ASSESSMENT OF ROAD IRREGULARITIES AS SOURCES OF EXCITATION INPUT TO VEHICLES HAULING FRESH TOMATOES

BY

MUHAMMAD ABUBAKAR

PGD/SEET/2001/2002/163

DEPARTMENT OF AGRICULTURAL ENGINEERING

FEDERAL UNIVERSITY OF TECHNOLOGY MINNA

MAY 2004

ASSESSMENT OF ROAD IRREGULARITIES AS SOURCES OF EXCITATION INPUT TO VEHICLES HAULING FRESH TOMATOES

BY

MUHAMMAD ABUBAKAR

PGD/SEET/2001/2002/163

A Project Report Submitted To The Department of Agricultural Engineering In Partial Fulfillment of The Requirement For The Award of Post Graduate Diploma In Agricultural Engineering

(Soil and Water Option)

School of Engineering and Engineering Technology, Federal University of Technology, Minna, Niger State.

DEDICATION

Dedicated to my parents, family and my lecturers. Both beginning and end of my studies.

DECLARATION

I hereby declare that this research project has been conducted by me under the Guidance of my supervisor in person of Engr. Mr Peter A. Idah of the Department of Agricultural Engineering and Engineering Technology, Federal University of Technology Minna and that I have neither copied someone's work nor has someone done it for me.

The authors whose works had been referred to in this project are duly acknowledged

Name ....

No..

Sign..

Date..

CERTIFICATION

This is to certify that this project work was carried out by Mohammed Abubakar in the Department of Agricultural Engineering, Federal University of Technology, Minna.

31/8/04

Engr. Mr. Peter A. Idah
Project Supervisor

Date

Engr. Dr. D. Adgidzi
Head of Department

Date

ACKNOWLEDGEMENT

All praise be to Allah, the all knowing and the most merciful for giving me the strength and ability to undertake this project.

I will like to express my sincere and profound gratitude to my project supervisor, Engr. Mr. Peter A. Idah, for the untiring guidance he gave to me in the course of undertaking this project. I also wish to thank the Head of Department Agricultural Engineering Engr. Dr. D. Adgidzi, Professor E.S.A. Ajisegiri, Engr. Dr. N.A. Egharevba, Engr. Dr. Mrs Osunde the Post Graduate Programme Course Coordinator and the rest of my lecturers in the department for letting me get a lot from their vast knowledge.

My sincere appreciation goes to Alhaji Isah Ahmed B/Kebbi. Director works and services Kalgo Local Gov't who assisted me in releasing me to come for this study, Umar Foruku Bala Mai Sallah Federal Mortgage Bank Minna who gave me all form of assistance in carrying out this course.

I also wish to thank Mal. Sani Bello Bosso, a collegue who assisted me a lot during this programme.

I also wish express my gratitude to all persons who assisted me in one way or the other. I also wish to express my appreciation to my wife, children and all other friends and relatives.

Thank you all may Allah the Almighty continue to shower you with His blessing.

Amen.

ABSTRACT

The physical transport of fresh produce such as tomatoes is characterized by a lot of transportation problems. Fresh produce such as tomatoes are susceptible to spoilage during transportation especially over along distances. There is no doubt that this problems encountered are due to the Irregularities on the Roads, such as potholes, bumps etc which produces excitation input to vehicles hauling fresh products. This project carried assessment on some selected Nigerian Roads (inter state, intra state and rural roads) with a view to quantify the irregularities on such Roads. Profiles survey and pothole counts and their dimensions were carried out. The data obtained from the survey were used to compute the expected velocity and the acceleration input into the wheels of the vehicles traversing such roads. The dynamic load onto the vehicle traversing over such potholes also computed. The results showed that the average number of potholes over a distance of 6km on these three roads were 102, 129, and 7 for inter, intra and rural roads respectively. The average ripples (depths) of these potholes were 0.08m, 0.053m and 0.37 respectively, acceleration and dynamic load that usually results from these potholes showed that as the velocity of the vehicles increases, the excitation from these irregularities also increases irrespective of the vehicle used. The acceleration was greatest for the data obtained from the rural road compared to the other two. This was clearly shown

from the ANOVA and Duncan multiple range test carried out on these data to ascertain any significant differences between the mean values of these data computed for the three types of roads. There were however no significant differences between the measure of the data computed for the vehicle type. The information obtain hence could be emphasized in the selection of appropriate travel speed that will results in minimal excitation in to the vehicle hauling fresh produce over these roads.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

1.0 GENERAL:

Fruits and vegetables are produced in large quantities in Nigeria. Their production are however location specific while some are prominent in the Northern parts, others are dominant in the South. The consumers are however found scattered all over the country. There is therefore the general need to equitably distribute these commodities all over the country, moving them from the area of production to that of consumption. These distributions are done over roads and rails generally in Nigeria.

The physical distribution of fresh produce in Nigeria is characterized by a lot of transportation problems resulting in heavy mechanical damage during the process. Most of these physical and mechanical damages are caused by vibration and the impact resulting from vehicle. The sources of this vibration are the road irregularities.

1.1 INTRODUCTION

Assessment of Road Irregularities as sources of excitation input to vehicle hauling Fresh tomatoes.

1.2 ROAD

Road can be defined as a specially prepared way, publicly or privately owned, linking places and made for the use of pedestrians, riders, vehicles e.t.c. (Osemenans 1994)

Road can also be defined as the travel way on which people, animals or wheel vehicles move. (Encyclopaedia Britannica 2002). In modern usage, the term road discusses a rural lesser traveled way, while the word street denotes an urban roadway. High way on the other hand refers to a major rural traveled way but more recent word road is derived from the old English word raid ("to ride") and the middle. English word roads or rade (a mounted journey) and is now used to include all vehicle ways.

1.3 ROAD TYPES IN NIGERIA

There are basically two types of roads in Nigeria. They are paved and unpaved roads. (Abdullahi, 2000). Paved roads are further classified in to flexible and rigid pavements. The flexible types consists of relatively thin surface built over a base course and sub base course.

They usually rest upon the compacted sub grade while rigid pavement are made up of cement concrete and may not have a base course between the pavement and sub grade.

The essential difference between the two types of pavement is the manner in which they distribute the load over the sub grade. The rigid pavement because of its rigidity and high modulus of elasticity tends to distribute the load over a relatively wide area of soil. Thus a major portion of the structural capacity is supplied by the slab itself, hence the structural strength of the concrete is crucial in the pavement design.

Unpaved roads are those constructed by removal of top soil and filling with suitable earth or gravel materials and which are mechanically stabilized to carry traffic loadings. These are further classified in to earth and gravel roads.

Earth roads have no added pavement and layers are therefore not structurally designed. Their performance therefore depends on their cross sectional shape, material properties location in the terrain and drainage facilities.

Gravel roads are those that are surfaced with gravel to provide traction for vehicles in wet weather at relatively low cost.

Surfacing with gravel also retards the increase in deformation of the surface. It is worthy to note that the structural damages suffered by these roads, where traffic loads are high and are influenced by the type of materials used in the construction and hence the need to review and know the various types of roads.

1.3.1 ROAD ADMINISTRATIO IN NIGERIA

Over the years the responsibility for the development of roads in Nigeria, has been shared by the federal (or central), state and local

Governments. Roads in Nigeria therefore fall into three main categories. First there are the Federal trunk roads which link the major parts in the country, the main urban centres (including the states capital), the major centres of Economic activity and the major border crossings to neighbouring countries, next, are the roads which feed the federal trunk roads and the farm to market roads for which the various state government are responsible.

The third category consists of rural roads and city streets (with the exception of aerial routes), which are the responsibility of the local government. (Osemenam 1994).

1.3.2 ROAD PLANNING, DESIGN AND CONSTRUCTION

- Pre-independence period.
- Before the advent of the motor car, all that was required for the limited communication between communities was the foot path. Along it went the traders in their journeys to and from the markets and it also served the need of the traveler paying visits to relatives and friends when the ubiquitous bicycle arrived on the scene, very little improvement was necessary for the foot path to cater for the new comer. As for pack-animals the foot path served just as well.

Nevertheless, records show that by 1914 that is just before the first world war, there were about 3,200km of motorable roads in Nigeria. These roads come in to being, as in other already populated countries, usually as a result of an improvement to the foot path or track. This was found to be cheap and readily available method, as the improvement could be undertaken by unskilled village labour working with local materials.

By 1926, the kilometrage of roads had increased to 4,750 and all these were open to traffic throughout the year as long as the bridges stood. There is no doubt that other roads did exist which were perhaps motorable during the dry season. In 1934, the recorded kilometrage of roads maintained by Governments stood at 6,040 and this increased to 8,280 by 1938.

By 1939, that is just before the out break of the second world war, the recorded kilometrage of roads maintain by Government stood at 9,480. (Osemenam 1994).

The first bituminous surfacing done out side on that section of the Lagos. Abeokuta road which lie within the then colony province. By 1946, there had been a classification of the road system in to trunk A, trunk B, and local government. The trunk road being maintained by the central and regional Government. The kilometrage of trunk roads 'A' and 'B' at the time stood at 13,240. By 1953, the total kilometrage of the road system had gone up to 46,000. Out of this only about 1,782 were surfaced with bitumen.

By 1960, the nations road network had increased to a total length of 65, 704 out of which 8,694 km were surfaced with bitumen. This phenomenal growth in the length of roads surfaced with bitumen occurred in the roads under the responsibility of the central Government and those under the responsibility of the then western region which was then enjoying self Government between 1957 and 1960.

From the on set, the standard of construction of the roads varied with its classification. Those for which Government was responsible had to comply with a minimum standard laid down on the official manual of Road construction and maintenance. The quality of the others depended very much on how much effort the villagers were willing to put into it. The drainage in almost all cases was sub-standard and in many cases non – existent. The same applied to the bridges and culverts which were mostly lightly built and constructed out of materials obtained near by. If the bridges were swept away in the rains which was not uncommon, they could be re-built when the water subsided.

The following design standard were in used at this time.

TABLE 1.0 Design Standard Table

S/No	Design Information	Design Standard
1	Design speed	30 – 40 miles per hour. (50 – 65 kilometre/hour.
2	Carriage way width	Mostly 12 feet (3.7 metre) occasionally 22 feet (6.7 metres)

3	Shoulders	5ft (1.5 metres)
4	Sub – grade	10% CBR (California Bearing Ratio). At 100% B.S.(British Standard). Compaction (soaked).
5	Sub – base	30% CBR (Soaked at 100% W.A.S.C.(West African Standards Compaction.)
6	Base	80% CBR (unsoaked) at 100% W.A.S. compaction.

(Osemenam 1994)

Post – independent period (1960 to date). There is little doubt as to the fact that between 1960 and 1977, the nations road network recorded an impressive growth.

By 1972, Nigeria had a Network of about 96,000 Kilometres out of which 77,266km were unpaved and 18,109 were paved. And as at 1992, the total kilometrage of the road network is as shown in Table below.

Table 1.1 Table showing the total kilometrage of the road network in Nigeria as at 1992.

Type of Road	Paved Km	Unpaved Km	Total Km
Federal	23,000	5,600	28,600

State	10,430	20,070	30,500
Local Govt	870	84,130	85,000
Total	34,300	109,800	144,100

1.4 IRREGURALARITIES OF TRANSPORT ROADS.

The driver and the passenger of a vehicle are affected by the vibrations which are excited by the irregularities of the road and this causes damage to the produce. (Singh and Singh 1992, Jones et al, 1991, Ogut et al 1999). These vibrations transferred through the wheels and through the chassis to the seats. It is thus believed that one of the most important elements in high way design is consistency, that is making every element of the pavement design to conform to the vehicle expectation and by avoiding abrupt and premature changes in the pavement (Ogaga 2000). It has also been asserted that the life of the vehicle component could be reduced to about 80%. If the vehicles traverse high ways with 4 to 5 potholes per square metre of the carriage way width at a minimum speed of 60 km/hr are capable of reducing the life of vehicle components by about 80% (Ogaga 2000). This is attributed to the severe terrain loads encountered, and which is caused by the highway irregularities inform of potholes and bumps resulting from localized pavement failures due to the poor design and maintenance which has characterized Nigerian roads.

It is noted that a vehicle loaded with fruit or vegetable traveling along smooth road at constant speed may be considered to be in a vertical static equilibrium. The forces between the various system elements are constant and there is no transformation of energy. However, when the vehicle encounters discontinuity in the road surface, a bump for example, some of the kinetic energy of the vehicle is dissipated in deforming the road, the tyres suspension (Jones et al, 1991). Damage to the produce is the direct result of the description of the energy in the produce. Road irregularities are therefore crucial in the investigation of the effects of roads-vehicle – packaging interactions in fresh product transportation.

