Vol. 04, No. 01, pp. 01 – 07 (2023)
ISSN: 2709-6904

JoCEF JOURNAL OF CIVIL ENGINEERING FRONTIERS

www.jocivilef.org

Assessment of Abuja-Kaduna Trunk A Carriageway Drains and its Implication on National Development

Dukiya J.J.[1,*], Adeniyi G[2], Adejumo T. E.[3]

[1]*Federal University of Technology, Minna, Department of Transport Management Technology, School of Innovative Technology, Nigeria, duksat2000@futminna.edu.ng*

[2] *Federal University of Technology, Minna, Department of Surveying & Geoinformatics, School of Environmental Technology, Nigeria, niyi.gbenga@futminna.edu.ng*

[3] *Federal University of Technology, Minna, Department of Civil Engineering, School of Infrastructure, Process Engineering & Technology, Nigeria, adejumo.taiye@futminna.edu.ng*

Abstract

The development of road transport in Nigeria dates back to 1910, when the existing bush pathways were converted into motorable highways. When the country witnessed a modernized network of important roads for articulated vehicles and passenger automobiles at the conclusion of the Second World War. Since 1975 and via the third and fourth Development Rolling Plans in Nigeria, the government at all levels has used road construction as a tool of pollution control since it impacts people's socioeconomic lives. As a result, many road construction projects are failing long before the worldwide standard lifespan of 20 to 25 years. This study evaluates the carriageway cambering condition, which is one of the primary fundamental elements influencing highway durability. It determines the carriage water drain and road pounding by vehicular weight transfer along the "A2" trunk route linking Lokoja, Abuja, Kaduna, Zaria, and Kano. According to the study, the gradient of all the portions of the road rehabilitated tends to be zero camber, resulting in the occurrence of visible surface folding, potholes, and pounding ln a defined pattern. It is thus recommended that all major road constructions in Nigeria be subjected to cambering tests prior to project delivery and utilisation in order to reduce the economic waste expended on constant repairs of this and other such roads in a country, which mostly transport its goods and services on roads.

Keywords: *cambering road, carriageway, highway, rotting road, vehicle axle*

Received: August 07, 2022 / Accepted: December 30, 2022 / Online: January 01,2023

I. INTRODUCTION

Every nation's transportation sector has seen significant technological advancement, which has influenced the pace of national or regional development and the level of Gross Domestic Product (GDP). Street paving can be traced back to the first human settlements in the Indus Valley civilization on the Indian subcontinent, such as Harappa and Mohenjo-daro, around 4,000 BC. A Greek street from the 4th or 3rd century before Christ (BC), known as the Porta Rosa, connects the northern and southern quarters of Elea. The street is five meters long and has an inclination of 18% at its steepest point [1]. It has limestone blocks on one side and a small gutter for drainage. blocks on a single side and a small gutter

Darius I began an extensive road system for Persia (Iran) in 500 BC, including the famous Royal Road, which was one of the finest highways of its time. Because of its superior quality, the road was used after the Roman Empire. It allowed mall couriers to travel 2,699 kilometers (1,677 miles) in seven days [2]. During the reign of the Roman Emperor, "Roman roads" enabled Roman charlots to travel quickly and maintain good communication with the Roman provinces [3]. John Metcalf was the first professional road builder to emerge during the Industrial Revolution, constructing approximately 180 miles (290 kilometers) of turnpike road. Turn piling would be the result of some geological features, drainage, and weather effects. Engineer-surveyor Thomas Telford also made significant advances in the engineering of new buildings.

In any country, standard road maintenance is a serious concern. Following national or regional growth, traffic volume has increased, and both public and private agencies have been trying to maintain their infrastructure assets in excellent and serviceable condition at the minimum cost, thus practicing infrastructure management [4]. However, as most of the nation's infrastructure systems developed and demands on them increased significantly in the mld-6os, infrastructure agencies began to focus on a systems approach to infrastructure management. The present Asset Management System principles

doi: 10.38094/jocef40158

are the product of this effort. The process started with the creation of Pavement Management Systems (PMS), Building Management Systems (BMS), and Infrastructure Management Systems (IMS) and has lately evolved to cover general asset management [5].

