TRANSPORT RESEARCH LABORATORY

DFID Department For International Development

TITLE: Engineering standards of the Kenyan rural access roads

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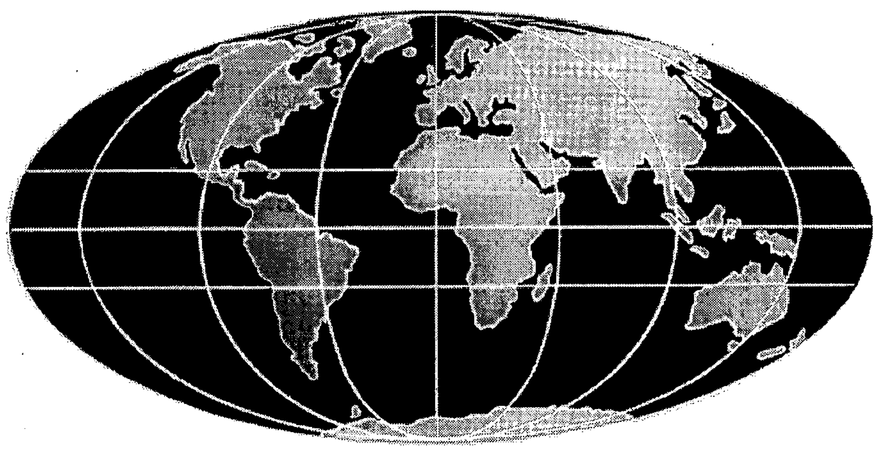

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PA1090/79

PA1090/79 ROLT, J (1979). **Engineering standards of the Kenyan rural access roads.** ***<u>PTRC Summer Annual Meeting, University of Warwick, 9-12 July, 1979.</u>*** London, 1979 (PTRC Education and Research Services Limited)

ENGINEERING STANDARDS OF THE KENYAN RURAL ACCESS ROADS

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Crowthorne, Berkshire
1979

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1. INTRODUCTION

One of the most important aspects of Kenya's current development programme is the economic and social development of the rural areas in which about 90 per cent of the population lives. The development of these areas is dependent, amongst other things, upon increased access between rural farms and marketing and social centres. Since 1974 a programme of construction of rural access roads (RAR) has been underway in Kenya. Initially the programme was started on a pilot scale with two construction units funded by the British Government. This increased to four units during 1976 and to six units by mid 1977. Rapid growth in the programme then occurred so that by mid 1978 twenty construction units were in operation and by early 1979 the number was above thirty. Each construction unit builds about 45 kilometres of road each year using labour-intensive construction methods. The aim of the programme is to build approximately 14,000 kilometres of all weather rural roads during the next few years using up to 70 construction units in 23 districts of the country. At least six major aid donors are currently funding or are about to fund construction units. The size and scope of the programme is apparent when it is realised that each construction unit employs approximately 300 people and thus with 35 units in operation the labour force is already over 10,000.

In January 1976 a team of advisors was set up to conduct research work in all aspects of the rural access roads programme (RARP) and to make recommendations to the Kenya Ministry of Works. The work of this team (the Technology Unit) included a) the development of suitable tools and hardware b) development of suitable task work organisation for each construction task c) development of suitable project organisation including the supervision and management structure of the construction units d) development of suitable methods and management for the maintenance of the roads e) recommending suitable training programmes for the various management and supervisory levels within the programme f) the development of indigenous capability for manufacturing small scale tools and equipment g) dissemination in Kenya and elsewhere of the results of the work h) development of appropriate engineering design standards for the roads.

It was the last of these studies which became the responsibility of the UK Transport and Road Research Laboratory (TRRL). The TRRL study consists of five main parts:

1. Initial appraisal of rural access roads to identify main problem areas.

2. Production of a detailed inventory of rural access roads and a general performance evaluation.

3. Construction of sections of road using different levels of input and subsequent monitoring of the performance of these sections to evaluate construction input versus performance trade-offs.

4. Detailed performance survey of a selection of roads built using normal construction methods.

5. Maintenance study.

It is the second part of this programme which forms the basis of this paper.

The roads themselves are built entirely by labour-intensive methods except for the operation of hauling gravel, which is done by tractor and trailers. After the alignment has been set out, the construction sequence is as follows:-

1. Site clearing. This includes clearing bushes, trees and stumps, vegetation and boulders.

2. Earthworks. The objective of this operation is to provide a transverse <u>level</u> bench. On this 'bench' the drains and camber are built in the next operation. Only handtools are used in the various operations of excavation, haulage, filling, spreading and compaction.

3. Drainage. This includes cutting two rectangular side drains (ditching), forming the sloping edges of the ditch (sloping), and forming the camber by spreading and shaping the spoil material previously excavated from the ditches. These tasks can only be done accurately if a proper level bench has been built in operation 2 above. Again only handtools are used. Included in this operation is the laying of culverts.

4. Structures. This includes multiple culverts, drifts and minor bridges.

5. Gravelling. This includes the preparation of the borrow pit, excavation, loading, hauling and spreading.

This is a very brief introduction to the construction sequence and methods. Full details can be found in the Technical Manual produced by the Technology Unit for the Kenya Rural Access Roads Programme.

2. THE INVENTORY

The objectives of the inventory study were:-

1. To quantify the engineering properties of the roads already constructed,

2. To compare the different standards represented and to compare these standards with the standards the engineers are trying to achieve,

3. To identify factors which might prevent the required standards from being achieved,

4. To establish a basis for comparison which can be applied to future rural access roads and also to the present roads at a future time so that performance trends can be identified,

5. To develop measuring techniques which can be used in the future monitoring of the roads.

The information which was collected for each road was as follows:-

1. Longitudinal profile,

2. Positions of culverts and mitre drains,

3. Lateral profile of the road at 200 or 250 metre intervals. These profiles were then analysed to produce for each cross section;

   (a) the constructed width of the road
   (b) the effective width of the running surface

(c) the effective camber

(d) the depth of drainage ditches

(e) the depth and extent of rutting

(f) the width of gravel wearing soil

4. Bearing capacities of natural soils,

5. Classification of subgrade soil types,

6. Classification of gravel types,

7. Longitudinal roughness (riding quality) on a selection of roads,

8. Traffic data,

9. Rainfall data.

The resulting information was then compared with the specifications in use to answer the following questions:

1. Which specifications are proving difficult to meet?

2. Why are these specifications proving difficult to meet?

3. METHODS

3.1 Sampling technique

At the time when field work for the inventory was commenced there were approximately 200 kilometres of rural access roads in existence spread between four construction units, namely Kwale (coastal), Nyeri (central), South Nyanza (basin of Lake Victoria) and West Pokot (north west). These areas represent quite different climatic and topographical regions of Kenya, hence it might be expected that roads built in each area would show distinct differences in performance after one or more climatic cycles. However it should be remembered that even within each area large differences in climate and topography exist which are likely to mask some of the regional differences.

