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TECHNOLOGICAL ADVANCEMENT IN DATA COLLECTION FOR PAVEMENT EVALUATION AND MANAGEMENT

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ABSTRACT

This paper is an appraisal of technological advancement in data collection technologies that are currently being practiced in developed countries for pavement evaluation and management. The type of pavement evaluation that has been practiced in Nigeria since 1985 is a project-level pavement evaluation type designed to provide information for overlay rehabilitation design of federal roads. Pavement evaluation for network- and research-levels is yet to be practiced while the data collection methodology is still largely manual in nature and becoming obsolete. Strict adherence to the laid down procedure is also observed to be dwindling among the engineering firms that conduct pavement evaluations.

Currently, Nigeria is making some moves towards the development of management systems for the nations over 34,000 kilometres federal highway pavements. As such, it is hoped that this paper will provide some guide into data collection technologies that could be adopted to aid successful implementation of modern pavement evaluation.

Keywords:* *Data Collection, Pavement Evaluation

1.0 INTRODUCTION

An essential part of any road project evaluation process is the determination of the condition of the existing pavement by conducting a pavement condition or pavement assessment survey. A poor or inadequate pavement assessment could result in the selection of an inappropriate rehabilitation method – which might result in less than expected performance. The pavement assessment must consist of a detailed visual inspection, which rates all the surface irregularities, flaws, and imperfections found at a given section of the pavement.

There are wide ranges of technologies available to collect pavement data, and these range from low to high cost, from very precise to approximate with the measurements. Data collection is also very expensive. The challenge therefore for federal and state highway maintenance agencies, is to select the appropriate technology given the data needs and the operating environment.

Collection of the pavement surface condition parameters by automated or semi-automated inspection equipment is increasing – due to improvements in the assessment technology, increased concern for surveyor safety, rising costs of manual inspections, and the cost and inconvenience to motorists.

Nigeria is currently making some moves towards the development of pavement management systems for her over 34,000 km federal highways. There are many important issues involved in the successful development of a pavement management system (PMS), data collection at both network and project levels, being one of the key issues. However, for a PMS to be effective, it is important to understand some of the intricacies and complexities of data collection.

Lack of adequate and regular evaluation of road pavement before subsequent maintenance and rehabilitation has resulted in gradual degeneration of the road pavements beyond the terminal serviceability level. Gradually, over the decades, the road network is slipping into a state of failure with the attendant economic losses to the road users and the nation at large.

This paper examines advances in data collection technologies with a view to recommending an appropriate technology, given the data needs and the operating environment of the country.

2.0 PAVEMENT CHARACTERISTICS AND INDICATORS CONSIDERED IN A CONDITION EVALUATION

The key pavement characteristics considered in an evaluation are [Bennett, et. al., 2005]:

1. Surface Distress;
2. Structural Evaluation;
3. Roughness (also called "smoothness");
4. Skid Resistance.

These characteristics are measured in the field through manual evaluations or using specialized equipment and are quantified by means of indicators or condition indices. A variety of survey equipment is available for the measurement of pavement characteristics. Table 1 gives an outline of some of the traditional and modern data collection techniques in practice today.

TABLE 1: AN OUTLINE OF TRADITIONAL AND MODERN DATA COLLECTION TECHNIQUES

Pavement Characteristics	Traditional Techniques	Modern Techniques
Surface Distress	Visual Survey: - Walking - Windshield Survey	- Spatially-encoded Video - Highly-accurate Aerial Photos - Global Positioning System - 35mm Analogue Continuous Film - Digital Camera - Digital Line Scan Imaging
Structural Evaluation	Destructive Testing - Coring Non-Destructive Testing: - Dynamic Cone Penetrometer - Benkelman beams - Deflectographs - Plate Load Tests - Curvature Meters - Dynaflect - Road Rater - WES Heavy Vibrator	- Falling Weight Deflectometer (FWD) - Low Weight Deflectometer (LWD) - Heavy Weight Deflectometer (HWD)
Roughness	Subjective Ratings: - Visual Inspection (Windshield Survey), - Ride over section, -Straight Edge, - Rod & Level, - Dipstick Profiler, - Profilographs (California, Rainhart), - RTRRMS (Mays Ride Metre, MERLIN, TRL Bump Integrator), - Profilometers	Laser Profilers: - Non-contact Lightweight Profiling devices, - Portable Laser Profiler System (MLP, ROSAN)
Skid Resistance	- Portable Pendulum-Type Device - Slope Wheel Friction Testers: Mu-Metre and SAAB Friction Tester	- The Locked Wheel Tester - The Spin Up Tester - Surface Texture Measurement

3.0 PAVEMENT SURFACE DISTRESS DATA COLLECTION

There are basically two modes of surface distress data collection for pavement management, namely, manual and automated. However, in many instances, the two modes could be employed together for data collection. In most Departments of Transportation (DOTs) in the U.S., automated data collection equipment is used to acquire at least part of the inventory and condition data.

3.1 MANUAL PAVEMENT SURFACE DISTRESS DATA COLLECTION

Generally, manual methods of asset data collection are expensive, often requiring labour intensive site surveys. Further, they create safety concerns and can sometimes cause disruption to traffic flows. In the evaluation, the network is divided into branches that are further divided into sections. Each section is again divided into sample units. The type and severity of sample distress is assessed by visual inspection of the pavement sample units and the quantity of each distress is measured.

