet (about 152m) from the road edge (Wisconsin Transportation Bulletin No. 13). The dust collected during the vehicle run and used for the calculation of the total emission was collected 2m from the road edge and the paper used in the collection of these road dust, covered a width of 2m .So our 9.9 75 tons value represent the dust collected within the 2m width of the paper, representing a small fraction. This may be responsible for the large difference in the two values. Also the effect if wind equally affected the amount of dust collected, as the average wind speed value throughout the period of experimentation was 7.3km/hr. the actual distribution of the dislodged particles in relation to the distance from the road is affected by wind speed alongside other factors.

CHAPTER FIVE
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

(i) In order to assess the effect of vehicular traffic on the quantity of material lost from unpaved road surface, an experiment was conducted on a 100 meter section of unpaved road leading to Shintaku village State in November and December 2010, with the primary objective of investigating the cause(s), quantifying the amount and effect, and finally suggest possible solutions to the problem of material loss on unpaved road surface (earth road).

This experiment was conducted during the dry season ensure that a high level of dust emission was achieved since during the dry season, the fines become lighter and are prone to be stirred up and blown away by vehicular traffic.

(ii) An average of about 854.4g of road material is lost per vehicle pass per kilometer on a speed of 40km/hr on this road. Thus more than 9975kg of road dust is expected to be lost yearly giving rise to higher surface irregularities resulting to an increase in accident potential is due to loss of visibility, skidding and swaying of vehicles, less positive steering response, longer stopping distance, and broken windshields from flying aggregates.

(iii) The magnitude of the emissions was controlled primarily by vehicle speed and vehicles weight, both of which had linear effects on the emissions. This suggests that emissions are linearly dependent on a vehicle's momentum. Other physical characteristics of the vehicles (e.g number of wheels, undercarriage, area, height) did not appear to highly influence the emissions.

5.2 Recommendations

(i) The hazardous effect of road dust to health, vegetation, aesthetics, soils, vehicles and aquatic sources is a fact and therefore efforts should be made by the relevant government ministries and agencies to enlighten the public on these hazardous effects.

(ii) The greater the speed of the vehicles traveling over an unpaved road, the greater the amounts of dusts that will be generated. Therefore it is recommended that vehicle owners/users should drive at low speeds on unpaved roads since this will help reduce the amount of dust kicked up in the air.

(iii) Heavier vehicles will entrain more dust into the air than lighter vehicles. Therefore controlling the weight and type of vehicles using an unpaved road can help reduce particulate emissions. However, this may not be for some public roads.

(iv) Reducing the silt or fine content of the top layer of the road will significantly reduce the amount of dust that will be kicked up into the air. There are many ways to treat the surface of an unpaved road. The relevant government agencies should adopt the surface treatment of putting gravel or recycled asphalt product (RAP) on the roadbed. They can also use chemical stabilization substances that are designed for use on unpaved roads, such as petroleum resins, asphalt emulsions, or adhesives. Dust control techniques tend to wear out or deteriorate quicker in areas where vehicles stop or accelerate frequently and also in curves. These areas may require more frequent applications of dust control measures than a straight stretch of roads.

(v) Finally, it is strongly recommended that as a long term solution, the government should come up with a programme whereby rural, feeder and farm roads in the country would be grouped and paved in phases although this may be more expensive but as a lasting solution to the hazardous effects of road dust.

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