THE ENGINEER IN ROAD BUILDING: THE KENYAN PERSPECTIVE

Professor F. J. Gichaga

Inaugural Lecture

University of Nairobi

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Professor Francis John Gichaga did his Cambridge School Certificate at Kagumo High School, Nyeri and Higher Cambridge School Certificate at Kangaru High School, Embu. His Mathematics teacher at Kagumo had "advised" him to take Engineering course and in March 1965 when he joined the then University College Nairobi, University of East Africa, Gichaga joined the Civil Engineering Department as an undergraduate student and completed the course in June 1968 with a First Class Honours.

After graduating he spent four months working with the City Engineer's Department of Nairobi City Council who had sponsored him for his degree course. He returned to the University to do a Masters course as a Graduate Research Assistant, which required him to carry out research on deflection characteristics and elastic response of flexible road pavements in Kenya which he successfully completed in March 1971 and returned again to the City Engineers Department of the Nairobi City Council where he was attached to the Transportation Division of the Nairobi Urban Study Group, where he was incharge of collection and analysis of data on Public Transport in Nairobi. He also worked in other sections of the City Engineers Department including Estates Development Section, Roads Section and Operations and Maintenance Section, where he was involved in design and supervision of road works. Meanwhile he was lecturing part-time at the University of Nairobi. He rose through the ranks of the City Engineers Department and by August 1974 when he joined the University of Nairobi on full-time basis he was acting Assistant City Engineer (Operations and Maintenance).

Professor Gichaga has spent most of his working life in the University of Nairobi training Civil Engineers where he has taught many undergraduate and postgraduate courses including Highway and Traffic Engineering, Urban Transportation Planning, Soil Mechanics, Engineering Drawing, Engineering Management and Administration. On joining the University on a full-time basis he continued with the research which he initiated in 1968 and wrote his Ph.D. thesis on "Structural behaviour of Flexible Pavements in Kenya" for which an award was made in 1980. The research continues with a number of Masters and Ph.D. candidates whom he has supervised, obtaining awards in the same field.

Professor Gichaga has participated and organized many Scientific Conferences and has published locally and internationally, and his latest book was published in 1988 on "Essentials of Highway Engineering with reference to Warm Climates". He has been consultant on a number of Government Projects and to a number of Engineering Consulting firms.

Professor Gichaga has been Chairman of the Department of Civil Engineering (1977-1985), Dean, Faculty of Engineering (1982-1985) and Principal, College of Architecture and Engineering (1985 to date) University of Nairobi.

Professor Gichaga has played a leading role in the development of the Engineering profession in Kenya and was Honorary Secretary of the Institution of Engineers of Kenya (1978–1984), its Chairman (1985–1988) and currently sits on the Council of the Institution as a Retired Chairman. He is also a member of the Engineers Registration Board and of the Kenya National Academy of Sciences.

The Engineer in Road Building: The Kenyan Perspective

INTRODUCTION

I chose this topic on the Engineer in Road Building because I have taken part in the training of engineers and I have also taken part in the various phases of road building in our country.

I have looked at the topic under three distinct elements namely the engineer, the road and the engineer in the road building scene in Kenya. The concluding remarks constitute my own thoughts on the engineer and road building in the future of our nation.

A. THE ENGINEER

First I would like to briefly discuss what we mean by the "engineer"and his role in society. The engineer is a key actor in development planning and as a planner he is involved in solving problems facing the society now and in the future. He is therefore required to be versed in development planning techniques and thus forecasting becomes a major pre-occupation of an engineer.

An engineer is basically a "problem-solver" and consequently his training involves analysing problems and looking for possible solutions. He is trained in analysing problems for which he must utilize scientific and technological knowledge in arriving at solutions to problems of society. He must of necessity have a sound academic base and must constantly update himself with science and technology in his area of specialization to be in a position to determine the relevant technology to apply in a given situation.

The above shows that an engineer will need during his training to cover basic science subjects especially those with heavy computational requirements like Mathematics and Physics.