Failure on the road could be structural or functional (Abdullahi 2000). Structural failure includes the collapse of pavement structure or break down of one or more of the pavement. Components in such a magnitude that renders the pavements incapable of sustaining the loads running on them.

The causes include the following:

(i) Faulty materials of construction.

(ii) Faulty construction and improper quality control during construction.

(iii) In adequate surface and sub-surface drainage of the road structure and the vicinity.

(iv) Increase in value of wheel load.

(v) Increase in traffic volume.

(vi) Settlement of foundation of embankment of fill material.

(vii) Environmental factors like rainfall, soil erosion, high water Table, frost action. (Gurcha Ran Singh- 1991)

Roads and fresh tomato handling. Transportation is the act of carrying people and goods from one place to another. Transportation generally involves two basic elements, the route and the device (Adeoti 1998 and Ogaga, 200). The route refers to the course or way such as road, water way, railway, tracks or air.

Damage during transport is a major distribution of farm produce (fresh fruit and vegetables) O. Brien et all (1963) as reported in (Jopies et al (1991) shows in loads of cling peaches on a road journey of 260km up to 40% of the fruits was damaged. It is important to assess the source from which the excitation that usually lead to the damage. Hence the need to assess the irregularities of the Nigerian roads on which the fresh produce are transported.

1.5 OBJECTIVES

1 To quantify the irregularities (potholes bumps) on the various road type in Nigeria.

2. To compute velocity and acceleration inputs from these irregularities on to the vehicle suspension system using known vehicles parameters.

3 To recommend based on 1 and 2 specific conditions that will gives optimum vibrations and hence reduce mechanical damage in fresh produce.

1.5.1 JUSTIFICATION:

Fruits and vegetable contain high moisture content ranging from 75 to 90o/o (singn and singh 1992). Fresh commodities such as tomatoes are therefore susceptible to spoilage during transportation especially over long distances. Tomatoes are largely produced under irrigation in Northern part of Nigeria and had to be transported after harvest to urban areas and markets for sells. The vibration caused to the commodity due to truck transport on Nigeria roads constitute serious quality deterioration losses due to transportation is extremely high. There is need to find possible solution to minimize produce losses between grower and consumer. One way of achieving this is to identity sources from which the factors responsible for the damage come from and try to find a way of avoiding conditions that will generate such factors, hence the essence of the present assessment.

CHAPTER TWO

2.0 LITRARATURE REVIEW

2.1 FRESH TOMATOES AND TRANSPORTATION

Tomatoes are transported over long distances resulting in significant spoilage due to vibrations. Based data in respect of magnitude of vibration are not available (singh and singh, 1992).

Transportation of fresh produce such as tomatoes are mostly carried out using the road as the route in Nigeria (Idah et al 1996) It is thus desirable to review the road transport system and the problems inherent in them as far as handling of fresh produce is concerned with the view to reduce the attendant quality deterioration in the fresh produce.

Transportation of fruits and vegetables must be carried as quickly as possible to get them to their destinations before they spoil. Tomatoes and other fruits are sensitive to the quality of roads and the mode of transport facilities (Robema and Husserin 1996). It is noted that a vehicle loaded with fruit or vegetables traveling along a smooth road at constant speed may be considered to be in a vertical static Equilibrium. The forces between the various system elements are constant and there in no transformation of energy.

However, when the vehicle encounters discontinuity in the road surface bump for example, some of the kinetic energy of the vehicle is dissipated in deforming the road, the types, suspension, chassis, package, cushioning and the produce. (Jones et al 1991) Damage to produce is the direct result of the dissipation of the energy in the produce. Road irregularities are therefore crucial in the investigation of the effects of road-vehicle-packaging inter-actions in fresh produce transportation.

2.1.1 Properties of ground surfaces. As noted earlier, vibrations in the vehicle and the subsequent damages that result in the produce are caused by road irregularities. In order to evaluate the vibrations properties of an existing vehicle or to analyse the same for a vehicle still in the design stage, two complex factors have to be evaluated by the critical means, the properties of the ground surface and the vibration characters of the vehicle.

Any access roads for vehicles require smooth surface free of potholes and which is passable in wet weather or immediately after rain storm conditions. The particular type of surface used is designed to meet the normal anticipated loading from vehicles (Habib 2001). Underneath any road are the compacted solid which is to distribute the vehicle loads. If the soil is saturated with excess water, their bearing capacity will be drastically reduced and could even eventually lead to failure of road surface. Geometric design data for the roads should therefore be consistent with the traffic design speed and access control compaction and drainage are two most important factors in the construction of roads. The information on the properties of ground surface is important because it has been shown that a constant smooth highway surface is important for the safe and long life operation of vehicles and their suspensions (Ogaga 2000). Such smooth rides will also minimize the incidences of mechanical damages in the fresh produce during transportation and hence reduce the incidence of post harvest losses in these produce.

2.1.2 ASSESMENT OF ROAD PROFILES

Several methods are known for the establishment of the terrain profile. It is revealed that most of these methods usually yield a continuous signal to the instantaneous height of the terrain profile. (Wendenborn 1966). Spectral density of the profile is then obtained by means of a frequency analyzer. The properties of the surface are usually represented by the spectral density of the ground profile. The mean square of the profile height is plotted as functions of the frequency of the road profile thus establishing the analysis of the ground profile(Ogaga 2000). These methods require complex measuring apparatus such as frequency analyzers.

Another method of measuring the road profile is the use of tape to measure the length and point heights of a path profile. The tape is laid over the ground and marked at equal distances and the relative profile height is measured at the marks. A surveyor's staff scaled in 2mm units is used. The staff which is equipped with a spherical base is placed next to the tape mark. The distance between the points on the ground and the optical axis of the telescope (cross hairs) which is set horizontally will be observed on the staff and recorded. The procedure is repeated for each mark so that the ground profiles along the line can be reproduced fairly well from the data sheet (Ogaga 2000).

High way profiles are noted to fit into the general category of broad – band random signals and hence can be fully analysed by the profile itself or the statistical properties, the power spectral density (PSD) (Ogaga, 2000). Thus like any other random signal, the elevation profile measured over the length of the highway can be analysed by Fourier transform process into series of waves of different wavelength. The sine waves vary in their amplitude and sphere. The power spectral density (P.S.D) or the profile elevation is a plot of these amplitudes versus spatial frequency thus displaying the amplitude content as functions of frequency. (Ogaga 2000).

For a typical vehicle traversing rough roads the spatial frequency is examined as the wave number with units of cycles/metre, and is the reciprocal of the wavelength of the sine wave on which it is based. This parameter can be derived from the vehicle wheel base and speed of travel. It is therefore important to have an insight into such assessment which can influence the choice of vehicle with the optimum suspension system that will fit into such irregularities on the road. This will help in minimizing the vibrations resulting from such encounters and hence leads to subsequent reduction in produce damage.

2.1.3 MEASUREMENT OF VIBRATION DURING TRANSPORT.

To transport tomatoes to distant places, generally greenish tomatoes are packed in either basket packs of 10 – 12kg or in wooden Boxes of capacity 18 – 20kg after sorting out good tomatoes from the lot as picked from the fields. In a study to measure the vibrations, on actual road conditions a vibration pick up instrumentation system was designed and developed for the purpose. The instrument was used to measure vibration between boxes and the truck bed and within tomatoes. Box to box vibration measurement were made by fixing the instrument to the base of the box and then the box packed with tomatoes. A single layer of news print paper was placed in boxes before filling in tomatoes. The second unit of the instrument was placed within the tomatoes in separate boxes to measure the vibration among tomatoes packed in the boxes.

Boxes thus packed with fresh tomatoes were placed on truck and transported to a distance of about 200km on National High way 1A. The second set of vibration data was obtained while transporting tomatoes to a similar distance on National High way 1. Another variety of tomatoes harvested manually from farm were graded and packed in the boxes with the same instrument installed in the same manner as in the first case. The data on vibration were then recorded on the cassettes and produced on the spectrum analyzer in processed form. [Singh and singh 1992]. Analysis of the data was carried out on spectrum analyzer and storage oscilloscope. Result obtained on the screen of storage oscilloscope was noted visually as well as photographically. Photographs were taken with the help of sophisticated camera, attached to the screen of the storage oscilloscope. One decision on horizontal scale represents 50Hz and one vertical division represents 1MV of amplitudes. The result showed that the road conditions determine the magnitude of vibrations acceleration 'g' to the fruits. These accelerations generated at the road surface are transmitted to the fruit through truck chassis and suspension system. The values of 'g' at various frequencies have been plotted for both routes. As evident from these figures generally the boxes experienced higher 'g' than the tomatoes. As a result of the tomatoes within the container received lesser shock than the container itself.

(Singh and Singh 1992)

The effect of vibration on the quality of tomatoes was seen from the firmness values obtained on the Instron universal testing machine (Singh and Singh 1992) It was found that firmness of tomatoes decreased as the storage period increased. The result are in closed agreement with the findings of 'O' Brien et al (1963).According to 'O'

Brien the damage to pear-shaped tomatoes; is sight as in the case of Punjab Chhuhara and standard round variety only in Punjab kasseri. It is noted that Punjab kasseri suffer considerable damage during simulated transit treatment and storage. (Singh and sigh 1992).

2.1.4 Vibration characteristics of vehicles. The potholes in highway are the deviation in elevation seen by vehicle as its moves along it. The potholes therefore acts as vertical displacement input to the wheels thus exciting ride vibrations (Ogaga 2000). The characteristics values and the properties of the vehicle are taken in to account by the amplification factors. That factor gives the radio of the amplitude measured on the vehicle and the exciting amplitude frequency. This can be established by subjecting the vehicle to vibrations at various definite frequencies using a vibrator table for the experiment. A review of the vibration taking place is necessary because damage to the fresh produce is a direct result of the dissipation of the energy in the produce which is also influenced by the energy dissipative characteristic of the constituents elements of the vehicle-load system and the way the elements are linked determined the overall response and the amount of damage to the produce. (Jones et al 1991, singh and singh 1992)

2.1.5 Vehicle-Road inter action.

The produce in the vehicle are affected by the vibrations which are excited by the irregularities of the road. The irregularities of the road cause various kinds of vibrations (Jones et al 1991, Ogut et al 1999). Damage during transport is a major cause of quality deterioration during the distribution of the fresh fruits and vegetables. The basic mechanisms involved seem to be impact of vibration experienced by individual items of the produce as the vehicle traverse abrust changes in road profile. The damage it is noted takes place when the road conditions are bad and the suspension system of the trucks are either too soft or too hard. For multi layered energy absorbing load such as horticultural produce, the road- vehicle load inter action determine the energy dissipated within the load and hence the mechanical damage to the produce (Jones, et al 1991).

It is noted that such damages to the fruits and vegetable during transportation are greatest on the top layer of the fruit and that under severe transport condition may extend down to other layers. (Ogut et al 1999). Evaluation of the vibrational properties of the vehicle requires evaluating two complex factors, the ground surface and the vibration characteristics of the vehicle. A review of these interactions and the attendant problems as far as the fresh produce transportation is concerned is very necessary especially in the country like Nigeria where the roads conditions are in deplorable states. It is stated that the damage resulting from this situation can be reduced by avoiding resonance vibration. This condition can be avoided by getting the natural frequency of the excitation force while in transit [Ogut et wwal,1999] .

2.1.6 Types and volumes of transport vehicles is the most important components in the marketing system of fresh produces that requires great attention is the physical distribution system. Transportation problems stand in the way of efficiently distributing these products, thus forcing the production of bulky perishable goods to be located near the market or in consuming areas because of high transportation cost (Boligor and Lidasan, 1996) several type of vehicles are involved in the transportation of fresh produce. In the rural areas bicycle and motorcycles are the predominant types being used to transport farm produce (Adeoti; 1998). The inter state movement however, involves the use of 4 wheel vehicles of various kinds. These include Mercedes, 911 lorry, fuel tankers, canter, pick-up and articulated vehicles (Idah et al, 1996). The transportation cost of goods depends on the nature of the commodity to be hauled. In the case of perishables such as fruits, vegetables and other products, there must be moved quickly to get them to their destinations before they spoil. The distance, time and the mode of conveyance thus becomes the important factors.

Delay due to non availability of transport vehicles when needed is one of the contributing factors to produce deterioration in the Nigerian fresh produce distribution. It is because of this that the transporters make use of any kind of vehicle even including fuel tankers to haul their produce. It is thus necessary to have a well co-ordinated system that will help the people to involve in this business to have better return for their produce because effective deliverance of the fresh produce will command better prices and this will go a long way in encouraging more production and hence improve in economy of the country.