Typically, this procedure requires a team of at least two engineers with maintenance knowledge, both driving at a slow speed and stopping occasionally (windshield survey), or walking through selected segments of a road. Apparently, walking provides more accurate and more detailed data than driving, but it is more expensive and time-consuming. The accuracy and consistency of the data also depend on the experience of the inspectors who perform the survey.

A pre-determined number of sample units are surveyed by the team, which will represent the actual pavement condition of the entire section. Each sample unit is walked upon (or adjacent to, depending on traffic control and safety) and the team keeps record sheets for each sample unit surveyed and records the appropriate code for distress type, severity and a measurement of quantity.

3.2 AUTOMATED PAVEMENT SURFACE DISTRESS DATA COLLECTION

An automated distress survey can also be adopted for data collection. New technology developments have produced a methodology that can quickly inspect roads and streets by using automated inspection equipment such as, but not limited to, a set of video cameras, profiling devices, and laser sensors. Cline, et al. [2001] reported on three different technologies that are currently considered acceptable: (i) 35mm analogue continuous film, (ii) digital camera, and (iii) digital line scan imaging. Digital line scan imaging is the newest of the three technologies.

The three systems also use a pulse camera, which photographs the transverse profile of the roadway at selected intervals to determine rut depth and shoulder drop-off. The pulse camera is synchronized with a hairline strobe projector mounted on the rear bumper and maintains a precision of + 2 mm and is synchronized to the actual vehicle speed.

The data collected (as frames) are downloaded into a workstation located at the office and analyzed. The frames are reviewed by engineers (or other qualified personnel), using a computer monitor to visually determine distress type, severity, and quantity. Distresses such as ruts are determined using data generated from a profiling device or laser sensor. It is recommended that when automated survey techniques are used, it is essential to contract with qualified contractors.

3.2.1 35 mm ANALOGUE CONTINUOUS FILM TECHNOLOGY

The 35mm analogue continuous film technology uses advanced film technology and custom electronics to obtain high-resolution, 35 mm film images of the pavement surface. The pavement surface images are collected using continuous strip photography. This system consists of a boom-mounted, 35 mm slit camera, electronic controller, and custom illumination system. The data collection vehicle is shown in Figure 1 and a workstation is shown in Figure 2.

3.2.2 DIGITAL CAMERA TECHNOLOGY

The digital camera technology uses a digital camera with strobe lighting. The imaging system collects full pavement width of 14 feet (4.3 metres) at the resolution of 1,300 x 1,024 pixel images in a continuous fashion. Images are generally collected at night using strobe lighting and all images are stored in an onboard computer system. Images collected are stitched together (using computer software package) to form a continuous image of the pavement surface. Image location is closely controlled through a highly accurate distance measuring instrument (DMI) and the use of global positioning. The data collection vehicle is shown in Figure 3. Data processing is completed in the office using the continuous image viewer as illustrated in Figure 4.

Figure 1: Data Collection Vehicle for 35mm Analogue Continuous Film Technology

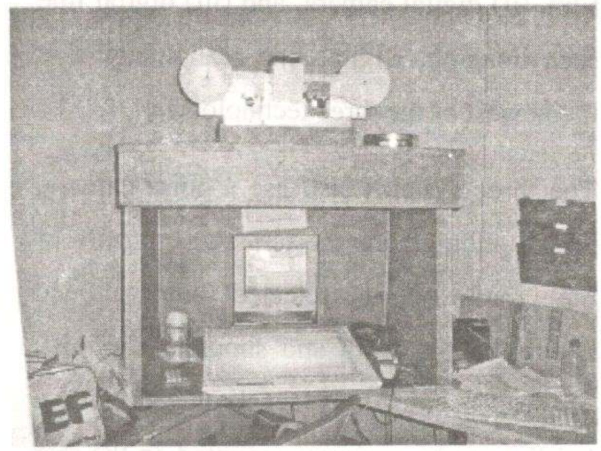

Figure 2: Workstation for 35mm Analogue Continuous Film Technology

Source: Cline et al., (2001)

3.2.3 DIGITAL LINE SCAN IMAGING

This technology is the most recent development for automated surveys. The digital system uses state-of-the-art digital imaging technology to collect continuous, high-resolution images of the pavement surface. The digital imaging system consists of a 2,000-pixel digital line scan camera, illumination system, and computerized controller. All images are stored in an onboard computer system and generally collected at night using an illumination system, which consists of an array of halogen lights mounted in a custom bumper. The data collection vehicle is shown in Figure 5 and a workstation is shown in Figure 6.

3.3 DATA COLLECTION USING VIDEO

One of the advanced methods of taking measurements on roads is through the use of highly accurate aerial photos, and street-level video of entire state highway system as executed by Pennsylvania Department of Transport [McGinnis, 2003]. Data capture through video, as utilized in the Philippines [Luz et al., 2003], facilitates the verification of existing data and could assist in the gathering of future data for identifying inventory features on or along a roadway. The video data also provides a historical record of visual features that can be used at a later date if needed. David Kamnitzer and Tim McCarthy [2000] also reported on the use of spatially encoded video and video browser software to collect highway asset information thus reducing the costs of collection and enabling the collected information to be better maintained and more widely deployed and utilized within highway authorities and their maintaining agents.