Another requirement for the engineer is that he must be able to harness the great resources of nature and transform these for the use and comfort of society. This requires that the engineer must cover in his training subjects relating to the natural resources such as water, wind, rain, sun, soil, rocks, minerals etc. Thus engineers will cover subjects like Fluid mechanics, Hydrology, Geology, Soil Mechanics, Rock Mechanics, Surveying, Strength of materials etc. The subjects that an engineer will study in a given course will depend on the desired specialization. In the training of engineers we stress safety of structures being conceived and their economic viability. We also stress the issue of optimizing use of resources both now and in the future. Thus the issue of conservation of energy and protection of environment are receiving considerable emphasis these days.

In summary, an engineer must have many attributes such as:

- he must first be a scientist in his own right;
- he must be familiar with problems facing the society for which he is assumed to understand the society;
- he must be able to analyse problems facing society;
- he must be able to formulate possible solutions to those problems;
- he must be able to work out the cost and the impact of the possible solutions so that selection can be made of the solution to be implemented;
- he must be able to work out detailed specifications or design of the selected solution;
- he must be able to supervise implementation of works which constitute the solution;
- he must be able to monitor the performance of the implemented solution and offer specifications for rehabilitation when necessary.

The definition of a professional engineer as defined by the Institution of Engineers of Kenya reads as follows: "One who is competent by virtue of his fundamental education and training to apply the scientific method and outlook to the analysis and solution of engineering problems. He is able to assume personal responsibility for the development and application of engineering science and knowledge, notably in research, design, construction, manufacture or management, or in the education of the engineer. His work is predominantly intellectual and varied and not of a routine mental or physical character. It requires the exercise of original thought and judgement and the ability to supervise the technical and administrative work of others. His education will have been such as to make him capable of closely and continously following progress in his branch of engineering science by consulting newly published work on a worldwide basis assimilating such information and applying it independently. He is thus placed in a position to make contributions to the development of engineering science or its applications.

His education and training will have been such that he will have acquired a broad and general appreciation of the engineering science as well as a thorough insight into the special features of his own branch. In due time he will be able to give authoritative technical advice, and to assume responsibility for the direction of important tasks in his branch."

During the 1987 International Engineers Conference we invited Lawyers, Political Scientists and Economists among others to address engineers.

The Political Scientist had his observation of engineers summarized as follows: "Despite such a clear vision, the performance of the engineer in politics has been disappointing worldwide. But no doubt the effect of his political indifference has been and is likely to be felt more in Africa than

elsewhere. It is here that conditions of social and economic insecurity are most threatening largely as a result of political miopia and administrative inefficiency. There is a wide gap in most African political systems between empty platitudes and tangible problem oriented decisions. It is unlikely that this gap will ever be bridged in the absence of a Major move to involve the engineer in politics. The opportunity, however, will not be offered on a silver-plate; the engineer has to seize it in the name of humanity".

From the engineers side the Nigerian delegation to the Conference had their observation which included the following "Engineers, scientists, industrialists, businessmen and future politicians must have some meaningful inputs in LDC National Planning Commissions. After all, all that are being formulated are the technological programmes of development for the countries in future years ..... More engineers should set up their own business, enter into politics, take more interest in village life and small scale industries and give populace the feeling that we can solve most of their technical problems. Herbert Macauly, Kosygin, Maples did, Margaret Thatcher and Lee-Lacoca are still doing just that. We must follow their shining examples".

The Economist complimented engineers role in development and had the following observation: "During the last thirty years or so, development experts have come to appreciate the critical importance of knowledge and skills in the development process. Traditionally, it had been assumed that social and economic development was accounted for almost exclusively by three factors — land, labour and capital. Of the three, capital was regarded as particularly important. However investigations carried out during the last thirty years have shown that land, labour and capital often account for less than half of increase in national output. The other half is accounted for by technological progress."

The Lawyer was however very cautious in analysing the engineer. He drew attention to the engineers role to society and his ethical requirements. In particular the lawyer pointed out that "Most of what the engineer does in his professional capacity is based on contract — that is an agreement between him and some other person, normally for a money consideration that is called the price .... In the conclusion of contracts there will be certain definite requirements to be met. To avoid any problems, it is prudent that these requirements are satisfied. Moreover, decisions in a given society at a particular stage in its history pervade scientific activity at almost every level. Engineering science and practice is therefore caught in the web of law in much the same way as social behaviour generally is. That has implications of an ethical nature which the engineer as a professional ought always to remember. The most important of this is the fact that it is the engineer (by reason of his expertise) who is ultimately responsible for

ensuring that the standards prescribed in the law are actually embodied in the product offered for consumption by the society."