The notion of integrated infrastructure management systems in transportation asset management is a milestone in the development of engineering management systems. An infrastructure management system (IMS) is described as an operational package that enables the systematic, coordinated planning and programming of investments or expenditures, design, construction, maintenance, rehabilitation, renovation, operation, and in-service evaluation of physical facilities. The system includes the techniques, processes, data, software, policies, and decision-making means necessary to deliver and maintain infrastructure at an acceptable level of service to the public or owners.

To properly design, build, manage, and maintain transportation assets, one must first model them using some sort of information system [6]. This information system should ideally be employed automatically, leveraging a range of innovative technologies. However, this sort of system is difficult and requires integration while also taking data exchange and confidentiality into account.

To design, create, manage, and maintain transportation assets efficiently, they must first be modeled using some sort of information system [6]. Ideally, this information system should be employed automatically, leveraging a range of innovative technologies. This sort of technology, however, is difficult and requires integration while also considering data exchange and confidentiality.

Nigerian roads are characterized by carriageway pounding, pavement distress, and alligator cracks. These characteristics are not unrelated to poor design and construction, substandard materials, and the non-application of reliability analyses, which can predict the degree of usability of the roads at any time. The load bearing capacity of Nigeria's newly constructed roads is decreasing, resulting in national economic waste of resources. The major causes of black spots on roads nationwide are the human factor, causes of road accidents, poor road conditions, especially potholes, and surface folding. Thousands of people and properties are killed or injured in road accidents each year, with or without redemption and compensation. For example, the Lagos-Ibadan expressway, the Benin-Ore-Lagos road, and even the famous Abuja-Lokoja-Benin dual carriageway have all drained the federal government's coffers due to poor construction and design. There is a critical need for engineering evaluation of structural and geometrical flaws in Nigerian Roads and its implications on national development. The results will aid in standardizing Nigerian roads and increasing economic activity nationwide. The study focuses on assessing the level of adherence to camber standards by the multimillion-dollar trunk "A" road construction project in Nigeria and its implications on national development with the hope of proposing a standard template for the design and re-construction of roads in Nigeria.

1.0 Carriageway Cambering

The carriageway convexity defines a road camber; the crown represents the highest point at the centerline of the road. The road slopes down from the crown to aid in water drainage, as illustrated in Fig. 1.

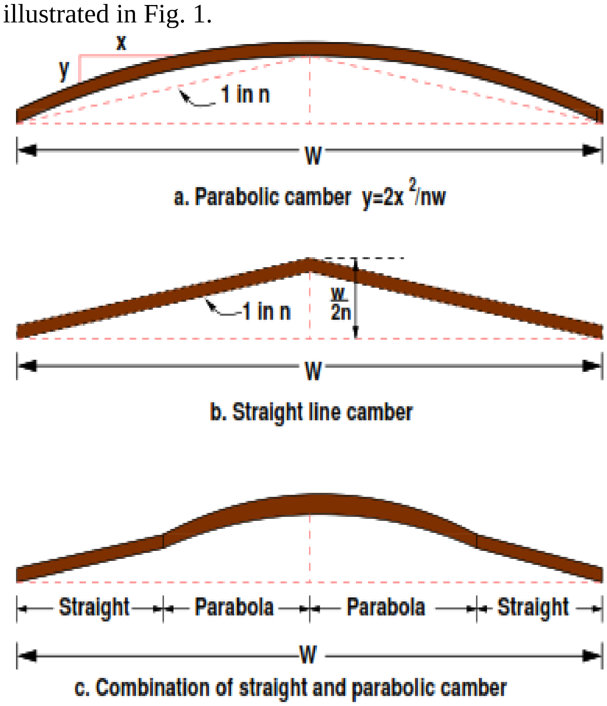

Fig. l. Deferent types of road camber (Source: [7])

Without proper road cambering, there would be puddles and stagnant water, which would cause road surface degradation, cracks, and potholes, all of which are potential hazards to motorists.