Figure 3: Data Collection Vehicle for Digital Camera Technology

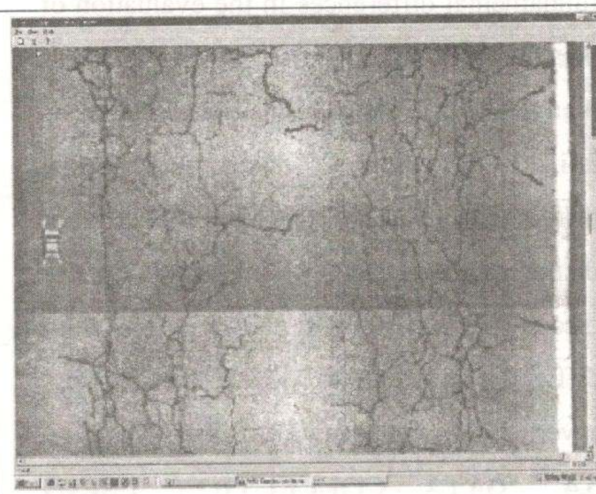

Figure 4: Continuous Image Viewer for Digital Camera Technology Showing Pavement Distress

Source: **Cline et al., (2001)**

Figure 5: Data Collection Vehicle for Digital Line Scan Imaging Technology

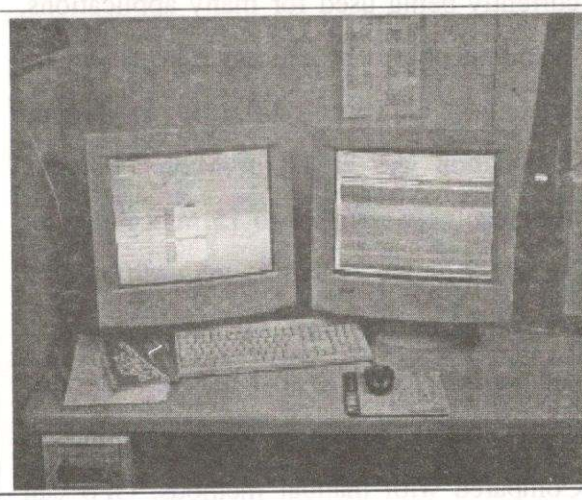

Figure 6: Workstation for Digital Line Scan Imaging Technology

Source: **Cline et al., (2001)**

In the mid-1990s, Virginia Department of Transportation (VDOT) began to collect pavement distress data through the use of videotaped images. VDOT recognized fundamental differences in the evaluation of pavements through the use of imaging rather than through direct pavement observation by trained observers. Those fundamental differences relate to the fact that not all distresses are readily captured on or discerned from images and that it is very difficult to evaluate levels of distress severity from images [VDOT, 1998].

3.4 DATA COLLECTION USING GPS

Global Positioning System (GPS) is currently being used for many applications, including pavement and asset management. Selective GPS availability or signal degradation was ended in May 2000, and users can now obtain 5 to 15 m accuracy or better without relying on differential correction. Furthermore, GPS receivers have been miniaturized to just a few integrated circuits, thus becoming very economical. Compared with manual methods, GPS can help automate and speed geographic information system (GIS) data processing and lower costs. It is also less labour intensive and may reduce digitizing and positional errors. Several studies have shown that the cost savings can exceed 50%. For example, the city of Ontario spent $515 and 41 person-hours to make an inventory of 942 fire hydrants using GPS. The same inventory by conventional methods would have cost $4,575 and would have taken 2 to 4 months [Hohl, 1998]. For these reasons, GPS is increasingly being used for facilities inventory and condition assessment. For example, the Virginia DOT (VDOT) has collected centreline information on 60,000 miles (96,000km) of roadway using GPS-equipped mapping vans outfitted with stereo cameras [Hovey, 2002].

The main advantages of using GPS for pavement management data collection include the possibility of determining the location accurately and using standard coordinate systems and reference datum. This makes it easy to import the information into a GIS and may reduce data collection costs, processing costs, and digitizing errors. The use of GPS during data collection may also speed up the data collection efforts, because the operations would not need to stop the vehicle and enter the location into the system. The main disadvantages include the need for specific equipment; potential problems with the signal owing to buildings or heavy foliage attenuating, reflecting, and/or blocking satellite signals; and potential compatibility problems with existing attribute data and maps.

3.5 GENERAL BENEFITS OF AUTOMATED DATA COLLECTION

David Kamnitzer and Tim McCarthy [2000] reported that automated data collection technology, like GPS Encoded Video Technology, offers significant potential to reduce the cost of information collection and improve the accuracy and operational usefulness of the information. Compared with traditional methods, the technology has the advantages of:

- more consistent measurements
- speed;
- cost savings over manual, mainly due to low levels of labour requirements;
- little or no disruption to traffic flows;
- less traffic control and less man hours;
- highly objective output;
- high levels of accuracy;
- record of information that was collected;
- ability to obtain all information about a particular route with a single survey; and
- ability to display information spatially (map), pictorially (stills and video) and as data (database application).

4.0 PAVEMENT STRUCTURAL EVALUATION

The structural capacity of a pavement is usually determined through the evaluation of mechanical properties of each layer of the pavement structure, such as: elastic modulus, fatigue properties, deflection conditions, and residual tensile stresses. The two common methods for evaluating these parameters are (i) coring, where pavement cores are studied in the laboratory, or (2) non-destructive tests done in the field. The bearing capacity of the pavement base/sub-base layers and subgrade can also be estimated using a dynamic cone penetrometer.