2.1.7 Vehicle suspension system. The suspension is in an assemblage of devices that provide connection between the load carrying system and axles or wheels of the auto mobile, decrease dynamic loads on the load carrying system and wheels and damp their vibrations. In other words the primary function of the suspension system is to isolate the structure, so far as practicable from shock loading and vibration due to irregularities of the road surface [Newton et al 1996].The suspension system is made up of elastic elements containing lateral stabilizer, guide and damper [shock absorber] of which combined to execute the above function [Stockel et al, 1996, Hillier and Pituck, 1990, Ogaga 2000]. In a study to investigate the effect of suspension and road profile on bruising in multi layered apple packs, Holt and schoorl, 1985) model the vehicle suspension system response.

2.2 Road construction and maintenance. Nigeria has some 32,000km of roads as far back as in the 1970's and more than four fifth were paved. Thus there was enough money to build roads and pave existing ones thus creating a well developed system. (Encyclopaedia Britannica, 2002). However since then the situation has greatly altered as most of these roads and those constructed after are not properly maintained and most have become very dangerous to use. This terrible state of affairs is actively hampering many activities especially those related to agriculture. For instance, agricultural extension workers find it difficult to reach the rural farming families so as to advice them on new farming technologies and improved methods because of lack of all weather roads and this is militating against agricultural development in the country. (Habib 2001, Adeoti, 1998).

Similarly transportation of Harvested crops to the markets becomes difficult and tedious with attendant produce losses in the process (Ogut et al 1999).

But since most goods and services are transported by the use of roads, it is necessary to sustain these roads to ensure the desired smooth ride (Abdullahi, 2000).

The delay in transit resulting from the poorly maintained roads constitute major factors in fresh produce deterioration during handling.

It can be seen from this review therefore that the role of the road in transporting fresh tomatoes and other fresh produce in Nigeria is very crucial. Since the vibrations and impacts which eventually lead to the damage in the produce actually stems from excitation produced by the irregularities of the roads. Reduction in the excitation through smooth ride could as well provide the desired reduction in produce damage thus enhancing produce quality.

2.3 Road maintenance over the years

More often than not people are unaware of the basic fact that building roads alone is not enough. They have to be maintained. Roads like any other structures built by man deteriorate over time. Cracking occurs in bituminous pavements which together with rain water ingress, result in rapid formation of ruts and potholes (Osemenam 1994) The bitumen in the wearing course gradually loses its binding quality and pavement becomes brittle.

Thus roads have to be built to standard, commensurate with climatic conditions and expected traffic and then they must be adequately maintained to prevent deterioration. It is necessary at this point to make mention of the procedure for maintaining the various classes of roads in Nigeria. The local councils or the local Government maintained their roads with their staff. The state Government do the same when the Federal ministry responsible for roads could not carry out the direct maintenance of federal roads. Consequently the states do undertake the direct maintenance of federal roads within their territories and the funds are provided by the federal Government. The state government are paid Agency fee which is an agreed percentage of the federal funds spent by the state or region for maintenance of federal roads. (Osemenam 1994).

CHAPTER THREE

3.0 THEORY, INSTRUMENTATION AND METHODOLOGY

3.1 THEORETICAL ANALYSIS

Potholes the greatest factor of pavement failure are viewed as displacement input factor to the wheels which generates: (Ogaga 2000).

a) Vertical "Velocity" and "acceleration" inputs to the wheels and excite vehicle ride vibration, with resonance (g) and force frequency (f).

b) Roll excitation input to the vehicle

c) Factors leading to loss of wheel contact with the road surfaces.

Potholes, a factor in highway roughness can be absorbed by the elevation profile of the wheel tracks along which the vehicle travels. Highway profiles fit the general category of "broadband random signals and hence can be fully analysed by the profile itself or its statistical properties; the power spectral density (PSD).

Like any random signal, the elevation profile measured over the length of the highway can be decomposed by the Fourier transform process into a series of waves of different wavelengths. The waves vary in their amplitude and phase relationships. The PSD or profile elevation is a plot ideally an instrument that could produce a continuous signal providing a recording proportion to the instantaneous height of the terrain profile is usually preferred. The spectral density of the profile is then obtained by means of frequency analyzer.

The power density for a continuous spectrum is given as

$$\phi\Omega = \lim_{x \to \infty} \frac{1}{2\pi x}\left[\int_{-x}^{x} y(x)e^{-i\Omega x}dx\right]^2 \text{ ----------- } 3.1$$

where

$\phi\Omega$ = power spectral density relative to road frequency.

X = length of curve,

x = limits of integration, y = relative profile height,

Ω = profile frequency.

Here the value of the function, y(L) is related to the frequency considered. All the values obtained for a given frequency summarized. The square of the sum gives the power density of the infinite function of the given frequency.

However because of lack of the desired equipment (frequency and spectrum analyzer) and the vigours of using equation (1) the continuous profile is sometimes evaluated step by step as if it were discontinuous and the finiteness of the length of the test course is considered.

The running average of the profile is given by

$$\overline{ym}(x) = \frac{1}{l+1} \sum_{k=-\frac{l}{2}}^{k=\frac{l}{2}} y(x + k\Delta x) \text{------------- } 3.2$$

where

$\overline{ym}$ = running average, l = number of terms

for averaging, y = relative profile height.

X = length of course.

The profile height is established as the instantaneous from

$$\overline{y}(x) = y(x) - \overline{ym}(x) \text{----------------- } 3.3$$

The function which is now distributed is squared by using the correlation factor

$$R_r = \frac{1}{n-r} \sum_{p=1}^{n-r} \overline{y}(x = p)\overline{y}(x = p + r) \text{ --------------------- } 3.4$$

where r = 0, 1, 2,...m

k, p, r–serial numbers in series, m= number of correlation factors; Rr = auto correlation factor, n = number of profile points measured. Y = corrected profile height.

The mean square deviation of the average obtained from equation (3.4). for the value r = 0 as follows:

$$Ro = \sigma^2 = \frac{1}{n} \sum_{p=1}^{n} \overline{y}^2 p \text{ --------- } 3.5$$

Where standard deviation or mean square deviation.

The series of these correlation factors represent the needed periodic function for which the Fourier analysis can be carried out.

In this aspect of the study the elevation profiles of the route (road) commonly used for the haulage of the fresh produce will be assessed. A survey of the occurrence of these irregularities (pot holes, bumps and the surface elevation) will be conducted on these roads. The data obtained will be used to establish the effects of vibration frequency distribution and duration the quality of the produce.

3.2 INSTRUMENTATION.

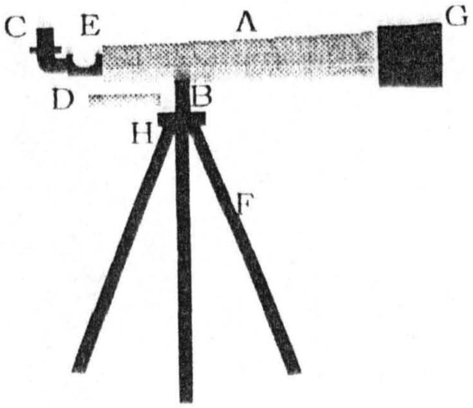
In order to successfully carry out this task, the following equipment and materials will be needed:

Engineer's level, leveling staff/rod, measuring, tape, spectral and frequency analyzer (optical), personal computer with relevant soft wave.

Engineer's level

This is an instrument used for direct measurement of vertical distances. This is the most precise method of determining elevation. It has a line of sight and spirit level tube. The level tube is so mounted that its axis is parallel to the line of sight engineer's level as shown in the fig. 3.0

Figure 3.0



It consists of the telescope A mounted upon the level bar B which is rigidly fastened to the spindle C. Attached to the telescope or the level band parallel to the telescope is the level tube D. The spindles fits into a cone shaped bearing of the leveling head E, so that the level is free to revolve about the spindle C as an axis. The leveling head is attached to a tripod F. In the tube of the telescope are cross hairs of G, which appear on the image viewed through the telescope. The bubble of the level is centered by means of the leveling screws H. Two distinct types of engineer's level are:

1 The dumpy level for which the telescope tube is permanently fastened to the level bar and

2 Self – leveling or automatic levels.

Leveling rods (staff).

These are graduated wooden rods of rectangular cross section by means of which difference in elevation is measured. The lower end of the rod is stood with metal to protect it from wear and is usually the point of zero measurement from which the graduation are the reading of the rod as indicated by the horizontal cross hair of the level is measure of the vertical distance between the point on which the rod is held as the line of sight the type include single process.

3.3 METHODOLOGY.

The road system is used in hauling the fresh tomatoes. The essential factors contributing to the deterioration of the fresh produce as far as the road system is concerned are the irregularities (i.e failures resulting in potholes, bump and other surface profiles). The excitation from these failures especially the pot holes result in ride vibrations on the vehicle which subsequently result in produce damage. Therefore the pot hole as a "displacement input" was considered and the elevation profiles was measured.

Ideally, an instrument that could produce a continuous signal providing recording proportions to the instantaneous height of the terrain profile would have been preferred.

This requires instrument such as spectrum and frequency analyzer which was not available. Therefore, an alternative method that uses a step by step procedure was used. The elevation profile was measured by performing a close interval rod and level surveys.

The experiment was conducted in the following sequence.

- Assessment of potholes and bumps
- Measurement of surface profiles

- Determination of wave length.

3.4 ASSESSMENT OF POT HOLES AND BUMPS.

This involve counting and taking necessary measurements of the dimensions of the pot holes and bumps.

Procedure:

Since there are different types of road surfaces (tarred, untarred, concrete and gravel/graded), a representative of these road trunks were selected. Thus the exercise was carried out on the following. Inter-state (for long distance movement), intra-state (for short distance) and rural or farm roads (for short duration). On each of these roads distances (2km each) in three replicates was marked. Within these distances, the number of potholes, their width and their depth were measured. The selected roads are:

- Tegina-Kagara Road (Inter State – road)
- Minna-Bida Road (Intra State Road)
- Tungar Yashi-Jukuchi (Rural Road)

Along the selected roads there were no identified bumps only the potholes were counted and measured.

3.4.1 MEASUREMENT OF SURFACE PROFILES:

Using the roads selected earlier, the deviation profile of the distances selected were measured as follows.

A measuring tape was laid over the ground. A selected length of 100m was used as chainages marked out at equal intervals along the measured distances. The relative profile height was measured along the marked distances.

A surveyor's leveling staff graduated was used with its base placed on the track next to the tape mark. The distance between the points on the ground and the optical axis of the telescope (cross hair in the theodolite) which was set horizontally was observed on the staff and recorded. The procedure was repeated for each mark so that the ground profile along the line could be reproduced fairly well from the data sheet. The process was repeated along the 3 distances of 2 Km set out on each road type (a total of 6Km was covered on each road).

3.4.2 Determination of the wave length and wave number (or frequency) for a typical vehicle of known dimension (Peugeot pickup van and Mercedes 911 Lorry)

On both vehicles the distances from the front wheel to the centre of gravity (CG) of the vehicle were measured and represented by letter 'a' and that from the rear wheel to the centre of gravity (CG) also denoted by 'b' are all known.

The wavelength was then computed from

$$WL = \frac{(a+b)}{n}$$ ----------------------3.10 for pitch motion, n = 1,3,5,

while $$WL = \frac{2(a+b)}{n}$$ ----------------------3.11 for bounce motion, n = 0,1,2,3.

a, b as stated above are the distances from front wheel and rear wheel respectively to the centre of gravity of the vehicle.

The wave number (*W*) is given by the relationship

$$W = \frac{1}{WL}$$ --------------------3.2

Similarly, knowing profile elevation along with the total number of potholes, number of potholes per square metre of the road, the average ripple amplitude for the road and travel time, then the following pothole input loadings to the vehicle wheels can be computed, from the following relationship:

1. A speed was assumed such that the elevation profile of the road with potholes could be transformed into displacement as a function of time.
2. The value of the elevation profile was then transformed to

(a) Velocity by the first differentiation

(b) Acceleration by the second differentiation. (Ogaga 2000)

$E_p = A \sin(2\pi Wx)$

E_p = Elevation profile

A = Sine wave aptitude (ripple)

W = spatial frequency

X = distance along the road.

π = 3.142

Two vehicles (Meriedes 911 lorry and pick up van) with the following parameters were selected.

Mercedes 911 Lorry:

a = distance from front wheel to the centre of gravity of the lorry = 2.6m

b = distance from the rear wheel to the centre of gravity of the lorry = 2.4m.

Peugeot pickup van:

a = distance from front wheel to the centre = 1.6m,

b = distance from rear wheel to the centre = 1.24m.