This report contains details of 60 per cent (120 kilometres) of the roads built when the inventory was undertaken, plus details of another 85 kilometres of road built during the subsequent nine months. Some of these additional roads are located in two extra districts, namely Kirinyaga (in the central area near to Nyeri) and Trans Nzoia near to West Pokot. The roads described here are those roads which were chosen for subsequent long term performance studies. Table 1 summarises the details of the roads included in the study. Table 2 indicates the area of the country where each road is located together with the average rainfall level to be expected. It can be seen that each area is adequately represented in the inventory.

It is important to note that the inventory gives a picture of the roads at varying stages in their lives.

Some roads are quite new and some several years old. The characteristics of the lateral profile described here were obtained from surveys conducted between June and October 1978. Details of longitudinal profile and soil properties were obtained from earlier surveys conducted between January and October 1977.

3.2 Survey procedure

Initially, reference markers were set up at either 1 or 2 kilometre intervals along each road and the vertical alignment of the road measured on a continuous basis using a travelling wheel to measure distance and an Abney level to measure gradients. Absolute levels were of no interest in this survey hence an Abney level was accurate enough for the purpose, and it was quick to use. During this part of the survey details of culverts were also recorded. Following this a second survey team took profile measurements at pre-determined intervals along the road. Usually this interval was 200 metres but in flat uniform terrain this was increased to 250 metres. This team also collected material samples and took bearing capacity measurements at pre-selected locations along each road.

Thus most of the parameters measured were associated with the physical properties of the roads but additional information was obtained on the external factors most relevant to the performance of the roads, namely the climatic factors and the traffic. The number and type of vehicles using the road was recorded throughout the time necessary to complete the other measurements. This was usually only one day but was longer on the longer roads. The number of vehicles was always so low that large errors are likely in such a short counting period. In addition many of the roads were not completed and hence only construction traffic was using the road. Periodic traffic counts are now being conducted by the rural access road unit themselves. These counts, together with further supplementary counts, will be used in future analyses of the road performance. Regular rainfall data are also being collected for subsequent road performance analyses.

From the profile measurements details were obtained of the construction width, the effective width of the running surface, the effective camber, the depth of drainage ditches and the amount of rutting. These results, together with the vertical alignment data, could then be compared with the design standards which the engineers were trying to achieve. These design standards are summarised in Figures 1 and 2 and in Table 3.

4. CHARACTERISTICS OF RURAL ACCESS ROADS

4.1 Lateral profile

4.1.1 Constructed width. The constructed width of each road was obtained from the profiles by measuring the distance between the centres of the side ditches on either side of the road. The centre of each ditch was usually the same as the lowest point and was relatively easy to locate. In relatively flat ground, where little or no sidecut is necessary, this ditch - centre to ditch-centre distance is related to the total width of the road and provides a good measure of the standards achieved and the variability in construction. Even in quite hilly terrain roads are usually located so as to minimise side-cut provided that longitudinal gradients can be kept within specification. Thus the normal condition is for both side drains to be present. Where side-cutting is necessary the width specifications are different and profiles of these roads have been omitted from this analysis.

The results are presented as percentages of road length within half metre width ranges in Table 4. In addition the mean value and standard deviation has been calculated for each road. The design standards originally required that the distance between the centres of each side ditch should be 7.1 metres or 7.6 if the traffic exceeds 30 vehicles per day. The current standards specify 6.9 metres.

It can be seen that in general a considerable length of each road displays a width of less than 6.75 metres, although roads 9 and 10, which appear to be very poor in this respect, have an average width of 6.7 and 6.8 metres respectively and a very small deviation about the mean. This indicates a consistent, and therefore probably high, standard of construction even though the widths are slightly less than the specification. However only seven roads out of the 23 in the table show widths less than 6.25 metres and one of these roads (No. 38) is one of the early roads built during the pilot phase of the programme. Similarly there are considerable lengths of road which are wider than 7.75 metres, the two oldest roads (Nos. 13 and 38) falling well outside the specification with 44 per cent of road 13 and 36 per cent of road 38 wider than 7.75 metres. Excluding these two early roads, only three roads display widths of over 7.75 metres for more than 10 per cent of their length and of these, road 36 was deliberately widened whenever is crossed an area of clay soil.

4.1.2 Effective width of running surface. The effective width of the running surface of each road was obtained from the profile by measuring the distance between points on the profile where the gradient exceeded 15 per cent. These points were defined as being the edge of the effective running surface, and they were easy to locate even on roads displaying deep rutting. The original specifications called for a shoulder of 10 per cent slope hence the definition of running surface used here includes this shoulder. The current specifications do not require a shoulder and the slope of the inside of the ditch is 30 per cent, hence the definition used here should define the edge of the running surface as now specified.

The width of the running surface cannot be defined by this method if the road is superelevated. This occurs only rarely and in these instances the edge of the running surface is assumed to be 0.75 metres from the bottom of the side drain. Occasionally the drain slope does not exceed 15 per cent. In these instances the edge of the running surface is also assumed to be 0.75 metres from the bottom of the drain. Two typical profiles are shown in Figure 3.

The effective widths obtained are shown in Table 5 where the mean widths, standard deviations and upper and lower quartiles are shown. The design standards originally required a width of 5.5 or 6.0 metres including the shoulder, whereas the current standards require a width of 4.5 metres in flat or gently sloping sidelong ground, and 6.0 metres on embankments or wherever the traffic is expected to exceed 30 vehicles per day. There are so few raised embankments that for the present analysis these can be ignored. Also none of the roads included here were designed for a traffic flow of more than 30 vehicles per day hence all roads should have an effective running surface less than 6.0 metres wide. The table shows that only roads 13 and 38 have more than 25 per cent of their length with widths greater than 6.0 metres and, as stated above, these are two of the roads constructed during the early days of the programme. What is perhaps more serious is that fourteen roads have lower quartiles less than 4.0 metres and eight roads have lower quartiles less than 3.5 metres. In other words on over 25 per cent of eight of the roads two landrovers would be unable to pass each other unless the drivers were able to put their nearside wheels well into the ditch. On properly shaped roads studies have shown that if a vehicle is leaning sideways at an angle to the horizontal of greater than about 5 degrees the driver feels extremely uncomfortable and an absolute limit beyond which most drivers would be unwilling to go is about 8 degrees. Whenever the outside wheels of a vehicle are beyond the point marking the 15 per cent gradient which we have used to define the width of the running surface the angle of the vehicle with the horizontal is above 5 degrees and consequently if two vehicles are to be able to pass in comfort the effective running width as defined here should be large enough to enable them to do so. In practice this means that 4.5 metres width is the lower limit, provided the road is not expected to carry many lorries. If two lorries are required to pass one another then an ever greater width is required. Of course the degree of discomfort experienced by the driver as the vehicle tilts sideways depends on many other factors not considered here such as the amount of superelevation, the speed of the vehicle, the local geometry of the road, the type of vehicle, type of road surface etc. It is arguable whether driver discomfort during rare passing movements should be considered in the design of low cost rural access roads. Nevertheless the design standards which have been selected require a minimum width of 4.5 metres and it has been shown that long sections of road do not meet this requirement. In addition the table shows that wide variations in widths occur, the standard deviations ranging to over 1 metre.