The use of non-destructive deflection testing (NDT) is one of the most reliable methods for determining the structural condition of an in-service pavement. NDT has two major advantages over destructive testing (Shahin, 2005). First, destructive testing by definition disturbs the underlying paving layers or requires removal of the pavement materials to a laboratory for testing, whereas NDT is truly an in situ test that evaluates the pavement without any material disturbance or modification. The second advantage of NDT is that the tests are relatively quick and inexpensive, allowing more tests to be completed while causing less disruption to traffic than destructive testing.

Non-destructive methods evaluate pavement deflections produced by the elastic deformation generated by a known vibratory or static loading applied over pavement surface. Deflection information is interpreted in order to determine pavement mechanical properties.

The many different commercially available deflection testing devices are grouped based on loading mode as: (1) Static, (2) Steady-state dynamic, and (3) Impulse. The impulse NDT devices are the most recently developed. They better simulate the load from a moving tyre and are currently used by highway and airport agencies more than any of the other devices (Shahin, 2005).

4.1 STATIC DEFLECTION OR SLOW-MOVING DEVICES

Static deflection equipments measure pavement deflection in response to a static load. A beam placed in the rear of a heavy 44kN truck acts as a probe that moves vertically when the pavement deflects. A dial indicator that measures half of the maximum deflection to within 0.025mm is depressed as the moving wheel load passes. Static or slow moving load deflection measurements started with the Benkelman beam in the early 1950's. These devices are simple to use and inexpensive to purchase, but they take longer to obtain data, present a Safety concern for operator during data collection, and are labour intensive. In addition, the tests do not accurately simulate the effect of moving wheel loads and their repeatability is low. Other devices under this category include the Deflectographs, plate load tests, curvature metres, etc. Figure 7 shows a Benkelman beam in operation.

4.2 STEADY STATE DEFLECTION DEVICES

Steady state deflection equipment measures the dynamic deflection of a pavement produced by an oscillating load. These devices consist of a dynamic force generator (that produces the oscillating load), a motion measuring instrument (to measure the oscillating load), a calibration unit and several deflection measuring devices (transducers, accelerometers, seismometers, etc.). The equipment must stop on the

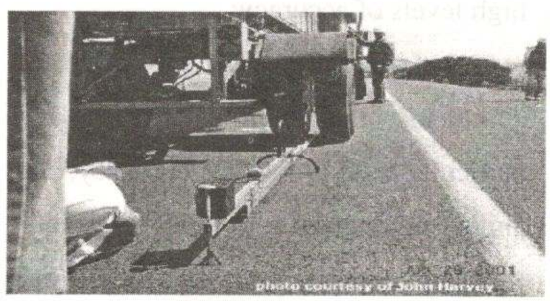

Figure 7: Benkelman Beam in use

pavement before the measurement process begins. The main advantage that steady state deflection equipments offer over static deflection equipment is that they can measure a deflection basin. They are generally easy to operate, acquire data quickly, and have good repeatability, but they are expensive. In addition, the test loads applied to the pavement are generally much lower than actual wheel loads; therefore extrapolation of the data is necessary. The most common steady state deflection equipments are the Dynaflect, Road Rater and WES heavy vibrator (see Figures 8 & 9).

Figure 8: Picture of a Dynaflect
Photo Courtesy of John Harvey

Figure 9: A Vehicle-Mounted Road Rater
Source: California Test 356 (2000)

4.3 DYNAMIC IMPACT DEVICES

The last and current generation of deflection devices deliver a transient impulse load to the pavement surface. The subsequent pavement response (deflection basin) is measured by a series of sensors. The most common type of equipment is the falling weight deflectometer (FWD) while other groups are the Light Weight Deflectometers (LWD) and Heavy Weight Deflectometers (HWD) (see Figures 10 – 12). The FWD can either be mounted in a vehicle or on a trailer and is equipped with a weight and several velocity transducer sensors. To perform a test, the vehicle is stopped and the loading plate (weight) is positioned over the desired location. The sensors are then lowered to the pavement surface and the weight is dropped. Multiple tests can be performed on the same location using different weight drop heights (ASTM D 4625).

Impact load devices tend to simulate moving wheel loads with a higher degree of accuracy, repeatability is very good, data acquisition is quick and automated, the impact load can be easily varied and it more accurately simulates the transient loading of traffic. The disadvantages of these devices include the high initial cost of the equipment (over US$ 50,000) and skilled technicians needed to calibrate the instruments and analyze the data.

Additional advantage is that the deflection basin/bowl information can be used in more advanced mechanistic-empirical design methods by back-calculation of the subgrade resilient modulus and the effective pavement modulus. Deflection bowl measurement can also be used to calculate various pavement parameters that can be compared to performance criteria, including [WAPA, 2002]: (i) surface curvature index, (ii) base damage index, and (iii) base curvature index.