911-lorry has a total of 5m wheel base,

Peugeot pickup has 2.84m wheel base

Distance covered during the survey = 6000m

Total no. of potholes for inter State – road within the 6000m covered = 102

Using the Data obtained from the field

Average ripple/amplitude = 0.08m for inter state road

Carriage way width = 7.5m

Wave length $WL = \frac{a+b}{n} = \frac{2.6+2.4}{n}$

For pitch motion, n = 1, 3, 5

$$WL = \frac{2(2.6+2.4)}{3}$$

$$= \frac{2(5)}{3} = 3.33m$$

$$W = \frac{1}{WL}$$

$$W = \frac{1}{3.33} = 0.3003m$$

$$Wv = 2\pi wv[A\cos(2\pi wvt]$$

$$Wa = -(2\pi wv)^2[A\sin 2\pi wvt]$$

$$V = \frac{S}{t}$$

$$\therefore t = \frac{S}{v}$$

Using the data obtain from the field,

the following input loadings to the vehicle wheels were computed.

(1) Wheel velocity input (Wv)

(2) Wheel Acceleration input(Wa)

(3) Wheel peak dynamic loading (Wg)

(4) Wheel effective frequency (Wf)

(1) For velocity input

$$Wv = 2\pi wv[A\sin(2\pi wvt]\, m/s^2$$

(2) For Acceleration input.

$$Wa = (2\pi wv)^2[A\cos 2\pi wvt]\, m/s^2$$

(3) For peak dynamic input

$$Wf = W(a)/9.81N$$

(4) For effective frequency in Hz

$$Wf = \frac{V}{WL} \text{ or } [(v)\ (w)]Hz$$

Where

W = wave number (cycles/metre)

WL = wave length (m)

V = vehicle velocity m/s

t = Travel time

Detail of calculation can be found in the Appendices.

3.4.3 Techniques of Analysis

The data collected on the potholes and the computed loadings to the vehicle were subjected to statistical analysis. The statistics used was the completely randomized detail was used to analyse the data. ANOVA of the data was carried out to hereby whether, there are any significant differences between the mean values of the data from the different roads.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Pothole.

The results of the pothole parameters obtained from the survey of the different roads are presented in Table 4.1.

TABLE 4.1 Measured parameters of the potholes along the selected three roads.

AD TYPE "A" INTER-STATE ROAD TEGINA KAGARA			ROAD TYPE "B" INTRA STATE MINNA BIDA ROAD			ROAD TYPE "C" RURAL ROAD OR FARM ROAD. RAFIN YASHI TO JUKUCHI		
	RIPPLES (depth)	DIAMETER/ WIDTH(m)		RIPPLES	DIAMETER/ WIDTH		RIPPLES	DIAMETER/ WIDTH
	0.04	0.9		0.018	1.42	Rep1 2km distance	0.54	1.54
ep1 km tance	0.025	0.85	Rep1 2km distance	0.02	0.98		0.34	1.23
							Total= 0.88 Average= 0.44	Total= 2.77 Average= 1.39
	0.64	1.1		0.022	0.96	Rep2 2km distance	0.34	1.4
	0.441	0.64		0.024	1.15		0.24	0.75
	0.042	0.76		0.03	1.32		0.2	1.24
							Total= 0.78 Average= 0.26	Total= 3.39 Average= 1.13
	0.63	0.8		0.026	1.42	Rep3 2km distnace	0.54	0.92
	0.026	0.56		0.034	0.76		0.4	0.56

	0.5	0.96		0.4	0.87		Average =0.47m	Average = 0.74m
	0.076	1.2		0.02	0.58			
	0.096	0.84		0.028	0.74			
	0.24	0.9		0.038	0.64			
	0.042	0.7		0.018	0.66			
	0.038	0.6		0.06	0.98			
	0.029	0.8		0.4	0.85			
	0.018	1.3		0.07	0.78			
	0.016	1.23		0.023	1.2			
	0.44	1.45		0.014	1.32			
	0.088	1.00		0.078	1.0			
	0.098	1.45		0.024	0.52			
	0.029	0.87		0.032	1.14			
	0.090	0.78		0.021	1.21			
	0.081	0.64		0.019	0.82			
	0.022	0.54		0.68	0.72			
	0.026	1.21		0.08	0.88			
	0.027	1.68		0.062	0.92			
	0.020	1.13		0.087	0.72			
	0.040	1.20		0.093	1.1			
	0.041	1.31		0.017	1.32			
	0.042	0.80		0.48	1.24			
	0.038	0.72		0.012	0.98			
	0.041	1.45		0.022	0.78			
	0.045	1.3		0.432	0.76			
	0.03	0.92		0.028	0.92			
	0.028	1.1		0.024	0.83			
	0.032	1.32		0.082	0.85			
	0.036	1.22		0.028	0.94			
	0.033	0.85		0.024	0.98			
	0.03	0.88		0.02	1.2			
	0.04	0.67		0.018	1.18			
	0.04	0.79		0.0167	1.56			
	0.038	0.98		0.024	0.94			
	0.039	0.85		0.028	0.84			

	0.039	1.23						
	Total=4.452 Average= 0.104	Total= 42.48 Average= 0.988		0.035	1.46			
Rep2 2km istance	0.02	1.2		0.04	1.34			
	0.028	0.98		0.041	1.23			
	0.04	1.13		0.0182	1.52			
	0.034	0.68		0.017	1.28			
	0.026	0.45		0.019	0.7			
	0.03	0.76		0.022	1.12			
	0.018	0.78		0.038	1.0			
	0.0176	0.9		0.34	0.8			
	0.041	0.86		0.028	0.67			
	0.028	0.8		0.097	0.72			
				Total= 4.3719 Average= 0.0825	Total= 52.82 Average= 0.9966			
	0.032	0.87	Rep2 2km distance	0.078	1.3			
	0.016	0.96		0.026	1.4			
	0.019	0.88		0.03	1.4			
	0.015	1.14		0.02	1.1			
	0.021	1.16		0.02	0.9			
	0.023	1.23		0.022	0.76			
	0.027	1.18		0.028	1.5			
	0.035	1.24		0.019	0.5			
	0.038	1.11		0.02	0.65			
	0.17	0.7		0.02	0.76			
	0.022	0.66		0.098	0.84			
	0.020	0.69		0.077	0.95			
	0.028	0.77		0.016	0.64			

	0.023	0.52		0.14	0.68			
	0.024	0.51		0.02	1.2			
	0.027	0.62		0.022	1.32			
	0.017	0.89		0.024	1.1			
	0.02	0.8		0.014	1.32			
	0.024	1.14		0.012	1.46			
	0.019	1.19		0.017	1.28			
	0.023	1.4		0.076	1.46			
	0.03	0.98						
	Total= 0.9556 Average= 0.030	Total= 29.18 Average= 0.912		0.09	0.55			
Rep3 2km distance	0.024	1.62		0.028	0.54			
	0.03	1.32		0.017	0.68			
	0.04	0.96		0.024	0.7			
	0.038	0.83		0.022	0.8			
	0.037	1.17		0.028	0.86			
				0.030	0.78			
	0.022	1.47		Total= 1.038 Average= 0.0371	Total= 27.43 Average= 0.9796			
	0.028	0.68	Rep3 2km distance	0.014	0.34			
	0.018	0.72		0.012	0.56			
	0.023	0.89		0.2	1.4			
	0.026	1.2		0.092	1.3			
	0.021	1.34		0.038	1.46			
	0.54	1.42		0.029	0.8			
	0.4	1.12		0.05	0.76			
	0.042	0.9		0.043	0.89			
	0.041	0.82		0.024	0.5			
	0.62	0.95		0.03	0.92			

0.61	0.67		0.028	1.0			
0.024	0.62		0.029	0.98			
0.086	1.1		0.026	1.0			
0.098	0.85		0.019	1.2			
0.087	0.74		0.03	1.5			
0.091	0.73		0.037	0.4			
0.078	0.87		0.035	0.54			
0.048	1.32		0.034	0.34			
0.042	1.4		0.022	1.0			
0.032	1.38		0.021	1.2			
0.039	0.96		0.029	1.3			
Total= 3.185 Average =0.1180 ≈ 0.12	Total= 28.05 Average =1.039m ≈ 1.04m		0.018	1.3			
			0.04	0.48			
			0.02	0.5			
			0.015	0.75			
			0.04	0.92			
			0.05	0.74			
			0.04	0.77			
			0.012	0.4			
			0.038	0.96			
			0.017	1.4			
			0.082	0.42			
			0.021	0.8			
			0.018	0.48			
			0.4	0.44			
			0.022	0.92			
			0.021	1.3			
			0.012	1.45			
			0.074	1.0			

				0.02	1.35			
				0.024	0.3			
				0.027	0.36			
				0.031	0.8			
				0.038	0.94			
				0.024	1.12			
				0.029	0.6			
				0.038	0.67			
				0.041	0.48			
				Total= 2.054 Average = 0.04279 ≈ 0.043m	Total= 41.04 Average = 0.85500 0.856m			

The results showed that along the inter-state road, within a distance of 6km, we have 102 number of potholes with an average ripple of 0.08m and average width of 0.969m.

On the intra-state road however, within the same distance the average number of potholes is 128 with average ripple of 0.5298m And width of 0.926.

Along the rural road the average number of pothole per 6km is 7 number while the average ripple is 0.37m and the average width is 1.09m.

The elevation profiles within the selected distances are presented in figures 4.1 to 4.3. The width of the roads were 9m, 7.5m and 5m for he inter, intra and rural roads respectively.

4.2 Velocity and Acceleration inputs.

The results of the computed velocities, acceleration inputs and dynamic loading in to vehicle wheels resulting from the potholes on the various roads are presented in Tables 4.2 to 4.7.

TABLE 4.2

COMPUTED WHEEL VELOCITY, ACCELERATION, PEAK DYNAMIC LOADING AND FREQUENCY OF POTHOLE INPUT TO 911 MERCEDES LORRY OF 5 METRE WHEEL BASE TRAVELLING AT 20, 40, 60, 80 AND 100 KM/H ON TEGINA KAGARA ROAD.

S/No	V/S/speed km/h	V (Sec.)	T (Sec.)	WL (m)	W** (m)	W(v) m/s^2	W(a) m/s^2	W(g) N	W(f) Hz	Ep m^2/cm
1	20	5.55	1081	3.33	0.3003	0.2	8.270	0.843	1.67	0.754
2	40	11.11	545	3.33	0.3003	0.336	33	3.36	3.3	0.78
3	60	16.67	361	3.33	0.3003	0.33	77	7.849	4.98	0.79
4	80	22.2	270	3.33	0.3003	0.587	138.2	14.08	6.67	0.787
5	100	27.78	222	3.33	0.3003	0.7134	204.47	20.8	8.1	0.787

TABLE 4.3

COMPUTED WHEEL VELOCITY, ACCELERATION, PEAK DYNAMIC LOADING AND FREQUENCY OF POT HOLE INPUT TO 911MERCEDES LORRY OF 5 METRE WHEEL BASE TRAVELLING AT 20, 40, 60, 80, 100 Km/H ON MINNA BIDA ROAD

S/No	V/S/speed km/h	V (Sec.)	T (Sec.)	WL (m)	W** (m)	W(v) m/s^2	W(a) m/s^2	W(g) N	W(f) Hz	Ep m^2/cm
1	20	5.55	1081	5	0.2	0.206	2.43	0.2477	1.11	0.403
2	40	11.11	545	5	0.2	0.6896	7.865	0.8	2.22	0.43
3	60	16.6	361	5	0.2	0.495	19.15	1.95	3.32	0.44
4	80	22.2	270	5	0.2	0.589	33.73	3.438	4.44	0.433
5	100	27.78	222	5	0.2	0.847	49.89	5.08	5.4	0.433

TABLE 4.4

COMPUTED WHEEL VELOCITY, ACCELERATION, PEAK DYNAMIC LOADING AND FREQUENCY OF POTHOLE INPUT TO ALL MERCEDES LORRY OF 5 METERS WHEEL BASE TRAVELLING AT 20, 40, 60, 80, AND 100Km/H ON RAFIN YASHI JUKUCHI ROAD.

