IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 18, Issue 5 Ser. II (Sep. – Oct. 2021), PP 58-69
www.iosrjournals.org

Evaluation of Asphalt Concrete Road - A case study of Voi - Maungu

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Abstract- *Road transportation system is considered as major component of the infrastructure in any country, it affects the developments in economy and social activities. Retention of acceptable serviceability and performance of asphalt concrete roads during the design life is highly dependent on long term monitoring of the road surface condition, and implementing the right decision to start the maintenance, and the right maintenance alternative at the right time. Asphalt Concrete Road is a multi-layer system that distributes the vehicular and pedestrian loads over a larger area. It helps to make them durable and able to withstand traffic and the environment. Pavement consists of three basic layers the first layer is Sub grade (Gravel) which is the foundation layer, the second layer is sub base (layer Assistant foundation) and the top layer is base (a layer of pavement) which consists of Bituminous Carpet + Bituminous Macadam. Roads are high-cost investments and need constant maintenance so that these investments continue to perform as required. Therefore, care must be taken to maintain the roads in optimum maintenance and in a scientific manner. This research paper describes assessment of Asphalt Concrete Roads (ACR) distresses; their causes and possible engineering solution to improve on its management. Visual inspection and walk through techniques for evaluating Asphalt Concrete roads surface condition along the 28Km stretch Voi to Maungu, questionnaires and interviews will be utilised to achieve this. The findings of this research will be very instrumental as it will be key in Distress Management (DM), as it provides data showing most to least distresses in asphalt concrete roads, their causes, and possible engineering solution more so distresses intensity and severity will be identified hence present condition rating index (PCRI) of the road surface determined.*

Key words – *Asphalt Concrete Roads (ACR), Distress Management (DM), Earth Moving Operations (EMO), Present Conditioning Rating (PCR), Crack, Pavement distress, road maintenance, Pavement deterioration, Hot Mix Asphalt (HMA)*

Date of Submission: 18-09-2021 Date of Acceptance: 03-10-2021

I. Introduction

Asphalt concrete roads are exposed to many distresses due to high stress on the surface hence causing various defects such as cracks and potholes. These distresses are nuisance to users as they results to discomfort, loss of life and where as the road transportation system is a major component of infrastructure in any country and are meant to deliver goods, people and services within acceptable costs in terms of comfort, time and safety. This is paramount and key as it affects the developments in economy and social activities Sarsam et al., (2014). Asphalt concrete roads needs proper maintenance as a result of over load, change in temperature, impact of climate (rains) and other factors. An asphalt concrete road distress as a result of various factors on the surface of the road requires maintenance immediately to maintain design surface life of the road.

Road maintenance is one of the important components of the entire road system. Even if the highways are well designed and constructed, they may require maintenance. Road maintenance is Necessary and required to protect the road in its originally constructed condition, protect adjacent resources and user safety, and provide efficient, convenient travel along the route. Unfortunately, maintenance is often neglected or improperly performed resulting in rapid deterioration of the road and eventual failure from both climatic and vehicle use impacts. It follows that it is impossible to build and use a road that requires no maintenance.

The specific objectives of the study would include:
To identify different types of distress in Voi- Maungu road.
To find out the different reasons that cause distresses in asphalt concrete roads.
To suggest possible Engineering solutions to various distresses·

Scope of Work:

This study is about Identification of Distresses in asphalt concrete road: Case Study on Voi - Maungu road. In this study the most frequently occurring types of distresses on Voi – Maungu road will be considered, by visiting the site and thorough examination will be analyzed. After which, the reasons which cause defects in the pavement are studied. Then the best maintenance option for each type of cracks and defects will be selected. In addition to that questionnaires will be used to collect data from road agencies on possible engineering solution on the defects for documentation purposes.