Most country roads feature the "A" kind of road camber, with the highest point in the middle of the road. Super elevated road shares are somewhat rare. They are typically utilized on motor racing courses to lessen the centrifugal force experienced by race vehicles as they pass around a bend at high speeds [8]. Public roads designed for high speeds may also employ this technique to minimize centrifugal force and drag. A highly raised road camber is utilized on mountain roads where the drainage is often inclined in a single direction (mono-pitched).

1.1 Skidding Resistance

Having water on the road surface has a significant impact on vehicle tire friction. The lubricating action of water on the carriageway considerably decreases the skidding resistance of vehicle tires when compared to dry surfaces. For a tyre to grip on a wet road, water must be displaced from the contact patch so that the tread may establish intimate touch or contact with the carriageway's microtexture [9, 10]. Drainage trails were created by the macrotexture of the surfacing and the tire tread pattern. Skidding resistance decreases with increasing vehicle speed, as does the time available for water to be moved from contact zones. Table 1 shows the influences on skidding resistance on wet roads, as well as the variables that influence it.

TABLE 1. INFLUENCES OF SKID RESISTANCE ON WET ROADS [7]

Factors	Control	Influence by
Water depth	Weather Conditions	Other
	Highway Design	Highway
	Standards	Designer
	Highway Design	Highway
Road Surface Micro	Design Standards	Designer
texture	Design Standards	Highway
Road Surface Micro	Maintenance Standards	Designer
texture		Highway
Road Surface		Designer
Condition (in service		Highway
texture)		Designer
Vehicle Speed	Road layout Legislation	Driver
Tyre Tread Depth	Legislation	Behaviour
Tyre Wear (Extent and	Legislation	Driver
Form)	Manufacturers	Behaviour
Tyre Pressure	recommendation	Driver
Vehicle Specification	Manufacturers	Behaviour
Tyre Materials	Manufacturers	Driver behaviour
Tyre Tread Pattern		Others
		Others
		Others

Major roads in the UK are built with a specified minimum texture depth to aid the drainage process and limit the extent to which skidding resistance lowers at high speeds. The legal minimum depth of tire tread is defined. Aquaplaning is hence less likely when such limitations are absent. The distance and gradient along the flow route for a given intensity of rainfall define the depth of water on a carriageway surface. The flow path is the path taken by rainfall runoff from the point to the carriageway limit. A carriageway with no longitudinal gradient flow routes will travel in a transverse direction. The flow routes will become diagonal as the longitudinal gradient increases. The flow route lengths and gradients were determined by combining carriageway width, cross fall, and longitudinal gradient [11, 12].

The flow route is the greatest distance travelled by runoff to reach the border of a carriageway channel or drainage system for assessment reasons. This was portrayed as rainfall beginning at the carriageway's border, on the high side of the crossfall, with the exception of super-elevation rollovers. The minimum cross fall in the United Kingdom is 2.5%, which is one of the higher national standards and is meant to enable effective water removal from highways, particularly undulations created by rutting [13]. Cross-falls in super-elevated sections are frequently equal to or greater than 2.5%, as shown in Fig. 2. However, pockets of low cross-fall will occur at super-elevated rollovers. To provide for appropriate water movement along the road's edge channel and to avoid excessive lengths of low gradient at super elevation rollovers, most roads are built with a minimum longitudinal gradient of 0.5%. Designers often provide a sufficient longitudinal gradient along the road centerline in order to provide 0.5% gradients at carriageway edges during super elevation roll-overs (para. 3.7 of TD 9/93 gives advice on avoiding drainage difficulties during super elevation roll-overs).

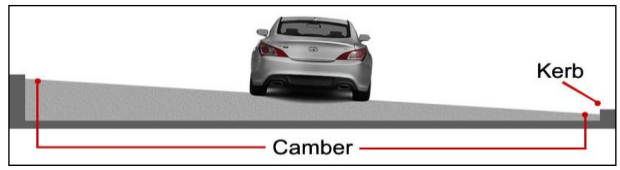

Fig. 2. Super-elevated road cambering (Source: [7])

Drainage paths and gradients must be constructed while considering the geometry of the proposed section. Contoured designs are typically the most effective way for this, especially for complicated layouts and super elevation rollovers. If the evaluation indicates a possible problem region, decreasing drainage path lengths and/or steepening drainage path slopes should be considered. Reduced route durations are more likely to have an impact than better grades. Designers should strive to minimize the size of such spots by following the stages in Fig. 3. when it is not practicable to avoid parts with low gradients, especially during rollovers.