S/No	V/S speed km/h	V (Sec.)	T (Sec.)	WL (m)	W** (m)	W(v) m/s^2	W(a) m/s^2	W(g) N	W(f) Hz	Ep m^2/cm
1	20	5.55	1081	1.67	0.59	5.9	99.27	10.11	3.23	0.234
2	40	11	545	1.67	0.59	13.77	251.68	25.65	6.586	0.15
3	60	16.6	361	1.67	0.59	21.9	389.40	39.69	9.940	0.1028
4	80	22.2	270	1.67	0.59	28.4	890.23	90.747	13.29	0.1313
5	100	27.78	222	1.67	0.59	34.6	1316.572	134.70	16.167	0.1313

TABLE 4.5

COMPUTED WHEEL VELOCITY, ACCELEATION, PEAK DYNAMIC LOADING AND FREQUENCY OF POTHOLE INPUT TO PEUGEOT PICKUP TRAVELLING ALONG TEGINA ROAD

S/No	V/S/speed km/h	V (Sec.)	T (Sec.)	WL (m)	W** (m)	W(v) m/s²	W(a) m/s²	W(g) N	W(f) Hz	Ep m²/cm
1	20	5.55	1081	2.84	0.35	0.974	11.89	1.211	1.95	0.799
2	40	11	545	2.84	0.35	1.884	5.35	0.544	3.87	0.18
3	60	16.6	361	2.84	0.35	2.78	32.75	3.33	5.8	0.245
4	80	22.2	270	2.84	0.35	3.77	49.73	5.069	7.8	0.208
5	100	27	222	2.84	0.35	4.59	73.57	7.49	9.5	0.208

TABLE 4.6

COMPUTE WHEEL VELOCITY, ACCELEATION, PEAK DYNAMIC LOADING AND FREQUENCY OF POTHOLE INPUT TO PEUGEOT PICKUP VAN ALONG MINNA BIDA ROAD

S/No	V/S/speed km/h	V (Sec.)	T (Sec.)	WL (m)	W** (m)	W(v) m/s²	W(a) m/s²	W(g) N	W(f) Hz	Ep m²/cm
1	20	5.55	1081	2.84	0.35	0.608	7.449	0.75	1.95	0.36
2	40	11	545	2.84	0.35	1.18	6.65	0.677	3.87	0.114
3	60	16.6	361	2.84	0.35	1.74	20.47	2.086	5.8	0.1535
4	80	22.2	270	2.84	0.35	2.36	31.086	3.168	7.8	0.1304
5	100	27.78	222	2.84	0.35	2.87	45.98	4.687	9.5	0.1304

TABLE 4.7

COMPUTED WHEEL VELOCITY, ACCELEATION, PEAK DYNAMIC LOADING AND FREQUENCY OF POTHOLE INPUT TO PEUGEOT PICKUP VAN TRAVELLING ALONG RAFIN YASHI JUCHUKU ROAD (RURAL ROAD) AT 20, 40, 60, 80, AND 100 Km/H.

S/No	V/S/speed km/h	V (Sec.)	T (Sec.)	WL (m)	W** (m)	W(v) m/s^2	W(a) m/s^2	W(g) N	W(f) Hz	Ep m^2/cm
1	20	5.55	1081	2.84	0.35	4.45	3.97	0.4	1.95	0.3
2	40	11	545	2.84	0.35	8.717	49	4.99	3.87	0.263
3	60	16.6	361	2.84	0.35	12.856	151.49	15.4	5.8	0.238
4	80	22.2	270	2.84	0.35	17.4419	230	23.4	7.8	0.36
5	100	27	222	2.84	0.35	21.212	340	34.7	9.5	0.36

The results generally showed that as the velocity of the vehicles increases the acceleration input in to the vehicle wheels and the dynamic loads increases. The increase is greater in the case of the vehicle plying the rural roads. Tables 4.4 and 4.7.

The results of the analysis of variance ANOVA and Duncan multiple range test for these data are prescribed in Table 4.8 – 4.13.

Table 4.8 ANOVA for the depth (ripples) of the potholes assessed on the three road types

Analysis of Variance

Source	D.F	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	2	0.659	0.3295	21.6582	0
Within Groups	235	3.575	0.0152		
Total	237	4.234			

Group	Count	Mean	Standard Deviation	Standard Error	95 Pct Conf Int for Mean
Grp 1	102	0.0842	0.1469	0.0145	.0554 TO .1131
Grp 2	129	0.0579	0.1004	0.0088	0.0404 TO .0753
Grp 3	7	0.3714	0.1331	0.0503	0.2483 TO .4945
Total	238	0.0784	0.1337	0.0087	.0613 TO .0945

GROUP	MINIMUM	MAXIMUM
Grp 1	0.0150	0.6400
Grp 2	0.0120	0.6800
Grp 3	0.2000	0.5400
TOTAL	0.0120	0.6800

Table 4.9 Results of Duncan Multiples Ranges test to ascertain the differences between means of potholes' ripples obtained from the roads.

Multiple Range Tests: Duncan test with significance level 0.5

The difference between two means is significant if

MEAN (J) - MEAN (I) >= .0872 * RANGE * SQRT (1/N(I) + 1/N(J))

with the following value(s) for RANGE:

Step	2	3
RANGE	2.79	2.94

(*) Indicates significant difference which are shown in the lower triangle

Mean		G r p 2	G r p 1	G r p 3
	ROADS			
0.0579	Grp 2			
0.0842	Grp 1			
0.3714	Grp 3	*	*	

Subset 1

Group	Grp 2	Grp 1
Mean	22.4700	63.4230

Subset 2

Group	Grp 3
Mean	372.1610

Table 4.10 Results of the ANOVA for the computed velocity input into vehicles on different roads.

Analysis of Variance for Wv

Source	DF	SS	MS	F	P
Vehicle	1	16.32	16.32	0.49	0.492
Road	2	1610.42	805.21	24.02	0.000
Error	26	871.71	33.53		
Total	29	2498.45			

Table 4.11 Results of ANOVA for the computed acceleration inputs into vehicle on different roads

Analysis of Variance for Wa

Source	DF	SS	MS	F	P
Vehicle	1	202011	202011	3.76	0.063
Road	2	730935	365467	6.80	0.004
Error	26	1397025	53732		
Total	29	2329971			

Table 4.12(a) Results of ANOVA for the computed velocities on the different roads.

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	2	1610.4209	805.2105	24.4818	0.0000
Within Groups	27	888.0330	32.8901		
Total	29	2498.4539			

Group	Count	Mean	Standard Deviation	Standard Error	95 Pct Conf Int for Mean
Grp 1	10	1.6164	1.5809	0.4999	.4855 TO 2.7474
Grp 2	10	1.1585	0.8821	0.279	.5274 TO 1.7895
Grp 3	10	16.9247	9.7669	3.0886	9.9379 TO 23.911
Total	30	6.5665	9.2819	1.6946	3.1006 TO 10.032

GROUP	MINIMUM	MAXIMUM
Grp 1	0.2000	4.5900
Grp 2	0.2060	2.8700
Grp 3	4.4500	34.6000
TOTAL	0.2000	34.6000

Table 4.12(b) Results of the Duncan Multiple range test to ascertain the differences between means of the computed velocities under roads.

Multiple Range Tests: Duncan test with significance level 0.05

The difference between two means is significant if
MEAN (J) - MEAN (I) >= 4.0553 * RANGE * SQRT (1/N(I) + 1/N(J))
with the following value(s) for RANGE:

Step	2	3
RANGE	2.90	3.05

(*) Indicates significant difference which are shown in the lower triangle

Mean	ROADS	Grp 2	Grp 1	Grp 3
1.1585	Grp 2			
1.6164	Grp 1			
16.9247	Grp 3	*	*	

Homogeneous subset (highest and lowest means are not significantly different)

Subset 1

Group	Grp 2	Grp 1
Mean	1.1585	1.6164

Subset 2

Group	Grp 3
Mean	16.9247

Table 4.13(a) Results of ANOVA for the computed accelerated on different roads.

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	2	730933.6544	365466.8272	6.1710	0.0062
Within Groups	27	1599032.2520	59223.4167		
Total	29	2329965.906			

Group	Count	Mean	Standard Deviation	Standard Error	95 Pct Conf Int for Mean
Grp 1	10	63.4230	64.0287	20.2476	17.6197 TO 109.226
Grp 2	10	22.4700	17.0347	5.3868	10.2841 TO 34.655
Total	30	152.6847	283.4496	51.7506	74.3798 TO 258.526

GROUP	MINIMUM	MAXIMUM
Grp 1	5.3500	204.4700
Grp 2	2.4300	49.8900
Grp 3	3.9700	1316.5700
TOTAL	2.4300	1316.5700

Table 4.13(b) Results of the Duncan Multiple Range test to ascertain the differences between means of the computed acceleration under different roads.

Multiple Range Tests: Duncan test with significance level 0.05

The difference between two means is significant if

MEAN (J) - MEAN (I) >= 172.0805 * RANGE * SQRT (1/N(I) + 1/N(J))

With the following value(s) for RANGE:

Step	2	3
RANGE	2.90	3.05

(*) Indicates significant difference which are shown in the lower triangle

Mean	ROADS	Grp 2	Grp 1	Grp 3
22.4700	Grp 2			
63.4230	Grp 1			
372.1610	Grp 3	*	*	

Homogeneous subsets (highest and lowest means are not significantly different)

KEY

Road 1 stands for Road A

Road 2 stands for Road B.

Road 3 stands for Road C.

4.3 DISCUSSION

One major problem in the physical distribution of fresh produce is the mechanical damage resulting from impact and vibration. The sources of this vibration are the irregularities on the road. In this study an assessment of the road irregularities (such as potholes and pumps) were carried out to ascertain the extent of excitation resulting from these roads. The result in Table 4.1 showed that an average of 102 and 128 of potholes can be found within a distance of about 6km on a tarred road in Nigeria especially during the period of this study which marks the beginning of the rainy season.

The results of the computation using the average depth of these potholes to determine the vertical displacement input to the vehicles traversing these irregularities showed that as the average velocity of the vehicle increases, the acceleration input into the vehicle wheels and the dynamic load also increases. This increase is however more in the case of rural road. It has been noted that it is this vertical displacement resulting in bounce and pitch motion that usually cause vibration. It is this vibration which is transmitted from the wheel to the chassis and then to the produce package in the container (Ogut et, 1999, Sighn and Singh, 1991, Ogaga, 2000).

The data obtained were subjected to some statistical analysis with the view to ascertain the effects of the different roads and the vehicle types used.

Table 4.8 showed that the average ripples (depth) of the potholes differed significantly between the three types of road studied in this work. The Duncan multiple range test (Table 4.9) initiates that there is a significant difference ($p \leq 0.05$) between the average potholes ripple along the rural road and other two thus conforming the fact that the acceleration inputs along the rural road are greater than those of the other two, irrespective of the vehicle used.

A similar trend can be observed in the results of the velocity input and acceleration inputs shown in Table 4.10 and 4.11. The ANOVA showed that the velocity and acceleration inputs differed significantly ($p \leq 0.05$) between the three road types.

The velocity and acceleration inputs of the vehicles plying the rural road are far greater than those plying the intra state and intra state (Tables 4.12b and 4.13b).

The increase in velocity and acceleration inputs to the vehicles which eventually result in the vibration that cause mechanical damage to the fresh produce is of great importance in the selection of appropriate vehicles.

The damage to the produce usually results from the absorbed energy which is dependent on the impact force. Since force is dependent on man and the acceleration. The information revealed from this study can be used to select vehicles with suspension systems that can cushion and reduce the impact loads into the wheels before it reaches the produce. It can also be used to select appropriate speed at which this produce will be transported knowing the conditions of the roads.

The frequencies obtained in the study which ranges from about 2 – 17Hz (Tables 4.2 – 4.7) also could be employed (if the fresh produce values of frequency is known) to vary them during transportation, because it is noted that greater damage result when the frequency of vibration of the vehicle coincides with that of the produce resulting in resonance. It is when this resonance results that the produce will accelerate extremely resulting in produce damage (Ogut et al 1999 and O'brien et, 1965).

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

An assessment of the road irregularities as sources of excitation input to vehicle hauling fresh produce was carried out. It can be seen from the results obtained that irrespective of the type of vehicle used, the acceleration input (which is a vertical displacement) in to the vehicle and the dynamic load doubles as the velocity increases. Since it is this acceleration which eventually is transmitted through the suspension system of the vehicle to the produce and which causes produce damage through impact; it can be concluded that under such roads as assessed here, the velocity of such vehicle can be appropriately selected such that the vertical displacement can be minimized. The quantification of these excitation inputs as carried out in this work can provide relevant information for developing models that can predict such vertical displacement on vehicles under given sets of conditions of roads.

5.2 RECOMMENDATIONS

The following recommendations are hereby made.

(1) Further research work should be carried out on the assessment of road irregularities selecting another different

types of vehicles other than the ones selected on this assessment.

(2) Government should give more attention on the repairs and rehabilitation of roads.

(3) Automobiles Engineers should think of designing new suspension system of vehicles to suit Nigerian roads.