B. THE ROAD

I would now like to briefly discuss roads in Kenya. Roads in Kenya are classified under two systems including the rural road system and the urban road system. The rural roads are categorized according to the function so that international trunk roads are in A class, secondary roads are in B and C classes and the feeder roads are in D and E classes. The roads in class A are constructed to cater for high speeds and therefore they have good geometrics.

The urban roads are also classified according to functions and traffic volume. We have primary urban roads, such as the Uhuru Highway in Nairobi, which carry high volumes of traffic and are therefore designed to high standards; and we have District distributors like Jogoo or Juja Roads which carry high volumes of traffic between the City Centre and the residential areas. In addition to catering for high traffic volume district distributors should also provide for non-motorised traffic.

Then there are access roads which basically serve environmental areas and which are designed to lower standards in terms of speed but will provide for facilities for pedestrians, cyclists etc.

A road consists of a number of basic elements which the Road engineer must consider in design. The following gives a summarized presentation of the basic elements:—

1. Layout

This is a representation of the road in plan form showing alignment in the horizontal plane in addition to associated features like drains, culverts, bridges, footways, cycle ways, adjacent structures like buildings etc.

In the horizontal plane a road will show the tangent sections, horizontal curves, alignment and widths of lanes, and layout of junctions and intersections. Curves can be simple, compound, parabolic, transitional etc. Carriageway widths can be as narrow as 4.5m (i.e. 2 lanes) and can be as wide as 15m (i.e. 5 lanes).

Junctions and major intersections constitute a major component in layout alignment of a road especially in terms of design. In a ranking order there will be T-junctions, Y-junctions, staggered-junctions, cross-roads, roundabouts, traffic-signal controlled junctions, separated grade intersections and sometimes a combination of some of these. Quite often inadequately designed intersections are a source of road traffic-accidents.

2. Vertical Alignment

This is the alignment form of a road in a vertical plane giving gradients — downhill or uphill or level gradient. There are also vertical curves that are

involved in connecting the different adjacent vertical grades. Vertical curves can be simple or parabolic.

3. Cross-section Elements

Cross-section elements of a road are seen when a vertical section is taken across a road reserve showing the road and its associated elements. Such elements include:—

- carriageway with the lanes
- the kerbs and channels marking the edges of a carriageway
- the footpaths adjacent to the roadway
- the verges planted with grass, flowers etc
- the Median for dual carriageway configuration
- side drains which could be earth drain ditches, concrete channels, pipes, etc
- extent of road reserve
- side service roads if provided
- cycle track if provided
- pavement make up

4. Pavement Structure

The pavement structure is a major road element which is designed to ensure that the vehicle running on the carriageway does not sink into the pavement. This requires the knowledge of the strength of road construction materials to be used, the required combination of these construction materials, in addition to the strength of the natural ground (subgrade) upon which the pavement structure is to be built. Thus occurrence of cracks, distortions, potholes and other distress features on road pavements indicate inadequacy of pavement structures.

5. Drainage Structure

As happens with most engineering works, the road structure has to be provided with adequate drainage. The drianage system comes in two forms — the surface or stormwater drainage which is normally provided at the edges of the carriageway as side drains, and the surface drainage which takes care of the internal drainage of the pavement structure. Inadequate drainage quite often leads to early pavement distortions and deterioration eventually leading to failure.

6. Road Furniture

A road requires furniture in terms of road signs, traffic lights, etc to guide the motorist to minimize road traffic accidents.

C. PLANNING, DESIGN, CONSTRUCTION AND MAINTAINANCE OF ROADS

Each of the road elements described above has to be given attention by the road engineer at planning stage, at design stage, at construction stage and during maintenance and operations stage.

At planning stage the road engineer works closely with physical planners and other professionals to ensure that his road will be adequately designed to serve the community both now and in the future.

During the design stage the road engineer spends his time analysing data to develop the type of road that meets the requirements of the people into the future. He must analyse traffic flows, carry out necessary forecasting to arrive at layout design. He must analyse survey data in his design for horizontal and vertical alignments. He must specify materials to be used and the quarries to provide suitable construction materials. Additionally, he must provide drainage specifications to ensure that his road is adequately drained. After carrying out the design he must cost it to arrive at an estimate cost-normally to within 20% accuracy, as there is a possibility of revising the design if available funds are not sufficient to complete the originally conceptualized design.