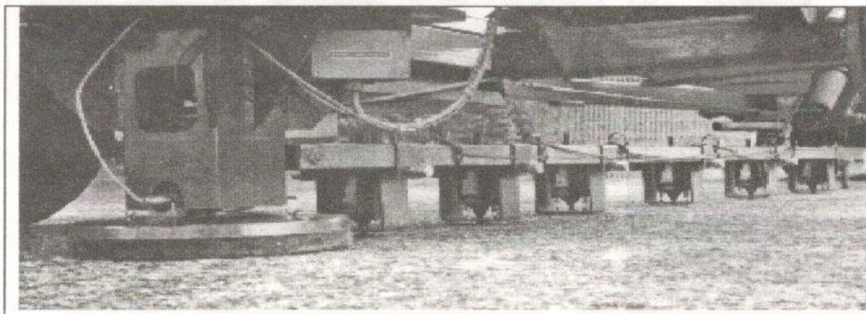

Figure 10: FWD Impulse Loading Mechanism (foreground) and Sensors (background)
Source: WAPA (2002)

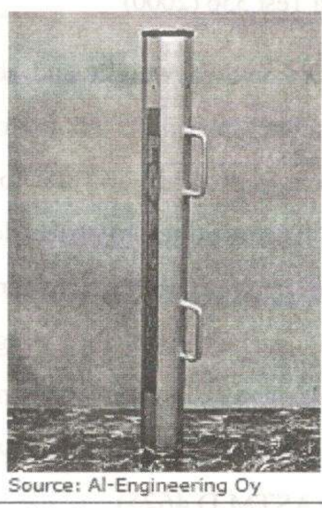

Figure 11: Loadman LWD
Source: Bennett et. al. (2005)

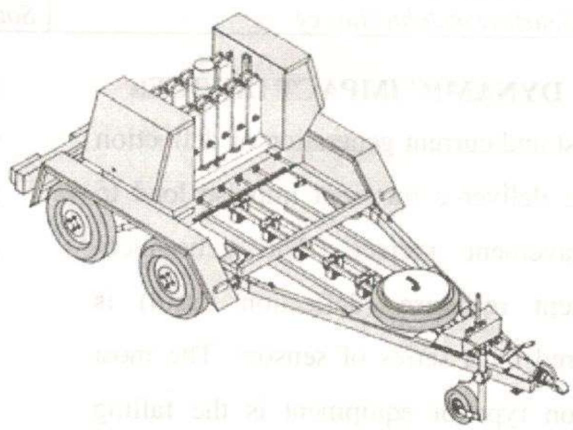

Figure 12: Dynatest Model 8082 Heavy Weight Deflectometer
Source: Dynatest® Systems (2007)

5.0 ROUGHNESS DATA COLLECTION

Pavement roughness is defined as "the deviations of a pavement surface from a true planar surface with characteristic dimensions that affect vehicle dynamics, ride quality, dynamic loads, and pavement drainage" [ASTM, 1999]. Roughness is primarily associated with serviceability; however, roughness is also related to structural deficiencies and accelerated pavement deterioration.

Roughness surveys are an important part of the pavement evaluation process. They can be conducted in a subjective manner (i.e., windshield survey) or in an objective manner (i.e., with roughness measurement equipment). Regardless of the method of determining roughness, the primary purpose of performing a roughness survey for a given project is to identify areas of severe roughness. Roughness surveys are also useful in determining relative roughness between projects and in gauging the overall benefits of various rehabilitation activities by measuring roughness before and after construction.

Roughness has a significant effect on vehicle operating costs (delay costs, fuel consumption and maintenance costs), safety, comfort (ride quality) and speed of travel. Studies have demonstrated that roughness is the primary criteria by which users judge pavement performance, and therefore, the condition of a highway system [Budras, 2001]. The effects of roughness are also associated with pavement structure deterioration, particularly when amplitude-wavelengths are high, causing appreciable dynamic forces in excess of dynamic weight [FHWA, 1991].

DEVICES AND METHODS FOR COLLECTING ROUGHNESS DATA

Many different types of equipment are used to measure roughness. These types of equipment can be broadly categorized as being either inertial road profiling systems (IRPS), which measure actual pavement profiles, or response-type road roughness measuring (RTRRM) systems, which measure vehicle response to pavement roughness.

RTRRM systems have enjoyed widespread use and have the advantages of low initial and operating costs, ease of operation, and high measuring speeds. However, their disadvantages are that the response output is sensitive to the vehicle type, suspension characteristics, tyre pressure, speed, and vehicle weight distribution. RTRRM systems also have the disadvantage of requiring frequent calibration to ensure that reasonable and reproducible measurements are obtained [Gulden, 1986].

In recent years, there has been more and more preference for the use of inertial road profiling systems, IRPS, such as the K.J. Law Profilometer and the South Dakota Profiler, which provide accurate, scale reproductions of the pavement profile along the path of the vehicle. Most IRPS utilize non-contact sensors (optical or acoustical) that measure the relative displacement between the vehicle frame and the road surface. IRPS yield highly accurate and repeatable profile measurements that can be used to compare projects to one another and can be used for the calibration of RTRRM systems. Disadvantages of IRPS include their relatively high capital and operating costs and the complexity of the system [Vorburger, et. al., 1989]. Table 2 lists roughness measuring equipments in order of complexity.

5.1 STRAIGHTEDGE

A straightedge is the simplest device to measure pavement roughness. At one time it was undoubtedly the only tool to evaluate pavement roughness. It is usually 8 to16 feet (2.4m to 4.8m) long and is made of wood or metal. When it is placed on the pavement surface, variations in distance from the bottom of the straightedge to the pavement surface is readily observed, and measurements of these variations can be made. This tool is labour intensive and its use for large projects is impractical and cost prohibitive; thus most applications are limited to the evaluation of localized areas [Ksaibati and Staigle, 1995].