Naturally the width of the effective running surface is correlated with the width between the centres of the ditches as shown in Figure 4, but the variations in effective running width are much larger than the variations in ditch to ditch width as indicated by the standard deviations in Tables 4 and 5. This implies that the variations in effective width are largely caused by improper carriageway shape. There is insufficient evidence available at present to decide whether this poor shape is a result of gradual deterioration under traffic and climate or whether it mainly reflects the initial condition of the road after construction. This is discussed in more detail below.

4.1.3 Effective camber. The effective camber of the running surface of the road was obtained from the profiles by measuring the maximum height of the road above a horizontal chord exactly 3 metres long touching the edges of the profile as shown in Figure 3. This method results in an effective camber which represents points approximately three quarters of a metre either side of the centre line or crown. Usually the sections of road outside these points is cambered more and the sections inside cambered less.

The procedure outlined above has disadvantages if the crown of the road is not close to the centre of the running surface. The profile would then display a higher camber on the side where the crown of the road is nearest to the shoulder and a lower camber on the other side. This problem arises if the road is superelevated or is badly rutted. Few lengths of road are superelevated and on those profiles displaying superelevation the average sideslope was calculated instead of the camber. The principle cause of errors in the measurement of effective camber occurred on badly rutted sections of road. The effective camber measured on a profile showing deep ruts is nearly always low hence as an index of poor shape and as a guide to the effectiveness of surface drainage this way of measuring camber serves its purpose. However, surface drainage on an unrutted road with low effective camber will be considerably better than on a rutted road showing the same value of effective camber. Any profile showing ruts deeper than 35 mm was assigned a zero value for camber.

The results of the survey are shown in Table 6. The specified camber was originally 4 to 5 per cent but the new specifications require 5 to 7 per cent. The table shows that out of a total of 38 roads, 24 have a mean camber greater than 4 per cent and 22 roads have over 25 per cent of their length with cambers less than 3.5 per cent.

It can also be seen from the table that relatively new roads display considerable lengths of low camber. Whether this results from slow deterioration under the action of traffic and rainfall or is the result of insufficient attention by the supervisor at the construction stage is difficult to determine. The time taken to complete each road is usually at least one year hence during this time, as the road settles down and consolidates, the road is unfinished but in use by various types of vehicle. The road is usually reshaped once or twice during this time and again before gravelling is started. There is some evidence that the roads completed most recently are better shaped than the older roads, but this could simply be a result of better control now that many of the overseers and supervisors have gained more experience rather than evidence that the older roads have deteriorated significantly. These questions will be resolved when the road performance study is completed. However it should be emphasised here that the importance or otherwise of improving the camber has not yet been determined. It should also be stressed that the difficulties of achieving the correct camber have been recognised and efforts are being made to make it easier for overseers to check the camber during the construction and settling period of the road.

4.1.4 <u>Depth of drainage ditches</u>. The depth of the drainage ditches on both sides of the road were also obtained from the profiles. The depths of these ditches below the highest point of the running surface have been tabulated in Table 7. The specifications require a ditch which is 0.30m below the horizontal excavated level hence for an ungravelled road of correct width and camber, the bottom of the ditch should be about 0.40m below the crown of the road and about 0.50m for a gravelled road. The table shows that only 14 roads out of 36 show a mean ditch depth in excess of 0.40m and 12 roads have over 25 per cent of their length with ditches less than 0.25m deep. Since the camber is formed from material excavated from the ditches it is to be expected that the camber is correlated fairly highly with the depth of drainage ditches. This is indeed true and the results indicate that if a camber of 5 per cent is to be exceeded then the ditches must be deeper than 0.40m for the road widths that are being constructed.

4.1.5 <u>Depth and extent of rutting</u>. The depth and extent of rutting was also obtained from the profiles as shown in Figure 3. The depth of rut was defined as the depth of water which could pond in the rut rather than the more usual depth measured below a straight edge placed across the road and bridging the high points. The rut depth was obtained by drawing a horizontal tangent from the lowest of the two high points defining the rut as shown in the figure. This procedure gives rut depths which are lower than those obtained using the straight edge method but gives values which are more useful when evaluating potential problem areas on the road. For example using the straight edge method a rut could be defined in a place where surface drainage is perfectly adequate as shown in the inset to Figure 3.

The most important rutting statistic for each road is the percentage length of the road which displays no rutting at all, and this is shown in the second column of Table 8. The importance of ruts depends critically on the type of soil. For example the most deeply rutted roads 17, 18, 19, 22, 23 and 26 are built on very sandy material, water rarely ponds in the ruts but drains freely through the soil. These roads are always trafficable even during very heavy storms. The soil is relatively loose and in dry weather deep ruts often form quickly. The importance of the ruts on these roads is therefore small. Conversely the deeply rutted roads 12, 13, 14, 15, 16 and 38 are older gravelled roads built on clay soils. The ruts in these roads denote areas which could make the roads impassable during wet weather and as a result they represent serious deficiencies. Furthermore the importance of the shallower ruts depends on the rate at which the ruts increase in size until impassable conditions are likely. It is possible, though not yet domonstrated, that with the expected low levels of traffic the normal maintenance procedure will have the effect of gradually improving the road from the point of view of rutting even though it is difficult for the maintenance men to check that they are obtaining a good camber.

4.1.6 Discussion. The general conclusion to be drawn about the lateral profile of the roads is that while specifications are not being met over considerable lengths of road, the overall standards are good and the effort required to bring the standards up to specification over much greater lengths of road is likely to be quite small. The first step towards this end would be achieved by exercising more careful supervision of the shaping of the road as the initial loose material begins to consolidate under construction traffic and climate. To make this task easier it is important to schedule such reshaping operations properly so that the material to be moved has not become too hard through having been left for too long, or conversely is not still too loose. The final stages of obtaining the proper shape could possibly be left to the maintenance men. These problems have been recognised and a design for a robust and light camber board to assist the shaping operation is underway and will be field tested soon.

The importance of good shape depends on the type of soil, on rainfall and on traffic. For example in free draining soil, where water does not pond, camber and depth of rutting are not nearly as important as in clay soils. Indeed in some sandy soils containing little binder it is almost impossible to maintain a good shape for very long but reshaping is very easy since the soil is relatively loose. In contrast in clay soils where traffic is relatively high the shape of the road will prove to be extremely important since as vehicles traffic the road any areas with ponded water will rapidly deteriorate.