II. Literature Review

Al Harthy. S, (2017) explains that the pavement is constructed in multiple layers of different material. Choice of material depends on the wheel loads and design life and material availability local conditions. The road needs regular and periodic maintenance. Life of flexible pavement depends on external loads, environmental conditions and engineering properties of materials. Abubakar.S, (2016) found that some basic requirements of a pavement; it should be structurally sound enough to withstand the pressure on it. The thickness of the pavement should be sufficiently to distribute the stresses and load to a safe value on the subgrade soil. Zumrawi. M, (2015) suggested that in the pavement or embankment, water plays a primary role in giving shorter service life and in increasing the need of rehabilitation measures. The cracks allow moisture to enter in the pavement, allowing accelerated pavement degradation and this is the main problem. This leads to the gradual deterioration of the pavement structure in the neighborhood of the cracks. To determine the best maintenance option, it is necessary to include a variety of alternatives that may be possible from an initial examination of the conditions. These possible alternatives could be subject to a more detailed examination of economic, design and stress factors. Defame. A. & Ibrahim. A, (2015) concluded that the possible causes of failure may be due to insufficient drainage, bad design and construction, poor maintenance culture and others. It has been suggested that the rehabilitation should be completely redesigned after rehabilitation and redesigned, as well as the subsequent disbursement of the local government, which must be built with reinforced concrete, and the thickness of the asphalt is increased later. Nega. A., Nikraz. H., Herath. S. & Ghadimi. B, (2015) conclude that the level of tensile strain in asphalt concrete road depends on the temperature. Khaing.H. & Htwe.T, (2014) explain that for good system of highway the factors that cause road defects should be considered. Road maintenance is very crucial to enable movements of goods and services. If the maintenance system is weak, road defects will appear and the defects will be the main causes of accidents. So, to be a successful engineer, a person should not only able to design the road, but also skillful to maintain the road. The deterioration of pavement is not only as a result of poor design or construction but also it is caused by the inevitable wear and tear that occurs over years, variation in climate, increasing multi axle's vehicles and heavy traffic. The maintenance of asphalt pavements consists of routine activities and periodic activities. Routine activities include sanding, local sealing, crack sealing, filling depressions surface patching and bass patching. Periodic activities include surface dressing, fog spray and slurry seal, asphalt overlays and pavement reconstruction. The structural maintenance of the highway specified in this study is considered. Deflection and stress subjected on the highway are calculated by using structural characteristics of the asphalt concrete road. Sorum, N., Guite, T. & Martina, N, (2014) conducted a study on "Pavement Distress". Pavement design, the process of developing the most economical combination of pavement layers, it mainly deals with the design of mixtures of materials and the thickness of different paving layers. Tarawneh. S. & Sarireh. M, (2013) Emphasized that traffic loads and climate effects cause deterioration of the flexible pavements. This effect depends on the technology and materials that is used for road construction. Also the increase in moisture content decreases the strength of the pavement and the Poor drainage causes also pavement failure. On the same line, the pavement tends to cracks at some point in their life under the joint action of environment, traffic and climatic conditions. The identification of vehicle uses and applications (industrial transport) is the key to reducing road degradation. From above literature a gap has been created where by the researchers were interested in the causes of defects in road pavements not possible engineering solution. This research is intending to address this.

III. Methodology

The following tasks were carried out in order to achieve the research objective:

A. Select 4 km length of the road which will be under the Study to carry out survey VOI – MAUNGU Road.

- Divide the road into eight sections A, B, C, D, E,F, G, and H.
- The length for each section will be 500m.
- Notes taken by two methods.

i. By car "Taking Notes while driving".

ii. By visual inspection, the cracks and defects were identified and measured.B. Get knowledge
about the reasons which cause defects in the roads.

B. Through notes, reasons for causing defects will be selected.

- Through Literature reviews.
- By using questionnaires and interview.
- Traffic Volume Studies.

C. Possible Engineering solution will be suggested for asphalt concrete distresses identified.

Fig.1Voi-MaunguRoad

3.2 Information about Voi – Maungu Road

Voi – Maungu road is a stretch along Nairobi – Mombasa highway forming a component of northern corridor. The stretch lies in Taita Taveta County and it's about 29km length. The width of the road without shoulders is 618 cm. Voi – Maungu road is a service road, serving industrial and commercial areas, educational institutions and large residential communities and as a component of the Northern Transport Corridor which is an economic lifeline within East and Central Africa, linking the landlocked countries of Uganda, Rwanda and Burundi with Kenya's maritime port of Mombasa. It also serves eastern part of the Democratic Republic of Congo, Southern Sudan and northern Tanzania. The road moves more than 50 percent of all goods traded in the East African Community. Due to the volume of traffic, and the concentration of heavy-duty transport vehicles, the route is distress development-prone. Below is Figure 2. Showing section of Voi – Maungu Road.