During the construction stage every interested party is aware that the road project is being implemented and this is when the road engineer is exposed to wide public scrutiny. He will be accused of many evils first because he will be responsible for certifying huge payments to be made to contractors and secondly because where big money changes hands, many will have interest. This is generally the time when the road engineer has to live up his professional ethics, otherwise his name and that of his profession may end up being scandalized. The road engineer will insist on the construction of the road to the design specifications.

After a road has been constructed, it is required to stand to the test of time when the flaws of design or construction start showing up. This is then the stage for the road engineer to undertake maintenance works as required. The road maintenance engineer ideally should have tools to enable him detect the area for maintenance well before motorists start complaining. The reality in the Kenyan context is obviously different as is attested by numerous letters, to the editors in our local dailies, of people requesting improvement on roads both in the urban and in the rural areas.

D. REVIEW OF HISTORICAL DEVELOPMENT OF ROAD TRANSPORT IN KENYA

At the present time, roads are the most important of all modes of transport in Kenya in terms of their extent and the level of service offered to the travelling public. Historically, the development of the road network in

Kenya was subsidiary to that of the railway, particularly the main railway line from Mombasa to the Western Kenya. Some of the restrictive measures imposed in earlier years to protect the railway were lifted in 1959, when a programme to upgrade the road network was embarked upon. Since that time, the expansion of the road network has been very rapid. At independence in 1963 the system, though extensive, was mainly of low standard, usually of gravel or earth roads standard, without a coherent network of bitumenized trunk roads. Immediately after independence, first priority was given to the upgrading of the principal highway arteries and the trunk roads. This was followed by the improvement of the primary network through selective bitumenisation of heavily used segments, realignment of critical bottleneck sections and the improvement to gravel standard of selected high priority earth roads.

The road development programmes of 1960's concentrated in up-grading major heavily trafficked trunk and primary roads to bitumen and gravel standards. A number of bridges were constructed to remove critical bottlenecks in the trunk and primary road network. In recognition of the need to have specialised road network to support development effort in other sectors, Special Purpose Roads Programmes were initiated, amongst which were tea and sugar roads and tourist roads programmes.

During the period 1970 to 1974 the road development programme was sharply accelerated with virtual doubling of capital expenditure over the previous five years. Emphasis during this period was directed towards feeder and other minor roads with a view to opening up areas where road communication did not exist earlier.

The 1974-78 Development Plan introduced an overall Government policy aimed at boosting rural development. In comformity with this policy the following two ambitious rural-oriented roads programmes were initiated:

(i) the rural access roads programme which covers improvement of unclassified farm-to-market access roads and

(ii) the gravelling, bridging and culverting programme, for up-grading of selected classified secondary and minor roads to all weather gravel standards. At the same time, a number of important projects in the trunk and primary road system aimed at relieving bottlenecks and congestion points were taken up.

The 1979-83 Development Plan provided for a balanced development of the entire road system, recognising in particular the need for strengthening and rehabilitation of deteriorated paved sections of the trunk road system. This strategy for the development and expansion of Kenya's road network continued to be the guiding principle during the 1984-88 fifth National Development Plan.

At independence in 1963 the classified road network had a total length of about 41,800 kms and this had increased to 53,800 kms in 1982. Of this the length of all-weather gravel roads increased from 16,000 kms to 18,400 kms and total length of Bitumen roads increased from 1,810 kms to 6,700 kms during the same period. The total number of registered vehicles rose from 89,093 in 1962 to 203,446 in 1976, 249,162 in 1982 and 299,279 in 1986.

E. THE ENGINEER IN ROAD BUILDING

Having considered the (road) engineer and road building in Kenya, we now come to the important phase of the lecture which is supposed to bring up the contribution of the engineer in road building in Kenya.

It is common knowledge that most of the development in Kenya has closely followed development of road network so that areas with higher density of road network have witnessed greater economic development. This is indeed one measure of the engineer's contribution to the development of the country's economy.