TABLE 2: ROUGHNESS MEASURING EQUIPMENT

Equipment / Technique	Complexity
Windshield, Straight Edge	most simple
Dipstick profiler	
Profilographs (California, Rainhart)	simple
RTRRMS (Mays Ride Metre, MERLIN)	complex
Profilometers	
Non-contact Lightweight Profiling devices	most complex
Portable Laser Profiler System (MLP, ROSAN)	

Source: FHWA (2004)

PROFILOGRAPHS

Road profilographs are low-speed devices (hand pushed at walking speed) designed to measure roughness of road surfaces. The profilographs are used to measure the longitudinal profile of a concrete pavement. They are used primarily to measure roughness of new or newly surfaced pavements before they are open for traffic. Their principal use has been for the construction control of pavements. Profilographs have successfully been used for construction quality control on thousands of kilometres of pavements in the U.S. over the last several decades [Kulakowski and Lin, 1991].

The two models of profilographs in wide use today, each with different support wheel configuration, are the California type profilograph (Figure 13) and the Rainhart type profilograph (Figure 14). The profilographs are relatively inexpensive, simple to operate and maintain, and provide a trace of surface that users can easily understand. Both are manually operated by one person at walking speed; however, because of its wheel linkage, it can not be used for high speed network pavement smoothness data collection.

Profilographs have a few definite advantages over other roughness measuring devices. They are somewhat more sophisticated than the rolling straightedge, can be used on pavement surfaces a few hours after placement, field personnel also easily understand them, and the strip chart provides the precise location of surface irregularities. The main disadvantage of this device is its slow operating speed (approximately 5 km/h) and the time required evaluating the charts and calculating the Profilograph Index (PI). In addition, the blanking band can hide certain cyclic features associated with some aspects of construction.

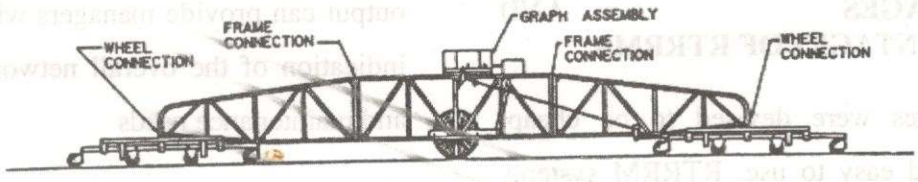

Figure 13: California Profilograph (Side View)
Source: Budras (2001)

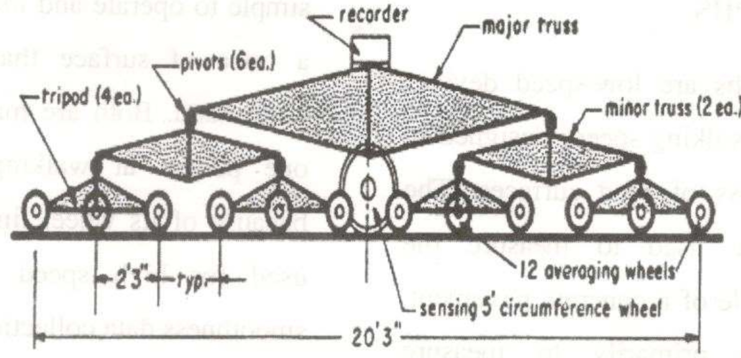

Figure 14: Rainhart Profilograph (Side View)
Source: Budras (2001)

5.3 RESPONSES-TYPE ROAD ROUGHNESS MEASURING SYSTEMS (RTRRMS)

RTRRMS evaluate road roughness by measuring the dynamic response of a mechanical device travelling over a pavement surface at a given speed. The most widely used profilometers are Bureau of Public Roads (BPR), Road Metres, PCA road metres, and the Mays Ride metre. The Mays Ride Metre has been by far the most commonly used (see Figure 15).

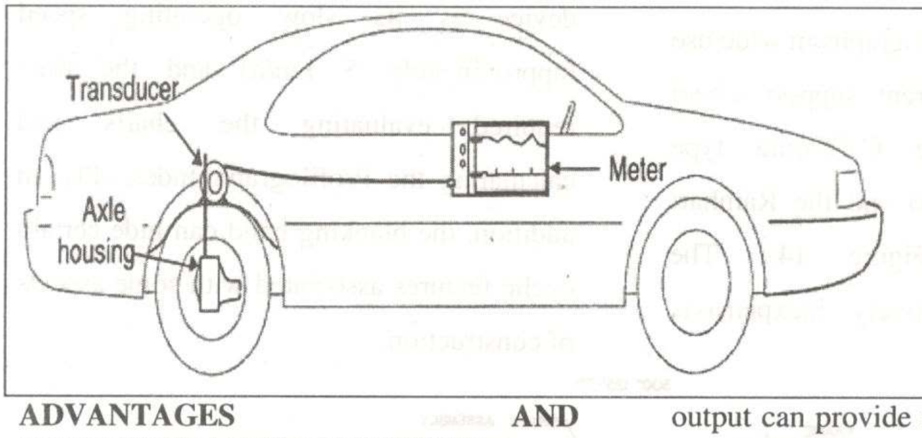

Figure 15: A Car with a Mays Metre
Source: Budras (2001)

ADVANTAGES AND DISADVANTAGES OF RTRRMS

Road metres were devised to be cheap, rugged, and easy to use. RTRRM systems are adequate for routine monitoring of a pavement network and providing an overall picture of the condition of the network. The output can provide managers with a general indication of the overall network condition and maintenance needs

The RTRRMS measure the response (bounce) of the vehicle to the road smoothness; it is therefore not a true measurement of smoothness. Another disadvantage of a RTRRM is that its measured axle body movement versus time depends on the dynamics of the particular measurement vehicle, which results in two unwanted effects (Budras, 2001):

- *Roughness measuring methods have not been stable with time.* Measures made today with road metres cannot be compared with confidence to those made several years ago.
- *Roughness measurements have not been transportable.* Road metre measures made by one system are seldom reproducible by another.