4.2 Longitudinal profile

4.2.1 Vertical alignment. The vertical alignment of some of the roads was measured as described in Section 2.2 above and the results are shown in Table 9. The specifications require that a gradient of 11 per cent should not be exceeded except in exceptional circumstances and even then this gradient should not be exceeded for more than 100 metres continuously. It can be seen that in hilly terrain these specifications have not always been met. Also the table shows that there are some lengths of road steeper than 15 per cent in most hilly regions. These sections, though usually short, would present serious obstacles to loaded vehicles even in dry conditions. Generally, however, these sections were constructed early in the programme and it is unlikely that many sections as steep as this will be constructed in the future. The importance of these specifications, as usual, depends on the type of traffic expected to use the road, the soil type and the climate. For example if passenger cars and lightly loaded goods vehicles are the only motor vehicles expected, gradients considerably steeper than 11 per cent are negotiable in dry weather without much difficulty. However problems of erosion and maintenance increase rapidly as gradient increases and furthermore the trafficability of such roads in wet weather will cause serious problems for most vehicles. For these reasons it is considered advisable for engineers to exert every effort to ensure that the specifications for vertical alignment are strictly followed.

4.2.2 Surface roughness. Surface roughness has been measured on a selection of roads using a towed fifth wheel roughometer (bump integrator) or a calibrated vehicle mounted integrator. On the main road network of Kenya roughness values for gravelled roads normally lie in the range 2500-8000 mm/km for good lateritic gravel roads and up to 9500 mm/km for coral gravel roads. These limits depend mainly on the particle size distribution of the gravel and the frequency of grading. Ungravelled roads have not been surveyed systematically but some roads adjacent to rural access roads were measured during this survey and these were found to have roughnesses in the range 5000-12000 mm/km. The rural access roads display roughnesses ranging from 5000-13,000 mm/km on ungravelled sections and from 9000 to 13,000 mm/km on gravelled sections. Occasionally gravelled sections which are made from poor gravel containing large particles exceed 15,000 mm/km. It should be noted that the calibration of a vehicle mounted integrator unit at levels of roughness as high as some of the values mentioned here has not been possible except under very unrealistic conditions and these figures should be viewed as being very approximate.

The roughness of rural access roads is important for two reasons. Firstly, high roughness values indicate that the drainage of the surface of the road is seriously impeded. For a road to be untrafficable through excessive roughness alone, values in excess of 15,000 mm/km are necessary and generally such values would arise not from gradual deterioration but from the existence of large sized particles of gravel, stones, boulders and the like. Very high levels of roughness can arise over short distances where surface drainage is poor and vehicles have managed to force their way through during wet weather while the soil is very weak. The resulting surface is then more uneven than before and traps more water during the next rain. However such an area is usually trafficable in dry weather even though it is very rough. Secondly, high values of roughness affect vehicle operating costs. Although the traffic levels are low, so is the cost of building the roads, hence vehicle operating costs can become significant. Vehicle operating costs for vehicles operating on roads as rough as these are not well established but costs are likely to increase rapidly with roughness. For example it can be shown[1] that the difference in cost of operating a light goods vehicle on a road of roughness 10,000 mm/km and a road of roughness 5000 mm/km is approximately 0.3 Kenya shillings per kilometre. Hence over a five year period this amounts to about 500 shillings per vehicle. At a traffic level of 20 vehicles per day the vehicle operating costs over the five year period are over 30 per cent of the road construction and maintenance costs. At high roughness values this figure would be substantially greater. If the road carries a few medium lorries then this figure would be even higher. A full analysis of the trade-offs between additional effort in improving surface roughness and vehicle operating cost savings requires more data than is available at present, but simple measures such as ensuring that no stones or gravel particles larger than 25 mm, are allowed in the running surface and the use of small hand guided rollers to provide some initial uniform compaction at the time of gravelling could easily and cheaply be put into effect. In fact on a few roads a small hand operated vibrating roller has been used and significant improvements in the shape of the road and the surface roughness have been obtained by this means.

4.3 Properties of the soils

4.3.1 Subgrades. The rural access roads programme encompasses almost all of Kenya hence a very wide range of soil types are encountered. Table 10 lists the properties of representative samples collected during the inventory survey. Kenyan soils have been studied from an engineering point of view for many years[2,3,4] and the University of Oxford has produced a land systems map of Western Kenya extending from Kitui in the East to the Uganda border in the West and from Kenya's southern to northern borders. The most common general soil type which will be encountered in the RAR programme is the 'red coffee' clay represented by five of the soils from Nyeri shown in Table 10. These soils are considerably stronger and easier to handle than their classification as clays would suggest. Some types can hold unusually large quantities of water and retain their strength. They also give little trouble as a result of shrinkage or expansion. To quote reference 3 'the fact that they possess a natural structure suggests that heavy compaction is not necessary to reduce settlement in embankments or to produce strong subgrades'. Other clay soils which are expansive such as the blacker clays encountered in some areas are likely to cause more problems, and studies are at present underway to determine how best to construct a rural access road in such material. It is inevitable that the majority of roads will be built on clay subgrades because one of the main purposes of the RAR programme is to provide all weather access for agricultural products and much of the evaluation of proposed roads is centred around the potential increases in agricultural output in the area surrounding the road. As a result the roads are most likely to be built on fertile subgrades which are generally clays or sandy clays. Few roads are likely to be built through good natural roadmaking material such as the soil represented by parts of road 36. Roads made in the sandy soils respresented by the soils from the coastal areas can often be left ungravelled and can provide all weather access for 365 days in the year. Occasionally these sandy soils contain insufficient fines to bind together to produce a durable shape and vehicles are unable to pass in the dry season, but to date this has occurred on only one short stretch of road and it can be easily corrected. The opposite problem occurs when the sand contains too much binder and tends to behave more like a clay soil when wet. Areas with too much binder are easily located during the rain and decisions can be made about which parts of the road to gravel at that time.

Probably the most serious problems are likely to occur in sandy silty soils with little clay binder in hilly areas of high rainfall. Here serious erosion can and does occur very quickly, and methods of design may have to be varied to take this into account.

4.3.2 Gravels. Few roads had been gravelled at the time of the survey but it has become clear in some areas that the location of suitable gravels near to a road project is difficult. Table 11 shows the properties of a representative sample of gravels. Three of the gravels are outside the preferred Ministry specification, though they are just inside the limiting specification. These gravels are unlikely to provide an all weather surface. Two reports have been produced concerning the location of suitable gravels in the coastal and the central areas[5,6].