(4) New packaging system of tomatoes should be introduced while hauling tomatoes from production area (farm) to the markets to reduce damages due to vibration during transit.

REFERENCES

Abdullahi, S.R. (2000): Rehabilitating a Failing Access Road. PGD Thesis (Unpublished) Department of Agricultural Engineering, Federal University of Technology, Minna.

Adeoti, J.S. (1998): Assessment of Two-dimensional Vehicles for Rural Transportation in the Savanna Region of Nigeria. J of Agricultural Mechanization in Asia. Africa and Latin America (AMA). 29(1): 31-39.

Boligor, R.A. and H.S. Lidasan (1999): Study on the Transport of Fresh Fruits by Road: The case of Fresh Mangoes for Export in the Province of Zambales. J. of Agric Engineering Research.

Encyclopedia Britannica (2002) Roads in Nigeria.

Habib, Y.M. (2001): Studies and Design of Farm Access Road PGD Thesis (Unpublished), Department of Agricultural Engineering, Federal University of Technology, MInna, Nigeria.

Hillier, V.A.W. and F. Pittuck (1990): Fundamentals of Motor Vehicle Technology Third Edition. Stanley Thormes (publishers) Ltd. LockHampton Cheltenham London pp351-367.

Holt, J.E. and D. Schoorl (1985): A Theoretical and Experimental Analysis of the Effects of Suspension and Road Profile on Bruising in Multilayered Apple Packs. J of Agricultural Engineering Research. 31:297-308.

Idah, P.A., J.S.; Adeoti and K. Oje (1996): Assessment of Packaging and Transport Devices in Inter-State Fresh Tomato Transportation in Nigeria: Survey Proceeding of the 18th Annual Conference of the Nigerian Society of Agricultural Engineers, Ile-Ife, Nigeria.

Jone, C.S.; J.E. Holt and D. Schoorl (1991): A Model to Predict Damage to Horticultural Produce during Transport. J. of Agricultural Engineering Research, 50: 259-272.

Newton, K.; W. Steeds and T.K. Garrett (1996): The Motor Vehicle 12th Edition British Library Cataloguing in Publication Data. Butterworth-Heinemannn. Pp 896-975.

Ogaga, A.O. (2000): Designing Vehicle Suspension to Suite the Irregularities of Nigerian Roads. Allah-Dey Concept (Nigeria) Ltd. Kwale. Delta State. Nigeria. Pp1 -96.

Ogut, H.; a. Peker and C. Aydin (1999): Simulated Transit Studies on Peaches: Effects of Containers, Cushion Materials and Vibration on Elasticity Modulus. J of Agricultural Mechanization in Asia, Africa and Latin America (AMA). 30:59-62,

Osemenam, (1994): Proceedings of the Lecture on Road Development in Nigeria, Yesterday, Today and Tomorrow.pp12 – 20.

Singh, A. and Y. Singh (1992): Effect of Vibration during Transportation on the Quality of Tomatoes. J. of Agricultural

Mechnization in Asia. Africa and Latin American (AMA). 23:70-72.

Singh, G.(1991): High way Engineering. Third Edition.pp123.

Stockel, M.W.; M.T. Stockel and C. Johnson (1996): Auto Fundamental: How and Why of the Design Construction and Operation of Automobiles, Application to all Makes and Models. The GoodHeart-Willcox Company, Inc. Tinty Park. Illinois. Pp 453-475.

Wendenborn. J.G. (1966): The Irregularities of Farm Roads and Fields as Source of Farm Vehicle Vibrations. J. of Terramechanics 3(3):9-40.

APPENDIX

For time t in seconds.

$$t = \frac{S}{t}$$

$$t = \frac{6000m}{5.55m/s}$$ = 1081sec for travel of 20km/hr

$$t = \frac{6000m}{11m/s}$$ = 545 secs for 40km/hr

$$t = \frac{6000m}{16.6m/s}$$ = 361 secs for travel of 60km/hr

$$t = \frac{6000m}{22.2m/s}$$ = 270 secs for travel of 80km/hr

$$t = \frac{6000m}{27m/s}$$ = 222 secs for vehicle traveling at 100km/hr

(1) Wv = 2 π Wv[Acos(2 π Wvt)]

= 2 x 3.142 x 0.3003 x 5.55[0.008 cos(2 x 3.142 x 0.3003 x 5.55 x 108km

= 10.47 [0.08 cos (2 x 3.142 x 0.3003 x 5.55 x 108 secs)]

= 10.47 [0.08 x 0.3343003794]

= 0.2m/sec^2

(2) Wv = 2 π wv[A cos (2 π wvt)]

= 2 x 3.142 x 0.3003 x 11[0.08 cos(2 x 3.142 x 0.3003 x 11 x 545 secs)]

= 2 x 3.142 x 0.3003 x 11[0.08 cos(2 x 3.142 x 0.3003 x 11 x 545)]

$= 20.75[0.08(0.2027872954)]$

$= 20.75 \times [0.01622298363]$

$= 0.336$

(3) $Wv = 2\pi wv[\Lambda \cos(2\pi wvt]$

$= 2 \times 3.142 \times 0.3003 \times 16.6[0.08 \cos(2 \times 3.142 \times 0.3003 \times 16.6 \times 361)]$

$= 31.3 [0.08 \cos(11308.5)]$

$= 31.3(0.01064971)$

$= 0.33m/s$

(4) $Wv = 2\pi Wv[\Lambda \cos(2\pi Wvt)]$

$= 2 \times 3.142 \times 0.3003 \times 22.2 [0.08 \cos(2 \times 3.142 \times 0.3003 \times 22.2 \times 27)]$

$= 41.89 [0.08 \cos(11311.2)]$

$= 0.587.$

(5) $Wv = 2\pi Wv [\Lambda \cos(2\pi Wvt)]$

$= 2 \times 3.142 \times 0.3003 \times 27 [0.08 \cos(2 \times 3.142 \times 0.3003 \times 27 \times 222)]$

$= 50.95 [0.08 \cos(11311.2)]$

$= 50.95 [0.08\ 0.17502306]$

$= 0.7134.$

for Wa

(1) $Wa = (2\pi Wv)^2 [\Lambda \sin(2\pi Wvt)]$

$= (2 \times 3.142 \times 0.3003 \times 5.55)^2 [0.08 \sin(2 \times 3.142 \times 0.3003 \times 5.55 \times 1081)]$

$= 109.69 [0.08 \sin(11321.7)]$

$= 109.69 [0.075397]$

$= 8.270 m/s^2$

(2) $Wa = - (2\pi Wv)^2 [\Lambda \sin (2\pi Wvt)]$

$= (2 \times 3.142 \times 0.3003 \times 11)^2 [0.08 \sin(2 \times 3.142 \times 0.3003 \times 11 \times 545)]$

$= 430.9 [0.08 \sin(11313.1)]$

$= 430.9 \times 0.07831224521$

$= 33 m/s^2$

(3) $Wa = (2\pi Wv)^2 [\Lambda \sin (2\pi Wvt)]$

$= (2 \times 3.142 \times 0.3003 \times 16.6)^2 [0.08 \sin(2 \times 3.142 \times 0.3003 \times 16.6 \times 361)]$

$= 981 [0.08 \sin(11308.5)]$

$= 981 \times 0.07928798$

$= 77 m/s^2$

(4) $Wa = (2\pi Wv)^2 [\Lambda \sin (2\pi Wvt)]$

$= (2 \times 3.142 \times 0.3003 \times 22.2)^2 [0.08 \sin(2 \times 3.142 \times 0.3003 \times 22.2 \times 270)]$

$= 1755.05 [0.08 \sin(11311.2)]$

$= 138.2 m/s^2$

(5) $Wa = (2\pi Wv)^2 [\Lambda \sin (2\pi Wvt)]$

$= (2 \times 3.142 \times 0.3003 \times 27)^2 [0.08 \sin(2 \times 3.142 \times 0.3003 \times 22 \times 222)]$

$= 2596 [0.08 \sin(11311.2)]$

$= 204.47 m/s^2$

For peak Dynamic load

Wg = W(a)/9.81N

(1) $Wg = \frac{8.270}{9.81} = 0.843N$

(2) $Wg = \frac{33}{9.81} = 3.36$

(3) $Wg = \frac{77}{9.81} = 7.849N$

(4) $Wg = \frac{138.2}{9.81} = 14.08N$

(5) $Wg = \frac{204.47}{9.81} = 20.8N$

For Effective Input Frequency

$Wf = \frac{V}{WL}$

(1) $Wf = \frac{5.55}{3.33} = 1.67Hz$

(2) $Wf = \frac{11}{3.33} = 3.3Hz$

(3) $Wf = \frac{16.6}{3.33} = 4.98Hz$

(4) $Wf = \frac{22.2}{3.33} = 6.67Hz$

(5) $Wf = \frac{27}{3.33} = 8.1Hz.$

For Elevation Profile

(1) $Ep = [A(Sin(2\pi Wx)]$

$$Ep = [0.08 \sin(2 \times 3.142 \times 0.3003 \times 5.55 \times 1081 \text{ sec.})]$$

$$= [0.08 \sin (11321.7)]$$

$$= 0.075$$

(2) $Ep = [A(\sin(2\pi Wx)]$

$$Ep = [0.08 \sin(2 \times 3.142 \times 0.3003 \times 11 \times 545)]$$

$$= [0.08 \sin (11313.1)]$$

$$= 0.078$$

(3) $Ep = [A(\sin(2\pi Wx)]$

$$Ep = [0.08 \sin(2 \times 3.142 \times 0.3003 \times 16.6 \times 36)]$$

$$= [0.08 \sin (11308.5)]$$

$$= 0.079$$

(4) $Ep = [A(\sin(2\pi Wx)]$

$$Ep = [0.08 \sin(2 \times 3.142 \times 0.3003 \times 22.2 \times 270)]$$

$$= [0.08 \sin (11311.2)]$$

$$= 0.0787$$

(5) $Ep = [A(\sin(2\pi Wx)]$

$$Ep = [0.08 \sin(2 \times 3.142 \times 0.3003 \times 27 \times 222)]$$

$$= [0.08 \sin (11311.18869)]$$

$$= 0.0787$$

ROAD TYPE B MINNA BIDDA ROAD

Distance covered = 6000m

Total number of potholes for intra state road within the 6000m covered = 129

Average ripple amplitude = 0.053

Carriage way width = 9m.

Wavelength WL = $\frac{a+b}{n}$

Dimension (wheel base distance of the selected lorry (all Mercedes lorry) = 2.6m for (a) and 2.4m for (b) Total length = 5m

$$WL = \frac{a+b}{n}$$

$$= \frac{2.6+2.4}{T} = 5$$

$$W = \frac{1}{WL}$$

$$\therefore W = \frac{1}{5}\ 0.2m$$

Wv= 2π Wv(A cos 2π Wvt)

Wa = $(2\pi Wv)^2$ [A sin (2π Wvt)]

$$V = \frac{S}{t}$$

$$\therefore t = \frac{S}{V}$$

Assumed speed are 20, 40, 60, 80, and 100 km/h.

