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RESEARCH ARTICLE

HYDROLOGICAL IMPACTS ON THE MAINTENANCE AND REHABILITATION OF RURAL ROAD NETWORKS IN KENYA: THE CASE OF CHEPTIRET-KESSES ROAD, UASIN-GISHU DISTRICT

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ABSTRACT

The Kesses-Cheptiret road was upgraded mainly to link Moi University and the surrounding rich agricultural region to the outside world. The road is 13 km long and can be divided into two sections. Section one is class D road which links Kesses to Cheptiret and section B is the access road from Moi University to Kesses market. The latter section is generally in a good condition, but the former has 56 % and 44 % respectively; of it classified as poor and completely failed respectively. This section of the road has become a major challenge to the Road Authority in terms of its cost of rehabilitation and maintenance. This paper examines the main factors that have contributed to continued deterioration of section one of this road in spite of past attempts at annual routine and periodic maintenance. A number of data collection methods were used, ranging from the use of topographic maps, climatic and hydrological data and site inspection to in-depth interviews with selected groups of local road users. This paper proposes mitigation measures to be taken to restore the road to its intended condition and hence to improve economic welfare of the surrounding community.

INTRODUCTION

The Cheptiret-Kesses-Moi University road (D305 and D305A) shown in Figure 1 provides an important commercial link for development of Kesses and Cheptiret market centres. It opens up the interior of Wareng District and parts of Nandi South to the outside market for their produce via main trunk road (A104) which joins Nakuru and Eldoret municipalities. That trunk road also connects Kenya to Uganda, Rwanda, Burundi and other central African republics.

Local Importance

This road also serves an agriculturally rich region that supplies a substantial amount of food to the national food reserve. It also serves local market centres besides and national University.

Current Road Condition

Some sections of this road are in what can technically be described as poor and completely failed. In fact the road has innumerable failures in its pavement and even the subgrade thus giving a heavy toll to the users. The road that had bituminous overlay placed just recently and had most of its surfacing. It is now spotted with numerous potholes and depression in many sections. Travelling on this road is very inconveniencing due to poor riding quality of its surface. Motor vehicle owners frequently using this road incur increased costs on vehicle repairs and increased fuel consumption period. In addition, it takes longer time than usual in using this road to transport people and goods from point of origin to various destinations. Together these problems have increased the cost of doing business between the region served by the road and the outside world.

Funding for Road Maintenance

The problems with this road started soon after it was opened to traffic at the inception of Moi University in 1984. The worsening bad condition of this road depicts similar conditions observed elsewhere on Kenyan roads. It is imperative therefore, to consider higher budgetary allocations for routine and periodic maintenance of roads in this country. The current budgetary allocations seems in adequate in deed this has become a challenge to the government for instance the amount that has been estimated and periodic maintenance in road in Uasin Gishu district in 2003/2004 financial year was Ksh.2,856,000 but available static show that the amount provided for those activities that year was only Ksh. 562,985. Prolonged and continuous deterioration of Kenyan roads have therefore a long-term impact on the economic development of the country. It is important, therefore that the factors contributing to the constant breakdown of roads including Kesses-Cheptiret road must be identified and isolated to foster remedial action. In the past no efforts have been made to identify the technical and / or related anthropogenic causes of frequent and rapid deterioration of this road. Hence no meaningful recommendations have been generated to offer a

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lasting solution to this perennial problem. It is for that reason that there was motivation to conduct a study covering the Cheptiret-Kesses-Moi University Road (D305 and D305A respectively). The general objective of this study was to identify and isolate the key factor(s) that contributed to the frequent failure and rapid deterioration of the Moi University-Kesses-Cheptiret road. The final goal therefore would be to recommend a technically viable alternative to rehabilitation of this vital road.

METHODOLOGY

A number of methods were used to obtain the data and information needed for objective analysis of the above stated problem. The data which was needed for the road pavement was obtained through study of available records on construction of Moi University Kesses-Cheptiret road. The information on the initial construction materials, was also obtain from available records and visits to the existing material sites along the road alignment from where construction material was obtained. The road design plan used and construction techniques employed were conventional and information regarding them was accessed through literature review of the road design manual. The traffic flow was estimated through conduction of classified traffic count on this road. The information on hydrological aspects was obtained through relevant literature review and study of meteorological data of the locality through which the road passed. Study of road site conditions were also carried out. .

The Design Phase

The Cheptiret-Kesses – Moi University road is a single carriageway whose total width is 8 meters. The carriageway itself is 6 meters wide with 1 meter shoulder on either side. The road structure is a flexible pavement. The construction layers were made of locally occurring natural materials. Interviews carried among local road engineers and the neighboring community to the road alignment confirmed that the current road was constructed following the initial murram track alignment. No detailed design work was therefore carried out. Design and construction were done simultaneously based on 'rule of the thumb'. The reason for that was great urgency to link Moi University to the main trunk road (A104) with a bitumen standard road. In practice pavement failure can be contributed to various causes which include inadequate design, excessive wheel and poor construction techniques. It was not possible to point out any significance aspect of those factors which could be blamed on the failure of this road. This was due to the fact that the study had not considered the pavement performance of this road over a long period. In fact the Ministry of Roads did not have the relevant data to that effect regarding this road.