4.3.3 Soil strength. The effective soil strength of a sealed pavement varies relatively slowly from season to season and variations are normally small, hence a single value of soil strength is usually sufficient to characterise the material. In climates which undergo freezing and thawing cycles this is not true but nevertheless the changes in strength under a sealed pavement are much less rapid than in an unsealed pavement. The effective strength of an unsealed pavement varies daily depending on the moisture content, and this in turn depends on the rainfall and the drying periods. Much work on the trafficability of soils has been done by the Waterways Experimental Station[7]. It can be shown from the results[8] that if a road exhibits a California Bearing Ratio greater than about 12 per cent it should be capable of supporting the passage of over 50,000 vehicles with tyre pressures of 50 Newtons/cm^2 and with axle loads of 8.2 metric tonnes.

The failure criteria chosen for this analysis was a rut depth of 50 to 76 mm. This bearing capacity is therefore more than adequate for rural access roads where traffic is likely to be less than 25 vehicles per day and axle loads and tyre pressures are likely to be much less than those used in this example. During the inventory survey in-situ bearing capacity measurements were made on a selection of roads and these are shown in Table 12. These figures represent typical conditions and it is clear that in such conditions the roads have adequate bearing capacities. The trafficability and bearing capacities of the roads will, of course, be very much less during wet weather and it is part of the future research programme of the TRRL to obtain some measure of the trafficability of the roads in the wet season.

4.4 Drainage structures

The time taken from the initial setting out of a road to its final completion is normally over one year hence it is relatively easy for the overseers and inspectors to locate all the places on a road where culverts, drifts, and other drainage facilities such as mitre drains should be constructed. Any problem areas which are not spotted in the early stages can easily be corrected later. The need for culverts and mitre drains varies enormously between one road and another. To illustrate this Table 13 shows the number and frequency of culverts and mitre drains on a selection of roads. During the inventory survey it was not possible to check whether additional culverts or mitre drains were needed because the weather was dry but subsequently field trips have indicated that on virtually all roads culverts are being placed where necessary. It would however, be worthwhile for the maintenance inspectors to check the slopes of mitre drains occasionally and to instruct the maintenance men to correct the slopes as required.

5. EXTERNAL FACTORS

5.1 Climate

Kenya is well supplied with meteorological stations in most of the areas of interest hence reliable average climatic data are available. In the areas covered by this inventory the expected average rainfall is as follows:-

South Nyanza 1000- 2000 mm

Nyeri	800- 1400 mm
West Pokot	600- 1200 mm
Kwale	600- 1200 mm

Information on the intensity of rainfall is less plentiful, but it is known that in most areas a storm giving 25 mm of rain in one hour is likely to occur about three or four times per year. Within each area large differences occur as shown in the rainfall maps published by the East African Meteorology Department[9]. To correlate road performance with rainfall it is necessary to obtain data from a rainfall station which is preferably next to the road and certainly within 5 kilometres. In many areas this is possible and such data is being collected regularly. It should be noted that the general opinion is that 1977 and 1978 have been extremely wet years for rainfall in most areas of Kenya. The rainfall figures for each station are not yet available but if the general opinion is confirmed then it will be unlikely that any more severe damage to rural access roads as a result of rainfall alone is likely to occur in the future than has occurred in these two years.

5.2 Traffic

Regular traffic counts have been made by the RAR engineers which have been supplemented by the TRRL counts. The traffic levels are, as expected, very low, although on some roads quite large numbers of pedal bicycles have been recorded. The natural variability of traffic flows throughout the week, month and year make the results of the counts extremely unreliable for predicting average or annual flows. It has been shown that on rural roads errors of 50 per cent are to be expected in estimating the average daily traffic from a five day count on roads carrying less than 25 per day. This error can be considerably reduced if counts are conducted during months where minimum sampling errors are to be expected (see reference 10) however this is not usually known. Generally the rainy months would give low results and months where major crops are harvested would give high results. From reference 10 June appears to be the best month but this can vary from year to year, being affected by the changing weather patterns. Table 14 is a summary of some of the traffic counts conducted since 1975.

6. SUMMARY

It is inevitable that however earth and gravel roads are constructed and maintained they are unlikely to meet the original design specifications over the total length of road at all times. An inventory study such as this, which has been designed to quantify the extent to which the standards achieved differ from the specifications, has rarely been undertaken in such detail before hence it is impossible to make comparisons between the standards of the Rural Access Roads and the standards of road built under other techniques. However it is believed that if such a comparison were made the standards achieved and maintained in the RAR programme would compare favourably with other programmes. One of the main reasons for this is the maintenance system that has been adopted. The system gives responsibility for the maintenance of a short stretch of road (1.5-2.0 kilometres) to one man living near the road. This maintenance man is expected to work on the road for about ten days every month and the result is that any local deterioration can be rectified almost at once before it is serious. Another reason is that the time between beginning the construction and finishing the gravelling is longer than one year hence the road experiences one or more rainy periods before gravelling. If any problems arise during this time they are corrected before gravelling.

Nevertheless the inventory has shown that more careful supervision of the construction and maintenance procedures could improve the roads considerably with little extra effort. Two examples are discussed briefly. The first is the low values of camber observed almost everywhere and the second is the shallow drainage ditches. It is inevitable that some reshaping of the road will be necessary as a new road settles down under traffic and climate. Unfortunately it is very difficult to judge slope and camber by eye hence it is important for overseers to use camber boards to check the shape and correct it if necessary. To this end some light portable camber boards are now being designed by the Technology Unit and these will be field tested shortly. The shallow drainage ditches are both the result of the construction itself and the slow filling of the ditch after the road is completed. The maintenance man generally does not notice the gradual filling of the ditches until they are very shallow, and by then it is a more difficult task to correct the fault. If the depth is checked regularly both before the road is finally completed and during maintenance inspections it will be easier to keep the ditches closer to the specifications and will also help to improve the camber and effective width of the road.