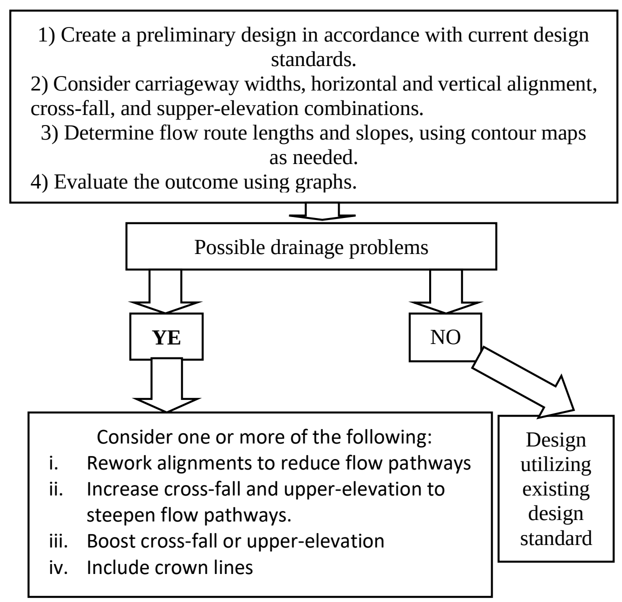

Fig. 3. Flow chat of road drainage design

1.2 The Laser Crack Measurement System (LCMS)

The Laser Crack Measuring System (LCMS) is a highway transverse profiling system with great speed and resolution. Using laser line projectors, high-speed cameras, and powerful optics, the LCMS records high-resolution 3D profiles of the road. Fig. 4 (a and b) shows an illustration of the LCMS's development as well as a photograph of the LCMS Survey Vehicle in action. Typically, the LCMS system can take one road profile every few centimeters. (5mm at 100 km/hr) by using two laser profilers to capture the shape of the pavement. Each profile is composed of up to 4160 data points that cover the complete 4-metre width 3D profiles of the road. The LCMS collects both range (height) and intensity (image) data from the road surface at 1 millimeter resolution, allowing for the characterisation and visualisation of high-quality images, cross-sectional shapes, and macro-textures of the road surface. The LCMS has a high enough resolution and acquisition rate to find fractures at speeds of up to 100 km/hr, although it normally runs at 80 km/hr.

The LCMS measurement covers around 4 meters, allowing the entire road width to be inspected at any time of day or night. The LCMS data was processed using specialist software to detect and evaluate fractures, lane markings, ruts, potholes, and Mean Profile Depth (MPD). Patches, ravelling (fretting), sealed cracks, and joints on concrete surfaces may also be recognized and quantified with LCMS data.

a b

Fig. 4. The RSP multi-function survey vehicle (Source: [l4])

The RSP is capable of continuous high-speed measurements in real time of:

i. Longitudinal Profile (including International Roughness Index) (IRI).
ii. Transverse proficiency (Rut Depth).
iii. Macro extrusion (Mean Profile Depth).
iv. Geometry (Cross fall, Gradient and Radius of Curvature). Forward View/Pavement or Digital Video.
v. The DMI linear change coordination system.
vi. Geographical Positioning System (GPS) backup system

II. METHODOLOGICAL APPROACH

2.1 The Road

The Lokoja-Abuja-Kaduna-Zaria-Kano dual carriageway is an important section of Nigeria's highway system, and the trunk A2 road is a major artery in the country's transportation network. It facilitates the flow of people and goods from the northern to the southern parts of the country, as well as the promotion of business and the unification of the Nigerian people. The highway is a vital link in the trans-Atlantic route, connecting Nigeria to the greater continent of Africa. It also facilitates commerce and contributes to the country's economic development. As a key highway in the country, as seen in Fig. 5., hundreds of large trucks and other types of vehicles travel on a daily basis along the Lokoja-Abuja-Kaduna-Zaria-Kano dual carriageway. The loads from these vehicles put the road under stress and create negative traffic influences that aggravate the road's terrible condition. The investigation included an examination of the road's regular pavement failures.