Fig. 2: Section of Voi - Maungu Road

More so Figure 3. Below shows a section of Voi – Maungu Road.

Fig. 3: Voi - Maungu Road

3.3 Natural Material for Base and Sub Base

Base and Sub Base material are basic for road construction. This is the accumulation or deposition of ground materials, naturally derived from rock breakage or vegetation decay that can be easily drilled with field power equipment Constructing the road, physical properties of the soil must be determined. The supporting material beneath the pavement is called sub grade. Compacted sub grade is the gravel compacted by controlled movement of heavy compactors. There are many types of soils that are used in road construction; the best ones are derived from rock breakage but this type are expensive. In Kenya gravel is mostly used because is readily available. Table 1 below shows distress definitions for asphalt surfaced pavements.

Table 1. Distress Definitions for Asphalt Surfaced Pavements

No	Distress Type	Description
1	Fatigue cracking	Occurs in series subjected to repeated traffic loading
2	Block cracking	Interconnected cracks that divide the pavement up into rectangular blocks.
3	Longitudinal cracking	Cracks are predominantly parallel to the pavement's centerline
4	Patch deterioration	An area of pavement that has been replaced with new material to repair the existing pavement
5	Potholes	A hole in a road surfaces that result from gradual damage caused by traffic or weather.
6	Edge cracking	Applies only to pavements with unpaved shoulders, crescent shaped or fairly continuous cracks.
7	Transverse cracking	This distress has cracks that are predominantly perpendicular to the Centre line.
8	Rutting	Longitudinal surface depression in the wheel path.

9	Shoving	Longitudinal displacement of localized area of pavement.
10	Polished aggregate	Surface binder worn away to expose coarse aggregate.
11	Bleeding	Bituminous binder on pavement creating shiny, glass-like, reflective surface tacky to the touch. Usually found in the wheel paths.
12	Lane-to-shoulder drop-off	Typically occurs when the outside shoulder settles as a result of layer material differences.
13	Raveling	Wearing away of the pavement surface in high-quality hot mix asphalt concrete.
14	Reflection Cracking at Joints	Cracks in asphalt concrete overlay surfaces that occur over joints in concrete pavements.
15	Cracks in asphalt concrete overlay surfaces that occur over joints in concrete pavements.	Seeping or ejection of water from beneath the pavement through cracks. In some cases, detectable by deposits of fine material left on the pavement surface which were eroded (pumped) from the support layers and have stained the surface.

3.4 The Measurements

The following Table 2. Shows measurement taken along Voi – Maungu Road, and for purposes of this research paper only results for five segments will be represented for discussions.

Table 2. Measurements of Distress in Voi – Maungu road

Section	Type of Distress	Length (mm)	Width (mm)	Depth(mm)
A	Raveling	38500	2500	
	Bleeding	26800	3500	

Table 3. Measurements of Distress in Voi – Maungu road

Section	Type of Distress	Length (mm)	Width (mm)	Depth(mm)
B	Raveling	36750	2400	
	Bleeding	37400	2500	
	Block cracking	200	3	
	Transverse Cracking	1500	2	

Table 7. Measurements of Distress in Voi – Maungu road

Section	Type of Distress	Length (mm)	Width (mm)	Depth(mm)
F	Raveling	47436	1300	
	Bleeding	48574	1700	
	Transverse cracking	2000	2	

Table 8. Measurements of Distress in Voi – Maungu road

Section	Type of Distress	Length (mm)	Width (mm)	Depth(mm)
G	Patching	865	405	

Table 9. Measurements of Distress in Voi – Maungu road

Section	Type of Distress	Length (mm)	Width (mm)	Depth (mm)
H	Patching	940	543	

Table 4. Measurements of Distress in Voi – Maungu road

Section	Type of Distress	Length (mm)	Width (mm)	Depth (mm)
C	Raveling	45950	3150	
	Bleeding	37650	1700	