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TABLE 1

Details of roads included in the inventory

Road number	Principal soil type	Terrain	Gravelled or not?	Age of road in years
1	Red Clay	Mainly flat	No	1 - 2
2	Red Clay	Mainly flat	No	1 - 2
3	Red Clay	Mainly flat	No	1 - 2
4	Clay	Rolling	No	1 - 2
5	Red Clay	Rolling	No	2 - 3
6	Clay	Flat	Yes	1 - 2
7	Clay	Mainly flat	Yes	1 - 2
8	Clay	Mainly flat	Yes	1 - 2
9	Clay	Flat	Yes	1 - 2
10	Clay	Flat	Yes	1 - 2
11	Red Clay	Hilly	Yes	1 - 2
12	Red Clay	Flat	Yes	>3
13	Red Clay	Rolling	Yes	>3
14	Clay	Rolling	Yes	>3
15	Red Clay	Hilly	Yes	>3
16	Clay	Hilly	Yes	>3
17	Sand	Flat	No	1 - 2
18	Sand	Rolling	No	2 - 3
19	Sand	Rolling	No	1 - 2
20	Sand/Clay	Rolling	No	1 - 2
21	Sand	Flat	Partly	1 - 2
22	Sand	Flat	Partly	2 - 3
23	Sand	Flat	Partly	2 - 3
24	Silty Sand	Flat	Partly	2 - 3
25	Silty Sand	Flat	Partly	1 - 2
26	Sand	Rolling	Partly	2 - 3
27	Silty Sand	Flat	Yes	1 - 2
28	Sand/Clay	Rolling	No	1 - 2
29	Sand/Clay	Hilly	No	1 - 2
30	Sand/Clay	Hilly	No	2 - 3
31	Sand/Clay	Hilly	No	2 - 3
32	Sand/Clay	Hilly	Partly	1 - 2
33	Sand/Clay	Hilly	Yes	1 - 2
34	Sand	Hilly	Yes	1 - 2
35	Gravel/Sand	Rolling	No	3
36	Gravel/Sand/Clay	Flat	No	2 - 3
37	Gravel/Sand/Clay	Flat	No	2 - 3
38	Sand/Clay	Hilly	No	>3

TABLE 2

Location of the roads included in the inventory

Road number	Area	Rainfall (mm)	Length surveyed (kilometres)
1	Kirinyaga	1200	6.2
2	Kirinyaga	1200	5.2
3	Kirinyaga	1000	5.2
4	Kwale	1000	5.0
5	Nyeri	1400	5.2
6	Kirinyaga	1200	4.6
7	Kwale	800	4.0
8	Trans Nzoia	800	5.0
9	South Nyanza	1200	10.0
10	South Nyanza	1400	5.0
11	Nyeri	1200	3.4
12	Nyeri	1200	5.2
13	Nyeri	1000	4.2
14	Nyeri	1400	4.2
15	Nyeri	1200	3.5
16	Nyeri	1000	3.5
17	Kwale	1000	4.0
18	Kwale	1200	5.2
19	Kwale	1200	5.2
20	Kwale	1200	4.6
21	Kwale	1000	5.2
22	Kwale	1200	5.2
23	Kwale	1200	5.2
24	West Pokot	600	5.2
25	West Pokot	800	10.0
26	Kwale	1000	9.0
27	West Pokot	600	5.0
28	Kwale	1200	2.8
29	Nyeri	1200	5.2
30	Nyeri	1200	2.8
31	Nyeri	1200	3.4
32	Trans Nzoia	1000	13.0
33	Trans Nzoia	1200	5.0
34	Kwale	1000	2.6
35	Kwale	1000	3.0
36	South Nyanza	1400	10.0
37	South Nyanza	1400	5.0
38	West Pokot	1200	8.0

TABLE 3

Design standards

A) CARRIAGEWAY		
WIDTH OF RUNNING SURFACE	ORIGINAL	CURRENT
Standard formation	4.00m	4.00m
Side cut	4.00m	4.00m
Embankment	4.00m	4.00m
SHOULDER		
Standard formation	2x0.75m(1.00m) [a]	2x0.25m,(1.00m) [b]
Side cut	2x0.75m(1.00m)	2x0.25m(2x1.00m)
		0.25,1.00m(2x1.00m) [c]
Embankment	2 x 1.00m	2 x 1.00m
SIDE DRAIN		
Standard formation	2 x 1.00m	2 x 1.40m
Side cut	1 x 1.00m	1 x 1.40m
TOTAL WIDTH		
Standard formation	7.50m (8.00m)	7.30m (8.80m)
Side cut	6.50m (7.00m)	5.90m (7.40m)
Embankment	6.00m	6.00m
Camber of running surface	4 to 5%	5 to 7%
Camber of shoulder	10%	none
Width of gravel course	4.00m	4.00m
Depth of compacted gravel	100-150mm	100-150mm
Depth of side drain below horizontal excavated level	300mm	300mm
B) ALIGNMENT		
Absolute maximum longitudinal gradient	10 - 11%	12%
Maximum desirable longitudinal gradient	9%	8%
Minimum longitudinal gradient	1 - 2%	2%
Minimum radius of horizontal curvature	15m	15m
Minimum desirable radius of horizontal curvature	40m	30m

TABLE 3 continued overleaf

WIDTH OF RUNNING SURFACE	
C) DRAINAGE	
Minimum longitudinal gradient of side drains	2.0%
Maximum longitudinal gradient of side drains	5.0%
Steeper drains require scour checks, frequency placed mitre drains or culverts according to the terrain and gradient	
Minimum diameter of culvert pipes	0.45m
Minimum gradient	2.5%
Maximum gradient	5.0%

NOTES

a) Brackets indicate dimensions for traffic >30 vpd
b) Height of fill <1.00m
c) Height of fill >1.00m, height of cut <2.00m
If height of cut >2.0m different cross sections apply

TABLE 4

Constructed width between side-ditch centres

Road number	PERCENTAGE OF ROAD LENGTH IN WIDTH RANGE (METRES)							Mean (m)	Std Dev
	5.25-5.74	5.75-6.24	6.25-6.74	6.75-7.24	7.25-7.74	7.25-8.24	8.25		
1	-	-	53	47	-	-	-	6.8	0.3
2	5.5	11	22	39	22.5	-	-	6.8	0.6
3	-	11	28	39	5.5	5.5	11	7.1	0.9
4	-	-	-	45	55	-	-	7.3	0.2
6	-	8.5	43.5	35	4.5	8.5	-	6.8	0.5
7	-	-	12.5	87.5	-	-	-	6.9	0.3
8	-	-	4.5	-	68	23	4.5	7.6	0.4
9	-	2	62.5	33.5	2	-	-	6.7	0.2
10	-	-	41	59	-	-	-	6.8	0.2
13	-	-	-	6	50	37.5	6.5	7.8	0.4
17	-	-	14.5	71	14.5	-	-	7.0	0.2
18	-	-	-	82.5	17.5	-	-	7.1	0.2
19	-	-	9	50	36.5	4.5	-	7.2	0.4
20	-	-	9	82	9	-	-	7.0	0.2
21	-	-	7.5	27	65.5	-	-	7.3	0.3
22	-	15.5	27	38.5	15.5	-	3.5	6.9	0.7
23	-	-	11.5	73	11.5	4	-	7.1	0.3
24	4.5	-	9	68.5	13.5	4.5	-	6.9	0.4
25	-	-	6	44	40	8	2	7.3	0.4
27	-	-	4.5	78	17.5	-	-	7.0	0.2
36	-	-	38	32	9	4	17	7.2	0.8
37	-	8	40	32	20	-	-	6.8	0.4
38	6.5	13.5	3.5	23.5	16.5	20	16.5	7.3	0.9