In spite of these and other problems associated with response-type metres, they have been in use for the past 50 years and even with the advent of non-contact profilers, a handful of states in the U.S. still use the Mays Road Metre. One reason this device has been in use for so long is that it has convinced engineers that this profiling method has produced meaningful pavement smoothness measurements.

5.4 PROFILING DEVICES - PROFILOMETERS

Profilometers are able to duplicate roughness measurement output of several RTRRMS roughness indices, including IRI, Mays Metre, BPR Roughmeter, PCA metre, and others [Budras, 2001]. Profiling devices are quite common for network pavement data collection; however, they are not designed for project level quality control. They measure and record the longitudinal profile in one or both wheel tracks. The profile signal processing is performed by a digital computer mounted in the vehicle. Profile computations are performed in real time as the vehicle is driven down the road. Interface between the user and the profilometer system is provided through a system terminal and printer. A schematic of road roughness profilometer van is shown in Figure 16.

5.5 NON-CONTACT LIGHTWEIGHT PROFILING DEVICES

A new generation of lightweight non-contact profilers have emerged for construction quality control and quality acceptance purposes. They are much smaller and lighter than the network level profilers, providing the benefit of use immediately after hot-mix asphalt (HMA) construction and much sooner than would be possible with the network level devices on new Portland cement concrete (PCC) pavements. However, they have operating speeds ranging from 8 (13km) to 25 miles (40km) per hour, which makes it impractical for high speed, large road network data collection. Examples are shown in Figures 17 and 18.

6.0 SKID RESISTANCE EVALUATION

Skid resistance is an important pavement evaluation parameter because [WAPA, 2002]:

(i) Inadequate skid resistance will lead to higher incidences of skid related accidents.

(ii) Most agencies have an obligation to provide users with a roadway that is "reasonably" safe.

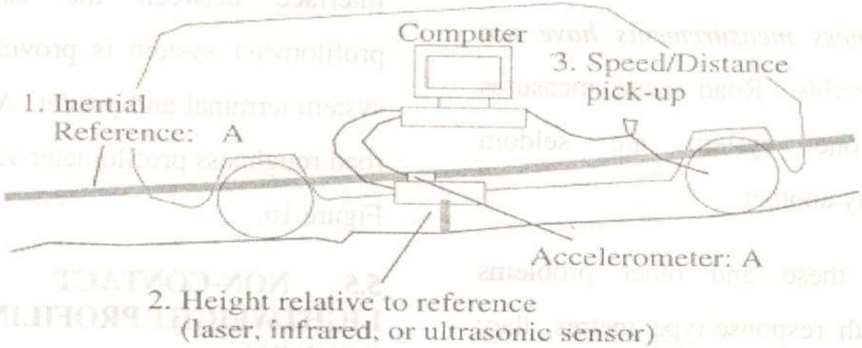

Figure 16: Schematic of Road Roughness Profilometer Van
Source: Budras (2001)

Figure 17: Non-contact lightweight profiler
Source: Budras (2001)

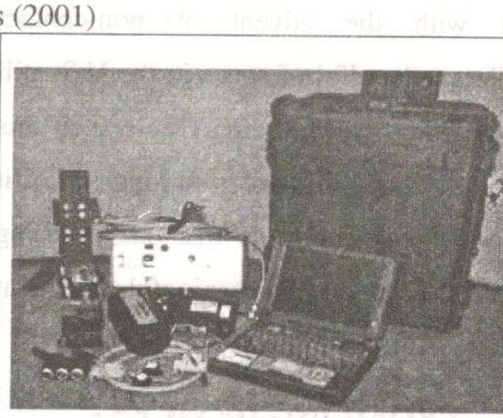

Figure 18: Rosan System
Source: Budras (2001)

Skid resistance measurements can be used to evaluate various types of materials and construction practices. Skid resistance is evaluated by indirectly measuring the resistance of a test tyre to wet pavement.

6.1 SKID RESISTANCE MEASURING DEVICES

Many different methods and devices are currently used to collect skid resistance data in a variety of modes. Some of the more common methods of skid testing, especially in U.S., include: (i) The locked wheel tester, (ii) The spin up tester, and (iii) Surface texture measurement. Other equipments that can be used to measure skid resistance include Portable Pendulum-Type Device (ASTM E 303) and Slope Wheel Friction Testers: Mu-Metre and SAAB Friction Tester. Figure 19 shows pictures of locked wheel skid testers.