The road engineer has continued to design, construct and maintain roads, and in some cases we have witnessed roads which have broken up being reconstructed. However, there is no doubt that we have continued to face problems in the road arena especially in terms of how it serves the public. The fact that we continue to face problems of road traffic accidents leading to loss of life and property; the fact that we still witness newly constructed roads breaking up early in their design life; the fact that we continue to witness traffic congestion in our major towns; the fact that driving in Nairobi's City centre looking for parking continues to be a "nightmare" and the fact that loss of parked vehicles in the city centre through theft continues to be alarming indicate to the Kenyan motorists that road engineers are far from perfecting the art of road building. However, such are the problems facing countries the world over, especially developing countries. Whereas in the developed countries substantial efforts have been put to overcome many problems facing the motorists, in many developing countries resources available are not sufficient to mount effective counter measures against the problems highlighted above.

In Kenya corrective action continues to be taken by various authorities and especially the Ministry charged with the responsibility of road development in the country — The Ministry of Public Works.

The following gives an outline of some of the works that have been carried out by the Road Engineer in an effort to improve the science and art of road building in Kenya:—

1. Road Traffic Accidents

Road traffic accidents have continued to rob Kenyans of their dear ones despite the many steps that continue to be taken to reduce road accidents. We see road traffic accidents being caused by three basic elements which include the drivers, the vehicle and the road.

The driver has to shoulder considerable blame especially when he is physically unfit to drive (due to fatigue, drugs such as alcohol, or sight impairment), or when he does not have adequate preparation to drive (due to poor driver training). The Police have continued to be vigilant in this area and currently police have alcometers which enable them arrest drunken drivers on our roads.

The condition of vehicles has been another concern and one notices that a number of road unworthy vehicles have been removed from our major roads. The Vehicle Inspection Unit has helped greatly in reducing the number of unroadworthy public vehicles on our roads. However, more still remains to be done.

The condition of the road and its environment will continue to be the road engineer's area of concern. First, because the road engineer designs, constructs and maintains roads but secondly, because even when the road engineer provides what he believes is an accident free road, accidents still occur. Some of the interesting research findings tend to suggest that an amount of roughness on the road is necessary to minimize road accidents (Agoki, 1988). Agoki has also investigated junction spacings in terms of accident causation and has found that junction spacing shorter than 0.25 km will tend to increase accident causation significantly. He also found that drivers with long driving experience tended to have higher accidents than newly licensed drivers which indicates that overconfidence by experienced drivers is a factor in road traffic accident causation.

Kimori (1989) carried out a short study of accidents in a few T-junctions in Nairobi area. He found as expected that matatus have higher rate of accident causation than buses and lorries. However, the accident causation by buses was found to be close to that of matatus particularly when compared to the passenger car.

The research work carried out by the Road Safety Unit of the Ministry of Public Works has shown that about 85% of road accident fatalities affect pedestrians and passengers and that about 15% of the fatalities involve drivers.

The Ministry of Public Works have gone around the various roads in the country identifying dangerous sections (sections showing high incidence of accidents) and remedial works have been carried out on a number of these dangerous sections.

The statistics that we now have indicate that for effective reduction of road traffic accident fatalities action should be directed towards pedestrians and passengers. Education on road safety awareness was introduced in the early 1980's and has therefore been with us for some time now.

There are indications that school children are becoming more conscious of road safety requirements than was the case before the introduction of road safety education in the education system.

Further Research Required

In addition to education on road safety there are areas requiring further, research in our country such as:—

- development of appropriate junction controls (e.g. Manual control, roundabout, traffic signal control, separated grade control) to ensure cost effectiveness
- development of ways of encouraging pedestrians and cyclists in urban areas
- development of optimum geometric designs to ensure cost effectiveness in design of the geometric elements.

2. Pavement Structure

Studies have been carried out on pavement materials and on finished flexible road pavements. Most studies have focused on finding out strength characteristics of the various materials used in road construction. The design of road pavements in Kenya, as in many developing countries, remains largely empirical. However, some research work has been going on to develop a theoretical basis for analysing road pavement structures. Theories on structural analysis require knowledge of strength parameters of materials used in road construction under conditions that prevail in the field when these materials are stressed by traffic loads.

Studies on strength characteristics of road building materials in Kenya have been carried out by Geotechnical engineers as well as road engineers. Such studies have been carried out on Subgrades, on Subbase and base construction materials, and on surfacing materials.