TABLE 5

Width of effective running surface

Road number	Lower 25% less than (m)	Mean Width (metres)	Upper 25% more than (m)	Standard deviation
1	3.48	3.91	4.51	0.70
2	4.28	4.69	5.22	0.70
3	4.25	5.03	5.56	1.14
4	4.42	4.85	5.25	0.59
5	4.04	4.29	4.72	0.73
6	2.45	3.97	3.97	0.76
7	3.88	4.32	4.73	0.76
8	4.81	5.06	5.80	0.87
9	3.45	3.81	4.27	0.53
10	3.04	3.28	3.70	0.56
11	3.07	3.35	3.65	0.45
12	4.00	4.42	4.75	0.60
13	5.25	5.63	6.09	1.10
14	3.36	3.59	3.90	0.61
15	4.32	4.76	5.21	0.68
16	3.63	3.82	4.16	0.47
17	4.28	4.72	5.52	0.83
18	4.53	4.76	5.10	0.31
19	4.63	4.93	5.48	0.74
20	4,72	5.05	5.54	0.53
21	4.63	5.08	5.80	0.80
22	4.29	4.77	5.36	0.77
23	4.14	4.76	5.50	0.88
24	3.50	4.06	4.57	0.73
25	4.21	4.87	5.62	0.95
26	4.08	4.79	5.50	0.87
27	3.23	3.68	4.07	0.70
28	4.78	4.95	5.28	0.49
29	3.58	4.04	4.53	1.09
30	4.25	4.33	4.65	0.34
31	4.41	4.87	5.43	0.81
32	2.98	3.94	4.60	1.20
33	4.31	5.17	5.84	0.93
34	4.41	4.82	5.52	0.91
35	3.75	4.24	4.88	0.74
36	4.20	4.85	5.47	0.93
37	4.16	4.70	5.23	0.78
38	4.65	5.36	6.22	0.97

TABLE 6

Effective camber

Road number	Lower 25% less than (m)	Mean Width (metres)	Upper 25% more than (m)	Standard deviation
1	4.00	5.28	6.75	2.39
2	3.17	4.38	5.50	1.79
3	2.00	3.71	6.21	2.67
4	4.07	4.55	6.50	2.85
5	3.31	4.35	5.74	2.14
6	4.20	5.91	7.77	2.41
7	5.12	5.81	7.17	1.54
8	3.15	4.33	5.27	1.98
9	4.46	5.26	6.35	1.45
10	5.40	6.71	8.38	1.92
11	3.50	5.31	7.51	3.32
12	1.0	2.29	4.08	2.02
13	1.32	2.59	3.63	1.89
14	2.50	4.48	6.40	2.51
15	3.43	4.77	5.81	1.77
16	2.51	3.89	5.38	1.91
17	0.50	3.37	6.67	3.71
18	0.79	2.80	4.81	2.37
19	0.55	2.40	5.01	2.63
20	2.25	3.16	5.38	2.13
21	4.20	5.74	7.49	1.99
22	2.88	4.23	5.59	1.67
23	3.65	4.37	5.75	1.50
24	5.28	5.99	7.25	2.19
25	4.88	5.65	7.18	2.07
26	1.67	3.59	5.66	2.39
27	6.00	7.03	8.33	1.98
28	2.25	3.07	4.83	1.93
29	4.81	6.44	7.95	3.10
30	2.50	4.38	6.25	2.67
31	0.85	3.57	4.95	2.91
32	4.13	5.91	7.94	2.97
33	4.31	4.74	5.92	1.56
34	5.25	5.95	7.24	1.69
35	3.10	4.32	5.75	1.92
36	2.40	3.46	4.67	1.54
37	3.10	3.76	5.13	1.84
38	0.48	1.81	3.43	2.08

TABLE 7

Depth of drainage ditches

Road number	Lower 25% less than (m)	Mean (m)	Upper 25% more than (m)	Standard deviation (m)
1	0.36	0.45	0.52	0.14
2	0.25	0.33	0.39	0.11
3	0.25	0.33	0.43	0.14
4	0.35	0.44	0.53	0.13
5	0.16	0.24	0.29	0.13
6	0.42	0.51	0.58	0.14
7	0.33	0.41	0.49	0.10
8	0.41	0.52	0.62	0.17
9	0.26	0.47	0.56	0.16
10	0.49	0.56	0.64	0.11
11	-	-	-	-
12	0.21	0.32	0.40	0.16
13	0.31	0.38	0.45	0.16
14	0.15	0.40	0.48	0.21
15	0.28	0.39	0.48	0.14
16	0.15	0.25	0.35	0.10
17	0.26	0.33	0.38	0.08
18	0.28	0.35	0.40	0.13
19	0.23	0.31	0.37	0.09
20	0.23	0.32	0.42	0.12
21	0.26	0.34	0.40	0.09
22	0.25	0.32	0.39	0.08
23	0.23	0.30	0.37	0.08
24	0.34	0.44	0.55	0.13
25	0.28	0.37	0.45	0.11
26	0.28	0.36	0.52	0.15
27	0.42	0.51	0.60	0.17
28	0.31	0.41	0.51	0.15
29	0.26	0.50	0.72	0.26
30	-	-	-	-
31	0.34	0.43	0.51	0.14
32	0.22	0.39	0.55	0.21
33	0.21	0.31	0.40	0.12
34	0.24	0.34	0.41	0.11
35	0.37	0.52	0.75	0.22
36	0.24	0.37	0.47	0.17
37	0.26	0.39	0.51	0.17
38	0.17	0.29	0.38	0.17

TABLE 8

Depth and extent of rutting

Road number	% of road not rutted	% of road with ruts <10mm	% of road with ruts >10mm	% of road with ruts >30mm
1	75	22	3	0
2	44	40	16	4
3	23	27	50	15
4	25	25	50	16
5	23	23	54	8
6	48	48	4	0
7	70	15	15	0
8	64	20	16	4
9	60	22	18	0
10	91	7	2	0
11	53	17	30	12
12	8	23	69	26
13	5	36	59	18
14	38	14	48	18
15	47	32	21	0
16	39	27	34	11
17	10	5	85	37
18	8	23	69	34
19	8	19	73	42
20	13	17	70	33
21	58	23	19	0
22	12	46	42	23
23	15	15	70	37
24	69	15	16	0
25	66	22	12	2
26	9	20	71	39
27	73	15	12	4
28	21	35	44	14
29	62	15	23	8
30	36	14	50	14
31	30	29	51	23
32	58	24	18	12
33	8	50	42	4
34	28	43	29	0
35	19	37	44	6
36	12	41	47	10
37	27	42	31	8
38	10	18	72	40