Table 5. Measurements of Distress in Voi – Maungu road

Section	Type of Distress	Length (mm)	Width (mm)	Depth(mm)
D	Raveling	38680	2400	
	Bleeding	35460	3500	
	Transverse cracking	1500	2	

Table 6. Measurements of Distress in Voi – Maungu road

Section	Type of Distress	Length (mm)	Width (mm)	Depth(mm)
E	Raveling	47436	1300	
	Bleeding	48574	1700	
	Transverse cracking	2000	3	
	Patching	815	645	

3.5 Survey Instrument Design

A questionnaire to capture data on distress Asphalt Concrete Roads prevalence in Kenya, their causes and Possible engineering solutions was designed and circulated amongst the road agencies in Kenya. For purposes of this research the extract of the questionnaires on distresses in Asphalt Concrete Roads prevalence in Kenya is attached as an appendix 1.

3.6 Target Population

This was as tabulated in Table 10 below;

Table 10. Target population distribution.

Institution	Number of agencies	% Of target population
Kenya Rural Roads Authority	47	70%
KeNHA	10	15%
KURA	10	15%
Total	67	100%

Key: Kenya Urban Roads Authority (KURA), Kenya National Highway Authority (KeNHA)

3.7 Method of data analysis from questionnaire

The data are processed through the following methods:

- *Frequency tabulation*: This is used to express prevalence of distress in Asphalt Concrete Roads. It is computed by capturing the frequency of distress per respondent and later getting the summation of individual frequencies per distress among the total correspondents and then later rank the distresses based on frequencies from highest to lowest.

4.1. Data Analysis and Discussion

4.2. Introduction

This part of the research deals with the analysis and discussion of the data gathered from Voi - Maungu Asphalt Road and the questionnaire survey.

It includes the identification of the distresses along the Voi - Maungu road and more so capture their causes and possible engineering solution through literature review and questionnaires. The questionnaire gave each respondent an opportunity to identify the prevalence of distresses in asphalt concrete roads, their causes and possible engineering solution. Kenya and give possible Engineering actor that was likely

4.3. Common types of distresses in Voi Maungu Road:

The Voi - Maungu road was most recently recarpeted before this exercise and generally the condition of the road is very good let's for few distresses as follows, their possible causes, severity index and Possible engineering solution.

a. Raveling

Raveling is loss of material that covered asphalt surface or is the progressive disintegration of HMA layer as a result of the dislodgement of aggregate particles. These defects indicate that asphalt materials may be hardness or the asphalt mixture that was used is poor as shown in Figure 4 below.

Figure 4. Raveling

i. Severity Levels

Not applicable. The presence of raveling indicates potential mixture related performance problems. Extent is sufficient to monitor any progression. (Paul, T., 2003.)

Table 11. Severity Levels in Raveling

Section	Type of Distress	Length (mm)	Width (mm)	Severity levels
A	Bleeding	26800	3500	Not Applicable
B		37400	2500	
C		37650	1700	
D		35460	3500	
E		48574	1700	
F		48574	1700	

ii. Possible Causes

The possible Causes of raveling are Heavy traffic volume (in Voi– Maungu road they are many types of vehicles), the emission of hydrocarbons from vehicles engines (hydrocarbons act as solvents for asphalt), water (Lack of drainage causes water pooling; Water permeates the layers through the blanks) and Inadequate compaction during construction (High density is required to develop sufficient cohesion within the HMA).

Possible Engineering Solutions

For small raveled areas, which centered areas of raveling (section F), Remove the raveled pavement and patch. For large raveled areas (section A, B, C, D and E) indicative of general HMA failure, Remove the damaged pavement and overlay.

b. Bleeding

Excess bituminous binder occurring on the pavement surface, usually found in the wheel paths. May range from a surface discolored relative to the remainder of the pavement, to a surface that is losing surface texture because of excess asphalt, to a condition where the aggregate may be obscured by excess asphalt possibly with a shiny, glass- like, reflective surface that may be tacky to the touch.