It has for example been found that our common subgrade soils (Red Coffee Soil and Black Cotton Soil) are likely to exhibit varying strength characteristics under varying loading and drainage conditions which calls for careful control during pavement construction. For example the road engineer should understand when the subgrade soil is likely to suffer from swelling, cracking and collapse.

Again studies have been directed towards subbase and base construction materials. The materials used for these layers include gravels, which may or may not be stabilized with chemicals like cement or lime, soft rocks and

crushed rocks. The characteristics of these materials vary from one quarry to another and the road engineer is required to carry out quarry identification and analysis during the road design stage. Materials are only used for road construction if they satisfy specific requirements which are stipulated in the Road Design Manual. Thus when roads constructed to the specified standards fail to survive their design life, we need to revisit these design specifications. One starting point regards the origin of the standards.

The road surfacing materials for our flexible pavements are mainly bituminous and the road engineer has spent a lot of effort in studying the behaviour of bituminous materials. Being visco elastic, bituminous materials present one of the greatest challenges to the road engineer because modelling bituminous materials is a very complex task. Indeed that is one reason why flexible pavement design continues to be largely empirical. Studies of behaviour of bituminous materials continue to be done both in Kenya and elsewhere. For us in the tropical zone we tend to think that bitumen gets oxidized under tropical weather (sunshine, solar radiation, rainfall, temperatures etc) rendering it brittle and hence susceptible to cracking. Consequently failure of bituminous surfacing layer tends to originate from this form of cracking thereby allowing ingress of surface water into the underlying pavement layers which leads to pavement deterioration and break up if the cracks are not sealed in time. Research work is continuing in this area to establish the chemical changes suffered by bitumen due to tropical weather and the geological properties of aggregates suitable for making bituminous materials.

Evaluation of Existing Road Pavements

After the roads have been planned, designed and constructed, it is necessary to monitor their performance so as to check the performance against design expectations. The exercise of evaluating pavements performance in Kenya has been going on for over two decades and we now have a wealth of information of certain types of design. Thus design specifications for material on perfomance combinations and thicknesses have changed over the years with considerable influence coming from the findings from field performance evaluation. The exercise of evaluating existing pavements continues in many countries and in our case the trend is towards more functional and structural evaluation.

Rehabilitation of Existing Pavements

When existing pavements have been evaluated and found to be inadequate there is need to take corrective action. Sometimes the action required could be simple (e.g. routine maintenance) but there are times when the engineer finds that he must strengthen the pavements by providing an overlay or by reconstructing the pavement structure. The issue of viability of the action

to be taken becomes important as the road engineer must justify the expenditure on overlay or by reconstructing the pavement structure. Sometimes overlays are to be expected particularly when we are dealing with stage construction or when design parameters have significantly changed (e.g. use of heavier axle loads than was anticipated at design stage). Design specifications for overlay designs for road pavements under the tropical environment are available from the TRRL who have done commendable research work in many developing countries of the Commonwealth through the TRRL Overseas Unit. Several sections of our trunk roads have been overlaid and performance results indicate these overlays to be effective in restoring service life of the pavements.

Need for Further Research

In addition to continuing with the studies described above there are areas requiring special attention including:—

- effect of repetitive loading on road building materials (i.e. dynamic loading);
- improvement on design standards;
- improvement on testing techniques of road building materials and on constructed road;
- study of economic and technical viability of concrete pavements (rigid pavements). The limited work done in respect of concrete pavements indicate that joint forming and maintenance can be major sources of maintenance problems in concrete roads.

3. Low Volume Roads

Low volume roads have received considerable attention in recent past particularly because they serve to generate economic development in agricultural areas of our country. Some limited research work has been done on low volume roads serving the various tea zones in our country. However the most interesting studies on the impact of low volume roads have been carried out by economists. They have established that the Rural Access Roads have had tremendous impact in the economic development of the areas where such roads have been built.

The role of the Road Engineer in the development of low Volume Roads is in the specification of technology which is appropriate and cost effective.

4. Drainage

Although drainage is very important in road performance the research work on drainage has mainly been carried out by hydrologists and drainage

engineers. A lot of the basic data that we continue to use comes from TRRL and the Ministry of Water Development.

There is no doubt that storm water drainage has become a major problem in our large urban towns of Nairobi and Mombasa. We also have problems of flash floods in some of the remote areas of our country. Some studies are currently going on in respect of drainage problems of Nairobi City and some research work has been carried out on flash floods in some parts of our country.