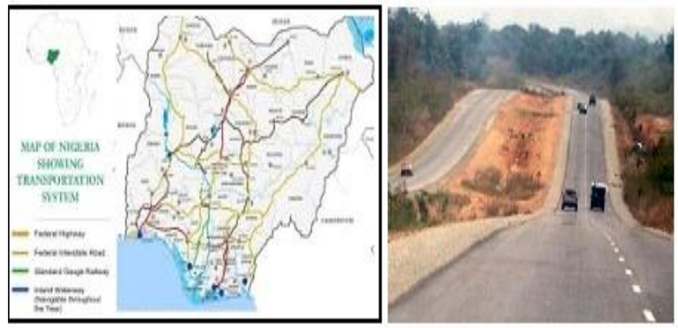

Fig. 5. The Lokoja-Abuja-Kaduna-Zaria-Kano dual carriageway

2.2 Reconnaissance Survey

A visual inspection of the carriageway pavements was carried out in order to identify areas of pavement defect and distress associated with improper carriageway cambering. Potholing, patching, rutting, ravelling, bleeding, cracking, and settling are examples of such distress. These signs are the result of underlying pavement structural concerns, which defined the correct survey strategy. The reconnaissance survey was carried out to determine the physical characteristics of the roads and the adjacent land usage. This entails the employment of a digital camera and a global positioning system (GPS) for spatial mapping and reference. This also includes liaising with key road management agencies such as the Federal Road Maintenance Agency and the Federal Ministry of Works.

2.3 Data Collection

Topographical As a foundation for the surface configuration of the impacted region, a map of the selected road segments in the geopolitical zone was gathered and maintained. Rainfall data from the specified locations was collected in order to determine the levels of precipitation as they affect the soil water table. Comprehensive laboratory soil tests include index property determination, Californian Bearing Ratio (CBR), the tri-axial test, the permeability test, the shear strength test, consolidation, and compaction of the samples.

2.4 Data Analysis

All data from the field and laboratory tests was analyzed and utilised as baseline data. The evaluation of the roads' existing geometrical properties, which include horizontal curves, vertical curves, alignment, and cambering over their whole length, was carried out. Samples were also tested at 2 km intervals, and the existing core road layering system was evaluated in comparison to the required standard. It also performed reliability analyses on the structural and geometrical properties of the sampled points in order to determine the degree of safety.

III. RESULTS AND DISCUSSION

Nigeria's road system is often classified into four primary groups. The Federal Trunk "A" Roads are managed by the federal government. Previously held by states, the Federal Trunk "F" Roads were taken over by the federal government with the intention of improving them to federal highway standards. However, as highway pavements age, they deteriorate due to traffic, weather, and radiant energy, manifesting as polishing, rutting, fretting, ravelling, and cracking, leading to disintegration of the surface layer over time. The source of the deterioration might be surface-related or a sign of deeper-seated structural issues with the pavement. Drainage is one of the most important considerations for pavement durability, and if the materials in the road pavement or foundations are highly soluble to water, deterioration/failure of the pavement structure will result as a consequence of water ingress into the pavement layers. Trapped water on the pavement caused by heavy cars can generate cycles of high-pressure "pumping," leading to rapid deterioration.

The longitudinally plotted field survey reveals that the road profile demonstrated a constant increase in altitude from south to north, as indicated in Fig. 6. But the lateral profile and sectional analysis reveal that the carriageway spot-patching and resurfacing did not maintain the as-built cambering, thereby leading to further deterioration of the carriageway within the contract delivery period, coupled with the traffic volume and overloading nature of the heavy trailer and truck vehicles connecting the northern and southern parts of the country. This profiling technique complies with the external norm of the profilometric device as specified in ASTM E 95-98 [15].