The Road Traffic

The study analysis worked under the assumption that the initial design of the road was based on an anticipated road traffic derived from the known facts of the day. In this study classified traffic count were carried out. The Average Daily Traffic (ADT) was calculated at 672 vehicles ranging from light goods vehicles to heavy goods vehicles. The light goods vehicles were 108, medium goods vehicle were 106 and only 3 heavy goods vehicles were observed. The calculated proportion of commercial vehicles in this particular ADT was 5.5%. This traffic estimation must be a build up of the traffic from the initial one at the time the road was opened to traffic after construction. The design data for the road in terms of cumulative number of standard axles was not available to us, but the observed level of traffic on this road did not suggest overloading of the pavement. However, this factor may be significant in the future as the number of high axle load vehicles increase.

Quality of the Construction Materials

The subgrade material was generally reddish brown clay derived from igneous rocks and their metamorphic derivatives. Those soils have low bearing capacities. Their California bearing ratio (CBR) was about 5% and unconfined compression strength (UCS) at maximum dry density and optimum moisture content is 1470kN/m^2 (Gichaga and Parker, 1988). The materials were mainly obtained from borrow pits along the road alignment. The road base was constructed of cement- stabilized laterites commonly known as murram. It was then overlain with bituminous road surfacing. Technically the materials used for the road construction had adequate engineering properties for the proposed road pavement. But at the time of this study cracks were observed on the road surface and in some section deep rutting and local settlement had occurred. Potholes had also developed for long section of the road. In other sections the road pavement had completely failed and vehicles were traveling on the subgrade. This damaged the subgrade extensively. The cracking of the road surface could be due to weakening of subgrade and ultimately roadbase. But in some sections they could be attributed to the ageing of the bitumen. Bitumen loses some of its volatiles due to photo-oxidation processes caused by sunlight radiation. When volatiles were lost bitumen became rigid and cracked when stressed. The cracks gradually widened as the road surface was being used by traffic. If left unattended these cracks allowed ingress of water into the pavement thus causing its weakening.

Hydrological Impact

The climate of the Uasin-Gishu plateau where the road is located has average annual rainfall of 1085mm.Thus surface runoff is high during rainy season. In addition subsurface water level generally appeared to be 4.5-6.0 meters below the ground surface in many sections along the road. Both the surface and subsurface water systems, particularly the seepage from high ground and surface run-offs could cause the deterioration of the road pavement if not taken care of.According to O'Flaherty (1974) water can enter or leave road pavement in many ways as shown in figure2. Indeed it was suspected that water entered and left the pavement and also the subgrade of this road as illustrated in figure 1. It was observed during site inspection that the access road connecting Moi University and Kesses market (D305A) was in a fairly good condition. Along this accesses road the ground gently slopes toward Kesses dam thus providing a relatively good natural water drainage system. There is also hard rock just below the ground surface and therefore the underground water table is very deep into the ground and could not reach the subgrade.

Road drainage

Many observations were made regarding the status of the road drainage at various points.

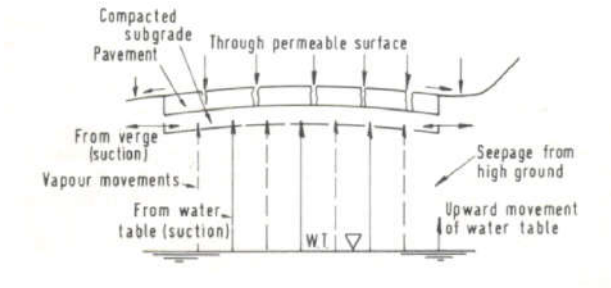

Fig. 1. Ways in which water can enter and leave road subgrades (After: O'Fl aherty, 1974)

The damage it caused to the road was also assessed accordingly. The key defects observed included silting up of side ditches and culverts as shown in plate 1. Due to silting up of those structures, the surface run-off could not flow directly to natural drainage systems as designed but flowed across on the road surface to those drainage systems. As it flowed across, the water therefore seeped through the cracked road surface into the pavement and to the subgrade causing instability of the road structure. Technically the water that percolates through road pavement to the subgrade increases moisture content of the road structure above that used during construction. This increase may particularly affect the subgrade adversely by reducing its ability to take the traffic loading distributed over it by the overlying pavement layers. This can result in disruption of the whole road structure.

Plate 1. Silted up culvert entrance along Kesses-Cheptiret Road

Pavement weakening could have been also caused by water reaching the subgrade through capillarity from high water table. This too could result in subgrade weakening and consequently make it overstressed, due to its reduced ability to take the intended traffic loading. The subgrade failure almost always gave rise to cracking and deterioration of riding quality of the road surface. The ingress of water into the pavement could have resulted in softening of roadbase leading to deep rutting and road surface cracking. That occurred despite the traffic using the road not being very heavy. Consequently the surfacing deteriorated further into potholes shown in plate 2.