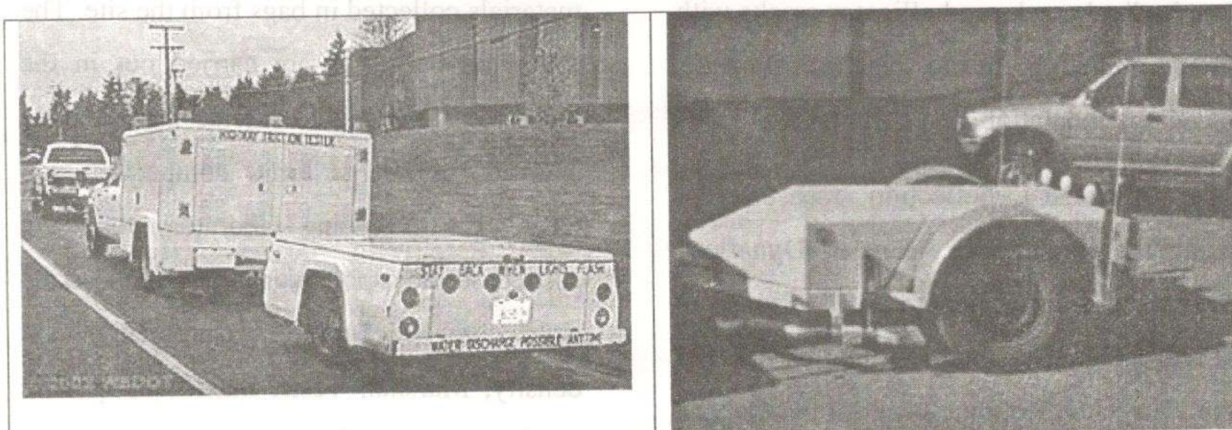

Figure 19: WSDOT's Locked Wheel Skid Testers
Source: WAPA (2002)

7.0 PAVEMENT EVALUATION IN NIGERIA

As earlier stated, it is only pavement evaluation at project level that is currently practiced in Nigeria. During the development of the pavement evaluation procedure/overlay design method for the country by Texas Research and Development Foundation (TRDF) in 1985, some equipment was acquired for the Pavement Evaluation Unit at Kaduna. The equipment for field measurements used to include: Dynaflects, Maysmeters, Truck Weight Scales, Nuclear gauges for density and moisture, Field CBR kits, Automatic traffic counters, and Rut depth gauges.

Project-level pavement evaluation in Nigeria usually involves the following activities:

(i) Pavement surface roughness measurement using the Rod & Level or Bump Integrator with output in International Roughness Index (IRI) scale.

(ii) A detailed visual inspection at areas where pronounced pavement distress are observed. The aim is to determine the cause(s) of the pronounced distress. Common distress types evaluated include AASHTO Classes I – III cracks (i.e. longitudinal cracks and alligator cracks with grain interlock), rutting, patches, slippage, bleeding, undulation, and potholes.

(iii) Pavement deflection measurement using the Benkelman Beam or Dynaflect. Pavement surface temperature is also taken at reasonable time intervals. On the basis of the design deflection, locations where test pits would be opened on site for in-situ testing and materials sampling are selected.

(iv) Traffic and axle load surveys are carried out along important intersections for a minimum period of seven days. Data collected are used in estimating the Average Daily Traffic; Percentage of trucks (commercial vehicles) in the traffic mix, and the average single axle equivalency factors for design.

(v) In-situ testing and sampling, including in-situ dry density tests, natural moisture content tests, in-situ CBR tests and pavement thickness measurements. In addition, in-situ CBR tests are also carried out on the pavement layers in 600x800mm test pits and used in estimating the initial values of modulus of elasticity during the mechanistic rehabilitation design.

(vi) Laboratory testing on samples of materials collected in bags from the site. The following soil tests are carried out in the laboratory: moisture content, particle size analysis, atterbergs limit, compaction and CBR. The following laboratory tests are carried out on asphalt concrete samples from site: core thickness measurement, bulk density, Marshall Tests, maximum specific gravity and extraction.

8.0 SUMMARY AND CONCLUSION

Objective measurements such as roughness, deflection, skid resistance, along with distress surveys are important and utilized by pavement managers to perform functions such as: (i) establishment of maintenance priorities, (ii) determination of maintenance and rehabilitation strategies, and (iii) prediction of pavement performance. This practice, of course, prevents sudden failure of pavement sections, maintains serviceability of pavement and also ensures riders' comfort.

In the area of non-destructive structural evaluation, Nigeria still uses Benkelman beam and Dynaflect machines. Out of the five (5) Dynaflect machines purchased in 1985 at the commencement of the development of overlay design program for federal highways, only one is currently functioning. For roughness measurement, Rod & Level and British Bump Integrator (old model) are being utilized. Rod & Level is too archaic and should be dispensed with totally. No form of skid resistance evaluation of road pavement is yet being carried out in the country. As Nigeria fully understands the importance of network-level pavement maintenance management, there would be the need to incorporate skid resistance evaluation, in addition to the other pavement evaluations.

In conclusion, Nigeria is lagging behind in adopting and practicing advanced and better data collection technologies. This contributes largely to the non-implementation of any form of viable pavement maintenance management of her vast road network. The repercussion of this is the degradation of the road pavements beyond permissible terminal serviceability levels resulting in huge annual rehabilitation budgets.

9.0 RECOMMENDATION

Nigeria is technologically ripe enough to commence experimenting with better advanced modern techniques of surface distress capture using highly accurate aerial photos, spatially-encoded video and global positioning system. This is more so since Nigeria has successfully launched satellites into space. The latest modern techniques of using 35mm analogue continuous film, digital camera and digital line scan imaging may be too advanced to be successfully practiced yet in the country.

For non-destructive structural evaluation, the global trend now is the use of falling weight deflectometer (FWD) and Nigeria should start incorporating this technique too.

Later versions of the bump integrator and Mays Ride Metre can be adopted and they will serve the needs of the nation for pavement deflection measurement. Laser profilers may prove challenging to adopt now because of the technological level required to successfully utilize them.

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