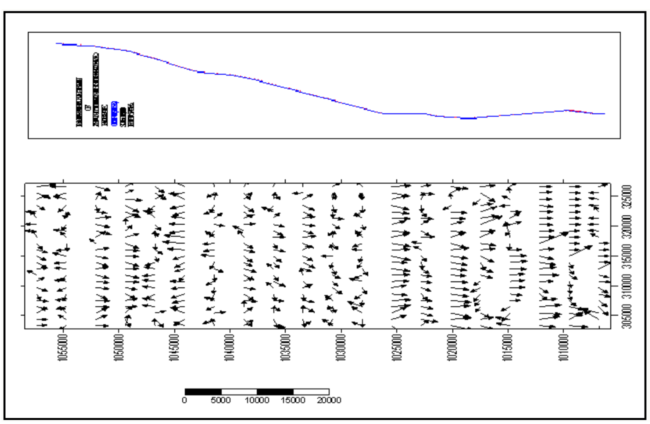

Fig. 6. Longitudinal profile of Lokoja-Abuja-Kaduna road section

The 3D was developed when analyzing the topography of the highway route direction as it affects the general slope analysis and carriageway drainage system, as illustrated in Fig. 7. It is obvious that the overall configuration of the horizontal profile supports good drainage, but the carriageway drainage functionality depends on the engineering computation and implementation following the cut-and-fill earthwork.

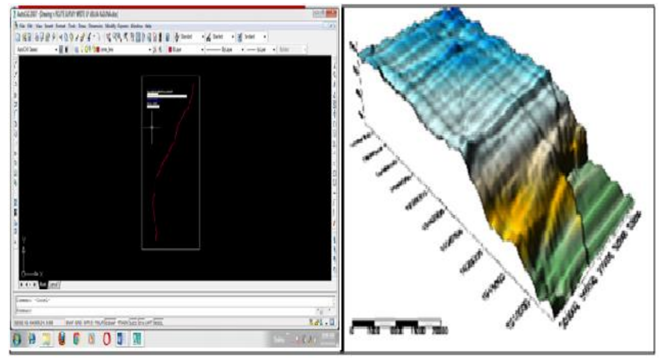

Fig. 7. Computer based onscreen profile and 3D plotting of the field data collected

No phasing issue develops and no corrective action is required when the horizontal and vertical curves are suitably separated or coincident. When faults exist, phasing can be achieved by either separating the curves or adjusting their lengths so that vertical and horizontal curves begin and terminate at the same point. There was misphasing in various parts of the road section.

The field survey indicates an insufficient separation between the ends of the horizontal and vertical curves, with a false reverse curve appearing on the outside edge-line at the start of the horizontal curve, leading to a visual defect, as illustrated in Fig. 8a. In certain areas, both ends of the crest curve lie on a steep horizontal curve, and the radius of the horizontal curve seems to decline suddenly across the length of the crest curve. In the section where the vertical curve sags, the radius of the horizontal curve seems to increase, resulting in a visual defect, as shown in Fig. 8b.

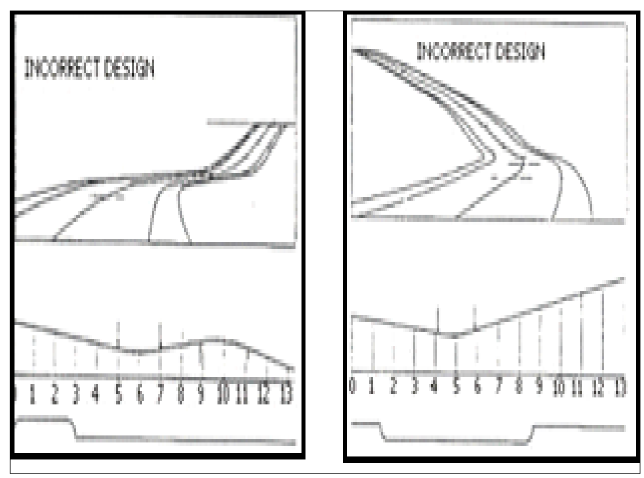

Fig. 8a Deformation of vertical curve Fig. 8b Deformation, short length of v/c

3.1 Determination of Road Camber

The road camber calculator online, provided by the Calculator Academy Team in Fig. 9, may be used to determine the levels of conformity to camber standards. Simply input the base of the road and the height of the camber into the calculator to determine the road camber angle. However, the following l in TERM [16] was utilized to compute the road camber angle in this study.

$$\tan^{-1}(H/B) = A \qquad (l)$$

where A denotes the road camber angle, H denotes the height of the camber, and B denotes the road base.