Figure5.Bleeding

Severity Levels

Not applicable. The presence of bleeding indicates potential mixture related performance problems. Extent is sufficient to monitor any progression. Table 12 shows severity levels in bleeding.

Table 12. Severity levels in Bleeding

Section	Type of Distress	Length (mm)	Width (mm)	Severity levels
A	Ravelir g	2500	38500	Not Applicable
B		36750	2400	
C		45950	3150	
D		38680	2400	
E		47436	1300	
F		2500	1500	

ii. Causes of Bleeding

Bleeding occurs when Asphalt binder fills the aggregate voids during hot weather and then expands onto the pavement surface. Since bleeding is not reversible during cold weather, asphalt binder will accumulate on the pavement surface over time. One or a combination of the following can cause this:

a) Excessive asphalt binder in the HMA (either due to mix design or manufacturing)
b) Excessive application of asphalt binder during BST application (as in the above figures)
c) Low HMA air void content (e.g., not enough room for the asphalt to expand into during hot weather)

iii. Possible Engineering Solutions

The following repair measures may eliminate or reduce the asphalt binder film on the pavement's surface but may not correct the underlying problem that caused the bleeding:

- Minor bleeding can often be corrected by applying coarse sand to blot up the excess asphalt binder.
- Major bleeding can be corrected by cutting off excess asphalt with a motor grader or removing it with a heater planer. If the resulting surface is excessively rough, resurfacing may be necessary (APAI, no date given).

c. Block cracking

Block cracking is overlapping cracks that divide the pavement into rectangular or square pieces. The area of the block range from about 0.1 m2 to 9 m2. Large blocks are classified as transverse or longitudinal cracking. The difference between the Block cracking and Alligator/Fatigue Cracking is that the Alligator Cracking is small pieces and located in the wheel path but the Block cracking is located everywhere on the pavement. The figure below shows the block cracks and levels of intensity:

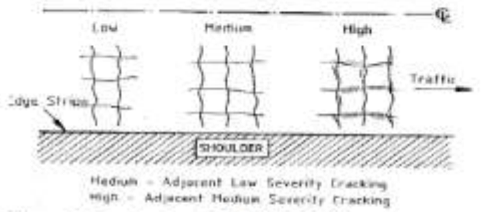

Figure 6: Severity Levels [Paul, T, 2003]

i. Severity Levels

Low: Cracks with mean width ≤ 6 millimeters (mm). Moderate: Cracks with mean width > 6 mm and ≤ 19 mm. High: Cracks with a mean width > 19 mm.

Table 13. Severity levels in Block cracking

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
C	Block cracking	2000	3	Low

iii. Possible Causes

The main cause of these cracks is the heat shrinkage of asphalt materials, due to stress. The appearance of these cracks also indicates the hardening of the asphalt. Also weak asphalt makes the appearance of cracking faster.

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
E	Patching	815	645	Low
G		865	405	Moderate
H		940	543	High

iii. Possible Engineering Solutions

The block crack in section C has low severity level and they need to be treated with Crack seal (fill the crack) to prevent moisture entering into subgrade through the cracks.

d. Transverse Cracking

The longitudinal cracks are parallel slits to the pavement's centerline; these cracks are structural defects (weakness of paving layer) and Functional defects (roughness of the paving surface). The loads and moisture accelerate the deterioration of these cracks.

i. Severity Levels

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
B	Transverse Cracking	1500	2	Low
D		1500	2	
E		2000	3	
F		2000	2	

Low: Cracks with mean width ≤ 6 millimeters (mm).
Moderate: Cracks with mean width > 6 mm and ≤ 19 mm.
High: Cracks with a mean width > 19 mm.