(1) $t = \frac{6000}{V}$

for Wv

(1) $Wv = (2\pi Wv)\,[A \cos(2\pi Wvt)]$

$= 2 \times 3.142 \times 0.2 \times 5.55\ [0.05 \cos (2 \times 3.142 \times 0.2 \times 5.55 \times 1081)]$

$= 6.97524\ [0.05 \cos (7540.23444)]$

$= 0.206$

(2) $Wv = (2\pi Wv)\,[A \cos(2\pi Wvt)]$

$= 2 \times 3.142 \times 0.2 \times 11.11 \times [0.05 \cos (2 \times 3.142 \times 0.2 \times 11.11 \times 545)]$

$= 13.96\ [0.05 \cos (7509.86116)]$

$= 0.6896$

(3) $Wv = (2\pi Wv)\,[A \cos(2\pi Wvt)]$

$= 2 \times 3.142 \times 0.2 \times 16.6 \times [0.05 \cos (2 \times 3.142 \times 0.2 \times 16.6 \times 361)]$

$= 20.86288\ [0.05 \cos (7531.49968)]$

$= 0.495$

(4) $Wv = (2\pi Wv)\,[A \cos(2\pi Wvt)]$

$= 2 \times 3.142 \times 0.2 \times 22.2 \times [0.05 \cos (2 \times 3.142 \times 0.2 \times 22.2 \times 361)]$

$= 27.90096\ [0.05 \cos (10072.24656)]$

$= 0.589$

(5) $Wv = (2\pi Wv)\,[A \cos(2\pi Wvt)]$

$= 2 \times 3.142 \times 0.2 \times 27 \times [0.05 \cos (2 \times 3.142 \times 0.2 \times 27 \times 222]$

= 33.9336 [0.05 cos (7533.2592)]

= 0.847

For Wa

(1). $Wa = (2\pi Wv)^2 [A \sin(2\pi Wvt)]$

= (2 x 3.142 x 0.2 x 5.55)^2 x [0.05 sin(2 x 3.142 x 0.2 x 5.55 x 1081)]

= 48.65 [0.05 sin (37701.1722)]

= 2.43

(2) $Wa = (2\pi Wv)^2 [A \sin(2\pi Wvt)]$

= (2 x 3.142 x 0.2 x 11.11)^2 x [0.05 sin(2 x 3.142 x 0.2 x 5.55 x 1081)]

= 194.9667 [0.05 sin (7540.23444)]

= 7.865

(3) $Wa = (2\pi Wv)^2 [A \sin(2\pi Wvt)]$

= (2 x 3.142 x 0.2 x 16.6)^2 x [0.05 sin(2 x 3.142 x 0.2 x 16.6 x 361)]

= 435.25976 [0.05 sin (7531.49968)]

= 19.15

(4) $Wa = (2\pi Wv)^2 [A \sin(2\pi Wvt)]$

= (2 x 3.142 x 0.2 x 22.2)^2 x [0.05 sin(2 x 3.142 x 0.2 x 22.2 x 270)]

= 778.46 [0.05 sin (7533.2592)]

= 33.73

(5) $Wa = (2\pi Wv)^2 [A \sin(2\pi Wvt)]$

$= (2 \times 3.142 \times 0.2 \times 27)^2 \times [0.05 \sin(2 \times 3.142 \times 0.2 \times 27 \times 222)]$

$= 1151.489 [0.05 \sin (7533.2592)]$

$= 49.89$

For Peak Dynamic Load.

$Wg = W(a)/9.81N$

(1) $Wg = \frac{2.43}{9.81} = 0.2477N$

(2) $Wg = \frac{7.865}{9.81} = 0.8N$

(3) $Wg = \frac{19.15}{9.81} = 1.95N$

(4) $Wg = \frac{33.73}{9.81} = 3.438N$

(5) $Wg = \frac{49.89}{9.81} = 5.08N$

For Effective Input Frequency

$Wf = \frac{V}{WL}$

(1) $Wf = \frac{5.55}{5} = 1.11Hz$

(2) $Wf = \frac{11.11}{5} = 2.222Hz$

(3) $Wf = \frac{16.6}{5} = 3.32Hz$

(4) $Wf = \frac{22.2}{5} = 4.44Hz$

(5) $Wf = \frac{27}{5} = 5.4Hz$

For Elevation Profile

(1) Ep = [A (sin(2 π Wx)]

Ep = [0.05 sin(2 x 3.142 x 0.2 x 5.55 x 1081sec)]

= [0.05 sin(7540.23444)]

= 0.0403

(2) Ep = [A (sin(2 π Wx)]

Ep = [0.05 sin(2 x 3.142 x 0.2 x 11 x 545)]

= [0.05 sin(7534.516)]

= 0.0428

≈ 0.043

(3) Ep = [A (sin(2 π Wx)]

Ep = [0.05 sin(2 x 3.142 x 0.2 x 16.6 x 361)]

= [0.05 sin(7531.49968)]

= 0.044

(4) Ep = [A (sin(2 π Wx)]

Ep = [0.05 sin(2 x 3.142 x 0.2 x 22.2 x 270)]

= [0.05 sin(7533.2592)]

= 0.0433

(5) Ep = [A (sin(2 π Wx)]

Ep = [0.05 sin(2 x 3.142 x 0.2 x 27 x 222)]

= [0.05 sin(7533.2592)]

= 0.0433

ROAD TYPE C. RURAL ROAD

RAFIN YASHI JUKUCHI ROAD.

Distance covered 6000m

Number of Pot holes 7.

Average Ripple 0.37m

Carriage way width 5 metres

Dimension (wheel base of the selected vehicles 5m.

$$WL = \frac{a+b}{n}$$

$$WL = \frac{2.6+2.4}{3} = \frac{5}{3} = 1.666 \approx 1.67$$

$$W = \frac{1}{WL} = \frac{1}{1.67} = 0.59$$

Wv = 2π Wv[A cos(2π Wvt)]

(1) Wv = 2 x 3.142 x 0.59 x 5.55 x [A cos(2 x 3.142 x 0.59 x 5.55 x 1081)]

= 20.576958(0.37 cos(22243.6916

= 5.8897

≈ 5.9

(2) Wv = 2 x 3.142 x 0.59 x 11 x [A cos(2 x 3.142 x 0.59 x 11 x 545)]

= 40.78316 x [0.37 cos(22226.8222)]

= 13.77

(3) Wv = 2 x 3.142 x 0.59 x 16.67 x [0.37 cos(2 x 3.142 x 0.59 x 16.6 x 361)]

= 61.80 x [0.37 cos(22217.922406)]

= 21.966

(4) Wv = 2 x 3.142 x 0.59 x 22.2 x [0.37 cos(2 x 3.142 x 0.59 x 22.2 x 270)]

= 82.3078 x [0.37 cos(22223.11)]

= 28.46

(5) Wv = 2 x 3.142 x 0.59 x 27 x [0.37 cos(2 x 3.142 x 0.59 x 27 x 222)]

= 100.10 x [0.37 cos(22223.11)]

= 34.62

For Wa

$Wa = (2\pi Wv)^2 [A \sin(2\pi Wvt)]$

(1) Wa = $(2 \times 3.142 \times 0.59 \times 5.55)^2$ x [0.37 sin(2 x 3.142 x 0.59 x 5.55 x 1081)]

= 423.4 [0.37 sin(22243.6916)]

= 99.27

(2) Wa = $(2 \times 3.142 \times 0.59 \times 11)^2$ x [0.37 sin(2 x 3.142 x 0.59 x 11 x 545)]

= 1663.26614 [0.37 sin(22226.8222)]

= 251.68

(3) Wa = $(2 \times 3.142 \times 0.59 \times 16.6)^2$ x [0.37 sin(2 x 3.142 x 0.59 x 16.6 x 361)]

= 3787.84 [0.37 sin(22217.92406)]

= 389.40

(4) Wa = (2 x 3.142 x 0.59 x 22.2)^2 x [0.37 sin(2 x 3.142 x 0.59 x 22.2 x 270)]

= 6774.579 [0.37 sin(22223.11464)]

= 890.23

(5) Wa = (2 x 3.142 x 0.59 x 27)^2 x [0.37 sin(2 x 3.142 x 0.59 x 27 x 222)]

= 10020.83 [0.37 sin(22223.11)]

= 1316.572

For Peak Dynamic Load.

Wg = W(a)/9.81N

(1) $Wg = \frac{99.27}{9.81} = 10.11N$

(2) $Wg = \frac{251.68}{9.81} = 25.65N$

(3) $Wg = \frac{389.40}{9.81} = 39.69N$

(4) $Wg = \frac{890.23}{9.81} = 90.747N$

(5) $Wg = \frac{1316.572}{9.81} = 134.20N$

For Effective Input Frequency

$Wf = \frac{V}{WL}$

(1) $Wf = \frac{5.55}{1.67} = 3.323Hz$

(2) $Wf = \frac{11}{1.67} = 6.586Hz$

(3) $Wf = \frac{16.6}{1.67} = 9.940Hz$

(4) $Wf = \frac{22.2}{1.67} = 13.29Hz$

(5) $Wf = \frac{27}{1.67} = 16.167Hz$

For Elevation Profile

$Ep = [A (\sin(2\pi Wx)]$

(1) $Ep = [0.37 \sin(2 \times 3.142 \times 0.59 \times 5.55 \times 1081sec)]$

$= [0.37 \sin(22243.6916)]$

$= 0.234$

(2) $Ep = [0.37 \sin(2 \times 3.142 \times 0.59 \times 11 \times 545)]$

$= [0.37 \sin(22226.8222)]$

$= 0.15$

(3) $Ep = [0.37 \sin(2 \times 3.142 \times 0.59 \times 16.6 \times 361)]$

$= [0.37 \sin(22217.92406)]$

$= 0.1028$

(4) $Ep = [0.37 \sin(2 \times 3.142 \times 0.59 \times 22.2 \times 270)]$

$= [0.37 \sin(22223.11)]$

$= 0.1313$

(5) $Ep = [0.37 \sin(2 \times 3.142 \times 0.59 \times 27 \times 222)]$

$= [0.37 \sin(22223.11)]$

$= 0.1313$

For Peugeot pick up van traveling along Minna Bida Road.

Road Distance covered = 6000m

Total Number of potholes found within the 6000 metres of Minna Bida Road = 129

Average ripple amplitude = 0.05m

Carriage way width = 9m

$$WL = \frac{1.6 + 1.24}{1} = 2.84$$

$$W = \frac{1}{WL} = \frac{1}{2.84} = 0.3\dot{5}$$

For Wv calculation

Wv = 2π Wv[A cos(2π Wvt)]

(1) Wv = 2 x 3.142 x 0.35 x 5.55 x [0.05 cos(2 x 3.142 x 0.35 x 5.55 x 1081)]

= 12.20667(0.05 cos(13195.41027)]

= 0.6087

(2) Wv = 2 x 3.142 x 0.35 x 11 x [0.05 cos(2 x 3.142 x 0.35 x 11 x 545)]

= 24.1934[0.05 cos(13185.403)]

= 1.1780

(3) Wv = 2 x 3.142 x 0.35 x 16.6 x [0.05 cos(2 x 3.142 x 0.35 x 16.6 x 361)]

= 36.51004[0.05 cos(13180.12444)]

= 1.737

(4) Wv = 2 x 3.142 x 0.35 x 22.2 x [0.05 cos(2 x 3.142 x 0.35 x 22.2 x 270)]

= 48.82[0.05 cos(13183.2036)]

= 2.356

(5) Wv = 2 x 3.142 x 0.35 x 27 x [0.05 cos(2 x 3.142 x 0.35 x 27 x 222)]

= 59.4[0.05 cos(13183.2036)]

= 2.867m/s^2

For Wa

Wa = $(2\pi \text{Wv})^2$ [A sin(2π Wvt)]

(1) Wa = (2 x 3.142 x 0.35 x 5.55)^2 x [0.05 sin(2 x 3.142 x 0.35 x 5.55 x 1081)]

= 149.00 [0.05 sin(2099.8425)]

= 7.449

(2) Wa = (2 x 3.142 x 0.35 x 11)^2 x [0.05 sin(2 x 3.142 x 0.35 x 11 x 545)]

= 585.32 [0.05 sin(13185.403)]

= 6.65

(3) Wa = (2 x 3.142 x 0.35 x 16.6)^2 x [0.05 sin(2 x 3.142 x 0.35 x 16.6 x 361)]

= 1332.98 [0.05 sin(13180.12444)]

= 20.47

(4) $Wa = (2 \times 3.142 \times 0.35 \times 22.2)^2 \times [0.05 \sin(2 \times 3.142 \times 0.35 \times 22.2 \times 270)]$

$= 2384.044\ [0.05 \sin(13183.2026)]$

$= 31.086$

(5) $Wa = (2 \times 3.142 \times 0.35 \times 27)^2 \times [0.05 \sin(2 \times 3.142 \times 0.35 \times 27 \times 222)]$

$= 3526.43\ [0.05 \sin(13183.2036)]$

$= 45.98$

For Peak Dynamic Load.

$$Wg = \frac{W(a)}{9.81N}$$

(1) $Wg = \frac{7.449}{9.81} = 0.75N$

(2) $Wg = \frac{6.65}{9.81} = 0.677N$

(3) $Wg = \frac{20.47}{9.81} = 2.086N$

(4) $Wg = \frac{31.086}{9.81} = 3.168N$

(5) $Wg = \frac{45.98}{9.81} = 4.687N$

For Effective Input Frequency of Peugeot Pick Up

$$Wf = \frac{V}{WL}$$

(1) $Wf = \frac{5.55}{2.86} = 1.95Hz$

(2) $Wf = \frac{11}{2.86} = 3.87Hz$

(3) $Wf = \frac{16.6}{2.86} = 5.8Hz$

(4) $Wf = \frac{22.2}{2.86} = 7.8Hz$

(5) $Wf = \frac{27}{2.86} = 9.5Hz$

For Elevation Profile

$Ep = [A (\sin(2\pi Wx)]$

(1) $Ep = [0.05 \sin (2 \times 3.142 \times 0.35 \times 5.55 \times 1081sec)]$

$= [0.05 \sin(13195.41027)]$

$= 0.0036\ m^2/s$

(2) $Ep = [0.05 \sin(2 \times 3.142 \times 0.35 \times 11 \times 545)]$

$= [0.05 \sin(13185.403)]$

$= 0.011364\ m^2/s$

(3) $Ep = [0.05 \sin(2 \times 3.142 \times 0.35 \times 16.6 \times 361)]$

$= [0.05 \sin(13180.12444)]$

$= 0.01535\ m^2/s$

(4) $Ep = [0.05 \sin(2 \times 3.142 \times 0.35 \times 22.2 \times 270)]$

$= [0.05 \sin(13183.2036)]$

$= 0.01304\ m^2/s$

(5) $Ep = [0.05 \sin(2 \times 3.142 \times 0.35 \times 27 \times 222)]$

$= [0.05 \sin(13183.2036)]$

$= 0.0130393\ m^2/s$

For Peugeot pick-up travelling along Rafin Yashi Jukuchi Road (Rural Roads)