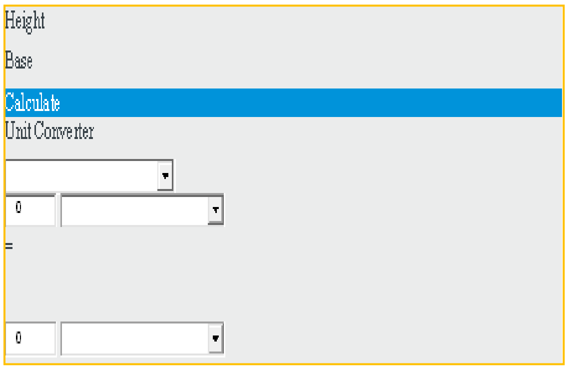

Fig. 9. Camber calculator online by Calculator Academy Team

To compute the road camber angle, we use the inverse tangent of the height divided by the base. The calculated value for the highway under consideration is less than 2%, resulting in poor water drainage and pounding activities.

Although steep cambers are excellent for eliminating surface water, they are rarely advised since they increase surface wear. Cambers of gradient '2' to ’3’ % are often advised. On straight sections of road, the shoulders with a higher cross fall by 0.5% compared to the carriageway.

3.1 Economic Implication on the State of Roads

The non-observance of the cambering principle by those in charge of road maintenance, as well as the loading condition of road users, is causing a long-term deterioration of the carriageway. All of this across the country impoverishes the country in the face of a dwindling economy, which leads to bad budgetary allocation by the government year in and year out to the road sector, exacerbating the hazardous status of roads in Nigeria. For example, the federal government cut the ministry's budgetary allocation to N70 billion in 2008. Despite the fact that the President Olusegun Obasanjo administration spent over N1 trillion on road rehabilitation between l999 and 2007, evidence shows that considerably more is required, as an estimate of N 3.3 trillion was required to finish the ongoing Federal highways being built around the nation (Table 2). Contractors working on federal road projects were owed money due to insufficient funding for road infrastructure. In reality, contractors were owed over N 60 billion in 2010 alone [l7]. The point here is that the government's allocation for road development is frequently insufficient to address the challenges associated with road construction and maintenance in the country.

Table 2 Road construction cost and the economic implications

Year	Road expenditure (Billion ₦)	GDP (₦)	Inflation (%)	Population (mpsk)	Death rate (%)
2008	94.46	2129	11.6	165.1	9572
2009	80.63	2216	11.5	169.5	1729
2010	57.09	2327	13.7	174.1	2056
2011	195.90	2377	lo.8	178.8	1839
2012	83.30	2413	12.2	183.7	1652
2013	92.19	2476	8.5	188.7	2062
2014	116.30	2563	8.1	193.7	3122
2015	114.60	2563	9.0	198.9	3666
2016	98.67	2458	15.7	204.2	4045

(Source: Federal office of Statistics) *₦ is Nigerian currency symbol; mpsk – million per square kilometre*

Apart from the massive budgetary allocation for highway rehabilitation, lives and properties are being lost in traffic accidents. For instance, according to the FRSC [l8], Nigeria has an average of 5,000 tankers involved in wet cargo haulage, moving around 150 million liters of gasoline daily, and 2,500 "trailers" involved in dry cargo ply Nigeria's highways daily. Kayode [l9] also claimed that during the years 207 and 2010. On Nigerian highways, a total of 4,017 tanker and trailer collisions were documented, with an annual average of 1,148 crashes, a monthly average of 96 crashes, and 4,076 individuals killed in tanker and trailer crashes.

IV CONLCUSION

In general, road construction is a multi-sectoral and multi-disciplinary process that should create sufficient projects to guarantee that no potentially valuable ones are eliminated from consideration.