If subgrade soil was very fine-grained material, longitudinal cracking of the pavement could subsequently occur. In case of the road understudy the verge including shoulders were permeable thus water reached road base and subgrade and caused damage.

Plate 2: Potholed section of Kesses-Cheptiret Road

The seepage of water from high ground to the subgrade causes softening of the subgrade and ultimately reduces its bearing capacity. With reduced bearing capacity, the subgrade may get overstressed when loaded and led to pavement failure. The failure may be in form of localized settlement of the pavement and caused extensive cracking of the road surface. It could also lead to pavement disintegration as illustrated in plate 3.

Plate 3: Completely failed road base along Kesses – Cheptiret Road

Soil Erosion

Soil erosion is the process whereby soil is loosened or dissolved and removed. In this study the concern was on removal of soil from road embankments, cuttings and drainage ditches by flowing water. The principle erosion determinants are the soil erodibility, climate, topography and vegetation.

There have been attempts by other researchers to combine these determinants into a "universal soil loss equation" which could be used to predict the soil loss due to rainfall. But the practical value of that equation for erosion associated with civil engineering works is limited. Thus it was not considered

in this study. The inherent susceptibility of soil to erosion is governed basically by its textural and gradation properties. Erodability is low in well graded gravels and cemented soils and high in uniform silts and fine sands. It is also a fact that erodability decreases with increasing clay and organic content of the soil. It also decreases with decreasing void ratio of the soil. A long this road soil erosion was not very severe. In fact the soil erosion that had taken place was not so much on the road structure as on the adjoining agricultural road. The soil erosion noticed was gully erosion that occurred at the edges of the road as shown in plate 4. In some sections deep gullies were noticed and shoulders were completely removed. The road embankments on this road are relatively low and of gentle slope. So, little soil erosion took place. Further more in most places the embankments have been covered with grown grass which resisted soil erosion and there were also no big cuttings that could have been eroded. The small ones which were observed appeared covered with vegetation too. For instance in some cuttings the soil was not severely eroded because it was held together by roots of big trees.

Plate 4. Eroded edge of the road along Kesses – Cheptiret Road at Kesses Centre

However, small rills could be seen on the exposed surface of the cutting. The drainage ditches along this road had silted up and became clogged up with debris and eventually became overgrown with vegetation. Vegetation growth therefore protected them from erosion. However, it was noticed that where side ditches entered cultivated private land erosion occurred. Also where the culvert was blocked and flow from the side ditch overtopped and went across the road, a certain amount of raveling took place. This was caused by abrasion of the road surface with the debris carried by flowing water. Besides, the surface run-off along the edges of the road, cattle crossing and vehicles moving on the edges of the road in an attempt to avoid potholes were some of the factors that led to wearing out of the road shoulders. The situation was aggravated when surface run-off flowed across the shoulders and down the slopes or through impact caused by raindrops or through dissolving action of water or a combination of them all.

Findings

The perpetual bad condition of this road adversely interfered with economic activities of its users. Thus many people affected by it were appealing for the situation to be reversed. But it was noticed that there was general inadequate funding of road maintenance activities by the concerned authorities. Thus road deteriorations were not arrested early enough which could have avoided requirements for huge sums of money. The rapid road failures occurring on the road understudy were mainly attributed to natural causes of weather and could be minimized if proper actions were taken in time.

Mitigation

- Install culverts of adequate size and lay them at suitable gradient.
- Provide a cambered and impervious road surface.
- Raise road embankment so that the road formation level is much greater than 600mm above the highest underground water table level..
- Repair damaged structures and institute regular maintenance programme.

Conclusion

The authorities responsible for road repair and maintenance failed to identify the real causes of this road's deterioration. Consequently no meaningful long-term remedial actions were taken. This resulted in permanent poor condition of this road. The main cause of the deterioration and subsequent failure of Moi University-Kesses – Cheptiret road was ingress of water into the road pavement. The rapid deterioration of the road mainly took place during rainy season. The condition of the road was so bad that reconstruction would be necessary especially for Kesses – Cheptiret section. Provision of properly designed road surfacing with sufficient camber will prevent ingress of surface run-off into road pavement. The raising of the road embankment particularly in flat areas would be necessary to avoid adverse effects of underground water on the subgrade. After reconstruction effective maintenance programmes should be put in place for arresting early signs of distress before the condition got out of control. The same can be said of other roads in this country in similar condition.

Recommendations

Further research is necessary in order to:-

i) Quantify different levels of drainage efficiency relative to the performance of the pavement.
ii) Review maintenance commitments and training need to ensure adequate performance.
iii) Find time – dependant benefit and cost ratios of acceptable subsurface drainage.
iv) Local communities need be included in road maintenance activities.

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