TABLE 9

Gradients of rural access roads

Table shows percentage of road exhibiting each gradient

Road	Gradients (per cent)									Number of times 11% 100m exceeded
	0-1	1-3	3-5	5-7	7-9	9-11	11-13	13-15	15+	
5	15	23	14	20	9	11	3	2	2	2
13	32	26	27	0	3	0	7	2	4	1
14	28	27	15	9	9	8	3	0	1	0
15	20	40	24	2	10	3	0	0	0	0
16	24	36	9	4	6	10	7	4	0	2
18	19	31	13	16	15	3	1	1	0	0
22	43	29	10	5	5	5	2	0	0	0
23	59	33	5	2	1	0	0	0	0	0
24	10	16	29	10	13	6	4	6	6	N/A
26	13	30	26	16	8	3	2	1	1	3
30	5	6	8	15	14	25	15	10	2	2
31	6	10	13	11	8	15	20	4	12	3
32	8	18	8	13	14	18	13	5	3	2
35	15	27	37	15	3	3	0	0	0	0
36	15	36	19	18	11	1	0	0	0	0
37	22	30	33	14	0	0	0	0	0	0
38	14	21	21	6	14	14	7	1	2	4
39 (a)	1	11	4	4	8	15	25	14	17	3
40	5	12	8	9	11	30	13	4	8	4
41	16	45	17	12	3	4	2	1	0	0

(a) Two sections of this road exceeded 11% gradient are more than 0.5 km long.

TABLE 10

Representative natural subgrades

	Road No.	Fines %	Sand %	Gravel %	Liquid limit %	Plastic limit %	Plasticity Index	Shrinkage %	Casagrande classification
Coastal area	5	64	36	0	61	38	23	17.0	CH
	11	73	20	7	-	-	-	-	CH
	13	63	26	11	60	40	20	15.5	CH
	15	50	50	0	-	-	-	-	SF
	30	61	29	10	62	40	22	16.0	CH
	40(a)	60	29	11	64	38	26	15.5	CH
	40(b)	45	37	18	53	32	21	10.5	GF
Central area	7(a)	12	88	0	22	NP	-	0.5	SC
	7(b)	64	26	0	43	20	23	-	CI
	18	20	80	0	22	NP	-	-	SC
	22	45	55	0	36	18	18	-	SF
	23	8	92	0	22	NP	-	-	SC
	26	18	82	0	19	NP	-	1.0	SC
	41	28	72	0	30	14	16	-	SC
North West	25	28	62	10	24	NP	-	4.5	SC
Lake Victoria	36(a)	45	29	26	45	22	23	11.5	GF
	36(b)	52	46	2	39	21	18	12.0	SF
	37	57	41	2	41	22	19	13.0	SF

TABLE 11

Representative gravels

Road number	Fines %	Sand %	Gravel %	Liquid limit %	Plastic limit %	Plasticity index	Shrinkage %	Casagrande classifi- cation
7	15	35	50	23	NP	-	-	GC
15	36	31	33	65	42	23	-	GF
23	38	46	16	38	24	14	-	GF
26 1)	22	33	45	27	13	14	-	GC
2)	29	51	20	30	14	16	-	GC
35	14	26	60	27	14	13	-	GC
41	28	47	25	44	24	20	-	GC

TABLE 12

In-situ bearing capacities

Road number	Surface		75-100mm	Depth
	Moisture content %	CBR %	Moisture content %	CBR %
5(c)	20	30	24.5	20
13 1)	14	90	22	50
2)	12.5	90	22.5	25
15	12.5	60	16	55
30(b)	9.5	47	13	60
40 1)	16	50	15	60
2)	14	25	12	20
3)	11.5	47	19.5	30
18(a) 1)	5	15	4	37
2)	10.5	5	8.5	5
23 1)	7.8	15	6.3	50
2)	7.5	20	3.7	45
26	6	30	9	12
2)	5.5	15	6.5	10
41	7.0	35	6.5	50
36 1)	8	95	14	15
2)	8	90	15	15
37	11	10	15	5

Notes

(a) New road at the time of the survey. Material still quite loose.

(b) At 150mm depth the CBR was 50 and the moisture content was 13.5.

(c) After recent rain.

TABLE 13

Frequency of culverts and mitre drains

Road number	Number of culverts	Frequency No/Km	Number of mitre drains	Frequency No/Km
Central				
5	4	0.7		
14	27	6.8	N/A	
15	10	2.6		
16	10	1.9		
30	19	6.6		
31	9	2.6		
40	31	7.6		
42	5	1.8		
Coast				
18	4	0.6	115	16.9
22	3	0.6	74	15.4
23	9	0.9	110	11.3
26	35	2.5	81	5.8
35	24	4.4	55	10.0
41	11	2.8	N/A	N/A
North West				
24	6	0.5	N/A	N/A
25	7	1.0	N/A	N/A
32	3	0.5	120	20.0
38	19	1.9	N/A	N/A
Lake Victoria				
36	48	3.6	N/A	N/A
37	12	2.9	N/A	N/A

TABLE 14

Average daily traffic on a selection of rural access roads

Road number	Date	Private cars	Light goods	Medium + heavy goods	Matatus + buses	Pedal cycles	Other (b)	Total motorised
11	Aug 77	2.8	6.4	2.4	0.0	6.0	0.2	12
12	Sept 76	5.0	2.0	1.0	(C)	N/A	N/A	8
	Nov 76	2.0	5.0	5.0	5.0	5.0	0.0	17
	Aug 77	2.0	3.6	0.2	0.0	0.2	1.8	5.8
13	Sept 76	5.0	1.0	1.0	(C)	N/A	N/A	7
	Nov 76	3.0	3.0	1.0	5.0	8.0	2.0	12
	Aug 77	0.0	1.0	0.8	0.0	0.4	0.6	1.8
15	Sept 75	2.0	1.0	2.0	(C)	N/A	N/A	5.0
	Sept 76	4.0	1.0	1.0	(C)	N/A	N/A	6.0
	Nov 76	2.0	4.0	2.0	3.0	5.0	0.0	11
	Aug 77	10	12	2.8	0.0	10	5.8	25
23	July 77	5.8	3.8	3.2	7.6	23	2.0	20
26	Sept 76	0.0	6.0	2.0	0.0	9.0	5.0	8.0
	Nov 76	2.0	2.0	2.0	0.0	3.0	2.0	6.0
	July 77	3.6	6.8	3.0	0.0	7.6	0.0	13
35	Sept 76	2.0	3.0	4.0	0.0	10.0	0.0	9.0
	Nov 76	1.0	2.0	2.0	0.0	9.0	1.0	5.0
41	Nov 76	1.0	3.0	3.0	5.0	53	2.0	12
	July 77	3.0	2.6	2.0	3.0	20	0.0	11

Notes:
(a) Results recorded to two significant figures
(b) 'Others' are animal drawn carts and motorcycles
(c) Included with private cars, light goods or medium goods