The other aspect of drainage of interest to road engineers is subsurface or internal drainage. When water is trapped inside the pavement structure the structure may break up and it is important to design a pavement structure allowing for subsurface drainage. Quite often a layer of granular material at subbase level is sufficient to take care of subsurface drainage. This is an area where road engineers depend on the research work done by Geotechnical Engineers.

In this area of drainage further research work could be carried out in the following areas:—

- establishing storm and rainfall intensity characteristics in various areas of our country;
- design or erosion control measures in rural areas where roads allow drainage structures to discharge in the fields causing erosion;
- design of drainage structures in remote areas such as drifts, Irish bridges etc.

F. CONCLUDING REMARKS

I believe I have given a reasonable review of the road engineers' role in road building in the Kenyan perspective. However the Terms of Reference of the letter inviting me to present this Inaugural lecture also require me to reflect pomp, versatility and wisdom.

Thus in my concluding remarks I wish to share with you a few ideas in this scenario of engineers and road building.

First the engineer of the future will need to be more versatile than has been the case before so that he can take his rightful role in a multi disciplinary approach to problems of society. This means that his training must be more broad based and include subjects like development planning, community participation, etc. so as to enable him understand the society more fully and appreciate the need to safeguard natural resources for future generations.

Secondly, there have been a question that has been raised as to whether we have capacity to usefully absorb our graduate engineers. Analysis of the relationship beween the engineers per capita and the level of development of a country in terms of GNP per/capita shows that those countries with high GNP per capita also have high number of engineers per capita. We are

way behind in the numbers that would reflect higher GNP per capita. Thus we must continue to produce more and more. The engineers produced must however be committed and usefully occupied more or less the way one witnesses a "Jua Kali" artisan taxing his ability to the limit in getting a particular problem solved with speed and at affordable cost.

In the area of technology in general including road construction where engineers are involved as the managers of technology we must aspire towards developing significant independence in terms of technology choice. If not we shall remain a dumping ground for untested and sometimes obsolete technology.

- Roads will need to be provided in poor urban areas as a means of access to avoid the fire and other risks that are associated with inaccessible environment. In my view therefore roads will need to be seen as an essential service in urban areas just like sanitation. One could also argue that as a minimum rural areas should have reliable roads to enable them receive necessary inputs for agriculture and also have access to social services.
- The need to develop standards for various classes of roads will be more apparent in the context of providing more roads in poor areas so that at the very local level whether in urban or rural areas, rich or poor areas, it will be possible to have motorable access. Currently the variety of road construction standards is limited. There is therefore need to adopt road construction standards for which when implemented, there will be follow-up in terms of effective restriction on traffic beyond the design standards to avoid the damage we have witnessed on roads which when opened to traffic have carried loads way beyond the design level with inevitable failure. The Roads of the future must meet the requirements of the community than has been the case before. For example the problems of urban centres in rural areas on overhanging cliffs caused by main roads passing nearby must be avoided by making roads match with the environment.
- Roads of the future must service even the remotest part of the country and thus there is need to develop appropriate techniques of developing cost effective low volume roads.
- Roads in urban areas will have to be seen in terms of comprehensive planning of these urban areas to minimise stressful environment. Thus we shall have to go for towns where more road space will be made available per capita thereby allowing for motoring space as well as for parking space. Additionally we shall need multi level intersections to minimize congestion at junctions and such need should be justified on a cost and benefit analysis.
- Roads in urban areas will need to be planned with emphasis towards public transport so as to reduce the traffic congestion caused by those who could take public transport if it were more reliable.

Planning of urban areas must be based on multi-disciplinary approach to avoid problems that other cities have gone through. We should for example avoid the planning problems that are evident in many large cities. In order to deal with the problems outlined above effectively there is need to carry out extensive studies at various levels on long terms basis the way, for example, we read about studies aimed at developing anti malaria vaccine by KEMRI etc. One notes that developed countries have Transport and Road Research institutes and indeed a few African countries (e.g. Ghana and Nigeria) have such research institutes. It would therefore be desirable to have a Transport or Road Research Institute in our country to be able to carry out and coordinate research on the numerous aspects relating to transportation including roads.

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