Carriageway cambering is absolutely determined by two primary factors: the type of surface for the road under consideration and the amount of precipitation in the region. Obviously, a lower slope may be fine if the surface is impervious, as in high-type bituminous surfacing, and steeper as you get to pavement types where the surface is more porous.

As a result, the cross slope or camber requirements for high-type bituminous surfacing or rigid pavement will be lower. The sad situation on the trunk "A" road is the result of an uncontrolled trailer and truck overloading system, which causes the folding of smooth impervious bituminous surfaces and increases the rainfall duration/pattern caused by climate change. The more difficult issue, however, is the issue of inadequate construction work carried out by the maintenance agency.

ACKNOWLEDGMENT

The authors would like to express their sincere gratitude to the Federal University of Technology's Department of Survey and Geoinformatics for making available the study instrument used in the field survey. Also acknowledged is the effort of

various departmental technical personnel, especially concerning the fieldwork.

REFERENCES

[1] A. Frederick, A. (trans.), ed., Virgil's Aeneid. Oxford UP. pp. l39–40, 2007, lSBN 978-o-l9-923l95-9.

[2] R. Devereux. John Loudon McAdam: Chapters ln the History of Highways: Oxford University Press, London, 1936.

[3] A. W. Skempton, ed. (2002). A Biographical Dictionary of Civil Engineers in Great Britain and Ireland: l500–l830. London: Thomas Telford. 2002. p. 4l6.

[4] UlTP. Investing ln Public Transport infrastructure as Part of the European Union Package for Jobs, Growth and Investment, 2014.

[5] A. Ferreira, and G. Flintsch, Life-Cycle Cost Analysis System for Infrastructure Management, Proceedings of the lCCESo4 - International Conference on Computational and Experimental Engineering and Sciences, Madeira, Portugal, 2004, pp. l687-l692.

[6] Houston Radar LLC (2ol4).Houston Radar Advanced Traffic Statistics Analyser User Manual. l28l8 Century Drive, Stafford, TX 77477. Http://www.Houston-Radar.com

[7] V. M. Tom, and K. V. Krishna Rao, Introduction to Transportation Engineering, 2017.

[8] EU Research and innovation for Europe's future mobility developing a European Transport-technology Strategy. Communication from the Commission to the Council and the European Parliament, 2012.

[9] Asset Management & Maintenance Standard. Pavement Assessment, Repair and Renewal Principles. Transport infrastructure Ireland Tll, National Road Authority Dublin, AM-PAV-o6o5o, Erratum No. l & 2,Vol. 7, Section 3 Part 4, NRA HD 3l/l5, 2015.

[10] TS. Surface Course Specification & Guidance, Transport Scotland, issue 01, Vol. 7, Section 5, Part 2 HD 37/lX, 2010.

[11] The Highway Agency. Surface Drainage of Wide Carriageways Design Manual for Roads and Bridges, lreland, 4(2) Part 2 TA 80/99, 1999.

[12] Kirklees Council. Highways Guidance Note – Gradients, version 2, 2019. https://www.klrklees.gov.uk/beta/regeneratlon-and-development/pdf/hlghways-guldance-gradlents.pdf

[13] Australian Design Templates. Australian Design Vehicles and Turning Path Templates. Austroads Publication, No. AP- G34/06, 2006.

[14] lreland National Roads Authority, 20l5)

[15] ASTM E 95-98-04. American Standard Test Method for measuring the longitudinal profile of travelled surfaces, American Society for Testing, 2004.

[16] TERM -0l. Indicators tracking transport and environment integration in the European Union. Copenhagen EEA; 2001.

[17] Oladipo, O. O. (20l4). "Development of the National Trunk Roads ln Nigeria and the Socioeconomic Impact, l960 – 20l3". A PhD Thesis submitted to Department of History and Diplomatic Studies, Olabisi Onabanjo University, Ago lwoye, Ogun State, Nigeria. unpublished

[18] Federal Road Safety Corps (FRSC). Traffic Digestion, 2011.

[19] Kayode, O. Corps Commander Corps Transport Standardization officer, Federal Road Safety Corps, National Headquarters, Nigeria, 2010.