Total Number of potholes = 7

Average Ripples = 0.37m

$$WL = \frac{1.6m + 1.24m}{1} = 2.84m$$

$$W = \frac{1}{WL} = \frac{1}{2.84} = 0.35$$

For Wv computation

Wv = 2π Wv[A cos(2π Wvt)]

(1) Wv = 2 x 3.142 x 0.35 x 5.55 x [0.37 cos(2 x 3.142 x 0.35 x 5.55 x 1081)]

= 12.20667(0.37 cos(13195.41027)]

= 4.453m^2/s

(2) Wv = 2 x 3.142 x 0.35 x 11 x [0.37 cos(2 x 3.142 x 0.35 x 11 x 545)]

= 24.1934[0.37 cos(13185.403)]

= 8.717 m/s^2

(3) Wv = 2 x 3.142 x 0.35 x 16.6 x [0.37 cos(2 x 3.142 x 0.35 x 16.6 x 361)]

= 36.51004[0.37 cos(13180.12444)]

= 12.856 m/s^2

(4) Wv = 2 x 3.142 x 0.35 x 22.2 x [0.37 cos(2 x 3.142 x 0.35 x 22.2 x 270)]

$= 48.82[0.37 \cos(13183.2036)]$

$= 17.4419 \ m/s^2$

(5) Wv = 2 x 3.142 x 0.35 x 27 x [0.37 cos(2 x 3.142 x 0.35 x 27 x 222)]

$= 59.4[0.37 \cos(13183.2036)]$

$= 21.212 m/s^2$

For $Wa = (2\pi Wv)^2 [A \sin(2\pi Wvt)]$

(1) $Wa = (2 \times 3.142 \times 0.35 \times 5.55)^2 \times [0.37 \sin(2 \times 3.142 \times 0.35 \times 5.55 \times 1081)]$

$= 149.00 [0.37 \sin(13195.41027)]$

$= 3.97 \ m/s^2$

(2) $Wa = (2 \times 3.142 \times 0.35 \times 11)^2 \times [0.37 \sin(2 \times 3.142 \times 0.35 \times 11 \times 545)]$

$= 585.32 [0.37 \sin(13185.403)]$

$= 49 \ m/s^2$

(3) $Wa = (2 \times 3.142 \times 0.35 \times 16.6)^2 \times [0.37 \sin(2 \times 3.142 \times 0.35 \times 16.6 \times 361)]$

$= 1332.98 [0.37 \sin (13180.12444)]$

$= 151.4908 \ m/s^2$

(4) $Wa = - (2 \times 3.142 \times 0.35 \times 22.2)^2 \times [0.37 \sin (2 \times 3.142 \times 0.35 \times 22.2 \times 270)]$

$= 2384.044 [0.37 \sin(13183.2026)]$

$= 230.03 \ m/s^2$

(5) Wa = (2 x 3.142 x 0.35 x 27)^2 x [0.37 sin(2 x 3.142 x 0.35 x 27 x 222)]

= 3526.43 [0.37 sin(13183.2036)]

= 340m/s^2

For Peak Dynamic Load.

$$Wg = \frac{W(a)}{9.81N}$$

(1) $Wg = \frac{3.97}{9.81} = 0.4N$

(2) $Wg = \frac{6\ .}{9\ .81} = 4.99N$

(3) $Wg = \frac{151.4908}{9.81} = 15.4N$

(4) $Wg = \frac{230.03}{9.81} = 23,4N$

(5) $Wg = \frac{340}{9.81} = 34.7N$

For Effective Input Frequency of Peugeot Pick Up Along Rural Road

$$Wf = \frac{V}{WL}$$

(1) $Wf = \frac{5.55}{2.84} = 1.95Hz$

(2) $Wf = \frac{11}{2.84} = 3.87Hz$

(3) $Wf = \frac{16.6}{2.84} = 5.8Hz$

(4) $Wf = \frac{22.2}{2.84} = 7.8Hz$

(5) $Wf = \frac{27}{2.84} = 9.5Hz$

For Elevation Profile

$Ep = [A (\sin(2\pi Wx)]$

(1) $Ep = [0.37 \sin(2 \times 3.142 \times 0.35 \times 5.55 \times 1081sec)]$

$= [0.37 \sin(13195.41027)]$

$= 0.3 \ m^2/s$

(2) $Ep = [0.37 \sin(2 \times 3.142 \times 0.35 \times 11 \times 545)]$

$= [0.37 \sin(13185.403)]$

$= 0.263 \ m^2/s$

(3) $Ep = [0.37 \sin(2 \times 3.142 \times 0.35 \times 16.6 \times 361)]$

$= [0.37 \sin(13180.12444)]$

$= 0.238 \ m^2/s$

(4) $Ep = [0.37 \sin(2 \times 3.142 \times 0.35 \times 22.2 \times 270)]$

$= [0.37 \sin(13183.2036)]$

$= 0.36 \ m^2/s$

(5) $Ep = [0.37 \sin(2 \times 3.142 \times 0.35 \times 27 \times 222)]$

$= [0.37 \sin(13183.2036)]$

$= 0.36 \ m^2/s$

PEUGEOT PICK UP TRAVELLING ALONG TEGINA ROAD

For Peugeot Pick up Van

Distance from front wheel to the centre of gravity of the vehicle = 1.6m

, from rear wheel to the centre of gravity = 1.24m

Total wheel base = 2.84.

Road Distance covered = 6000m

Total No of potholes found within the 6000 metres of Tegina Kagara Road = 102 potholes.

Average ripple amplitude = 0.08m

Carriage way width = 9m.

$$WL = \frac{a+b}{n}$$

$$WL = \frac{1.6+1.24}{1} = 2.84$$

$$\therefore \quad W = \frac{1}{WL} = \frac{1}{2.84} = 0.35$$

For Wv calculations

Wv = 2π Wv[A cos(2π Wvt)]

(1) Wv = 2 x 3.142 x 0.35 x 5.55 x [0.08 cos(2 x 3.142 x 0.35 x 5.55 x 1081)]

= 12.20667(0.08 cos(13195.41027)]

= 0.9739m^2/s

(2) Wv = 2 x 3.142 x 0.35 x 11 x [0.08 cos(2 x 3.142 x 0.35 x 11 x 545)]

= 24.1934[0.08 cos(13185.403)]

= 1.884 m/s^2

(3) Wv = 2 x 3.142 x 0.35 x 16.6 x [0.08 cos(2 x 3.142 x 0.35 x 16.6 x 361)]

= 36.51004[0.08 cos(13180.12444)]

$= 2.77960\ m/s^2$

(4) $Wv = 2 \times 3.142 \times 0.35 \times 22.2 \times [0.08 \cos(2 \times 3.142 \times 0.35 \times 22.2 \times 270)]$

$= 48.82668[0.08 \cos(13183.2036)]$

$= 3.77\ m/s^2$

(5) $Wv = 2 \times 3.142 \times 0.35 \times 27 \times [0.08 \cos(2 \times 3.142 \times 0.35 \times 27 \times 222)]$

$= 59.3838[0.08 \cos(13183.2036)]$

$= 4.586 m/s^2$

For $Wa = (2\pi Wv)^2 [\Lambda \sin(2\pi Wvt)]$

(1) $Wa = (2 \times 3.142 \times 0.35 \times 5.55)^2 \times [0.08 \sin(2 \times 3.142 \times 0.35 \times 5.55 \times 1081)]$

$= 149.00 [0.08 \sin(13195.41027)]$

$= 11.889\ m/s^2$

(2) $Wa = (2 \times 3.142 \times 0.35 \times 11)^2 \times [0.08 \sin(2 \times 3.142 \times 0.35 \times 11 \times 545)]$

$= 585.32 [0.08 \sin(6592.7015)]$

$= 5.354 m/s^2$

(3) $Wa = (2 \times 3.142 \times 0.35 \times 16.6)^2 \times [0.08 \sin(2 \times 3.142 \times 0.35 \times 16.6 \times 361)]$

$= 1332.98 [0.08 \sin(13180.12444)]$

$= 32.75\ m/s^2$

(4) Wa = $(2 \times 3.142 \times 0.35 \times 22.2)^2 \times [0.08 \sin(2 \times 3.142 \times 0.35 \times 22.2 \times 270)]$

$= 2384.04468\ [0.08 \sin(13183.2026)]$

$= 49.73\ m/s^2$

(5) Wa = $(2 \times 3.142 \times 0.35 \times 27)^2 \times [0.08 \sin(2 \times 3.142 \times 0.35 \times 27 \times 222)]$

$= 3526.435702\ [0.08 \sin(13183.2036)]$

$= 73.57 m/s^2$

For Peak Dynamic Load.

$$Wg = \frac{W(a)}{9.81N}$$

(1) $Wg = \frac{11.889}{9.81} = 1.211N$

(2) $Wg = \frac{5.334}{9.81} = 0.5437N$

(3) $Wg = \frac{32.75}{9.81} = 3.33N$

(4) $Wg = \frac{49.73}{9.81} = 5.069N$

(5) $Wg = \frac{73.57}{9.81} = 7.49N$

For Effective Input Frequency of Peugeot Pick Up

$$Wf = \frac{V}{WL}$$

(1) $Wf = \frac{5.55}{2.84} = 1.95Hz$

(2) $Wf = \frac{11}{2.84} = 3.87Hz$

(3) $Wf = \frac{16.6}{2.84} = 5.8Hz$

(4) $Wf = \frac{22.2}{2.84} = 7.8Hz$

(5) $Wf = \frac{27}{2.84} = 9.5Hz$

For Elevation Profile for pick up

$Ep = [A (\sin(2\pi Wx)]$

(1) Ep = [0.08 sin(2 x 3.142 x 0.35 x 5.55 x 1081sec)]

= [0.08 sin(37701.1722)]

= 0.07999 m^2/s

(2) Ep = [0.08 sin(2 x 3.142 x 0.35 x 11 x 545)]

= [0.08 sin(13185.403)]

= 0.018 m^2/m

(3) Ep = [0.08 sin(2 x 3.142 x 0.35 x 16.6 x 361)]

= [0.08 sin(13180.12444)]

= 0.0245 m^2/m

(4) Ep = [0.08 sin(2 x 3.142 x 0.35 x 22.2 x 270)]

= [0.08 sin(13183.2036)]

= 0.0208 m^2/m

(5) Ep = [0.08 sin(2 x 3.142 x 0.35 x 27 x 222)]

= [0.08 sin(13183.2036)]

= 0.0208 m^2/m

ROWS: Vehicle COLUMS: Road

	1	2	3	ALL
1	0.200	0.206	5.900	--
	0.336	0.690	13.770	
	0.330	0.495	21.900	
	0.587	0.589	28.400	
	0.713	0.847	34.600	
	0.433	0.565	20.914	7.304
2	0.974	0.608	4.450	--
	1.884	1.180	8.717	
	2.780	1.740	12.856	
	3.770	2.360	17.442	
	4.590	2.870	21.212	
	2.800	1.752	12.935	5.829
ALL	--	--	--	--
	1.616	1.158	16.925	6.567

CELL CONTENTS --

Wv: DATA

MEAN

ROWS: Vehicle COLUMNS: Road

	1	2	3	ALL
1	8.27	2.43	99.27	--
	33.00	7.86	251.68	
	77.00	19.15	389.40	
	138.20	33.73	890.23	
	204.47	49.89	1316.57	
	92.19	22.61	589.43	234.74
2	11.89	7.45	3.97	--
	5.35	6.65	49.00	
	32.75	20.47	151.49	
	49.73	31.09	230.00	
	73.57	45.98	340.00	
	34.66	22.33	154.89	70.63
ALL	--	--	--	--
	63.42	22.47	372.16	152.68

CELL CONTENTS --

Wa: DATA

MEAN