Table 14. Severity levels in Bleeding

ii. Possible Causes

Weak joint construction or location: The joints are usually the least dense areas in the pavement. Therefore, the joint should be constructed outside of wheel path so that it is loaded only irregularly. Shrinkage of the asphalt layer due to temperature change or hardening of asphalt: During casting asphalt (the temperature must be more than 140 °C). Also the possible Causes is the thickness of the asphalt layer is Insufficient (found that the road thickness is 55 mm).

iii. Possible Engineering Solutions

The longitudinal cracking in sections B, D, E and F are low severity levels. So, the suggested maintenance is Crack seal (fill the crack) to prevent moisture entering into subgrade through the cracks. Provide side drainage ditches to reduce cracking.

e. Patching

Patching is a part of the pavement surface that have been removed and replaced with additional materials applied to the pavement after the original construction. Some of defects that can treat by patching are longitudinal cracks, pothole, edge cracking and others of defects. If the patching is inappropriate it will affect into vehicle wheels. In fact, patching is a defect in itself, even if it is performed well.

i. Severity Levels

Low: Patch has; at most, low severity distress and Low impact on driving quality.
Moderate: Patch has moderate severity distress and moderate impact on driving quality.
High: Patch has high severity distress of any type including rutting and high impact on driving quality.

Table 15. Severity levels in Bleeding

ii. Possible Causes

Possible causes of faulty patching are excessive traffic poor quality of materials that are used to construction and poor implementation of asphalt.

iii. Possible Engineering Solutions

Cut and reconstruct. Care must be taken in dealing with the maintenance procedures used in the treatment of any previous defects.

4.4. Distresses causes and possible solutions as captured by questionnaires

This part of the research deals with the analysis and discussion of the data gathered from the questionnaire survey. It includes the identification of the frequency and severity of distresses in Asphalt Concrete roads in Kenya. The questionnaire gave each respondent an opportunity to identify the common types of distresses in asphalt concrete roads, causes and possible Engineering solutions. The respondents were given possible distresses in Asphalt Concrete roads.

4.5. Characteristics of Respondents

To promote respondents and raise the response rate face-to- face delivery are preferred but other means were employed such as emails. A total of fifty questionnaires are sent into road gencies in Kenya and out of this only fourty two got a response from fifty.

4.6. Ranking of Distresses in Asphalt Concrete Roads

Ranking of distresses in terms of occurrence the most frequent distresses in asphalt concrete roads rankings causes and possible engineering solutions. Four different respondent groups rated these distresses. The more the distress frequently happens, the more it severely impacts the asphalt concrete roads. The distresses in asphalt concrete roads for purposes of this research only considered only ten distresses their severity characteristics if any, cause and possible engineering solutions. Table 16 shows the distress frequency in Kenya. It shows the popularity of distresses from highest to lowest ranked as number one to ten respectively.

The respondents gave out various causes of each distress in asphalt concrete roads, severity if any and possible engineering solutions. All these are summarized for each distress below.

Table 16: Distress frequency table

S/No	Distress	Frequency
1	Potholes	42
2	Rutting	33
3	Fatigue cracking	24
4	Bleeding	13
5	Longitudinal cracking	13
6	Edge cracking	11
7	Patch	12
8	Transverse cracking	4
9	Raveling	4
10	Polished aggregate	2

For purposes of this research the distresses captured in Voi Maungu road analysed above will not be re analysed, and are raveling, bleeding, block cracking, transverse cracking and patching. The remaining list of eight frequent distresses in asphalt concrete roads their causes and possible engineering solutions are as follows.

a. Potholes

Pothole is a hole in a road surfaces that penetrate the road through the HMA layer down to the base course. Potholes generally have sharp edges and vertical sides near the top of the hole. Normally the potholes occur on road that has the thickness less than 70mm.

i. Severity Levels

Low: the depth < 25 mm.

Moderate: the depth between 25 mm to 50 mm.

High: the depth > 50 mm.

ii. Possible causes

Generally, potholes are the end result of cracking. As alligator cracking becomes severe, the interconnected cracks create small chunks of pavement, which can be dislodged as vehicles drive over them. Also the possible causes of pothole are Weak spots in the base or subgrade, Poor surface mixtures, pavement surface have been dislodged, heavy traffic volume (traffic action accelerate potholes) and insufficient pavement thickness.

iii. Possible engineering solution

The suitable maintenance for pothole in section is patching. More so a pothole terminator method is used not commonly in Kenya. This is a sustainable, green, cost-effective long-term solution to potholes. Pothole Terminator is a way of binding crushed stone aggregates together into a load bearing cellular building unit. The Pothole Terminator unit can support compressive loads and resist lateral soil pressure.

b. Rutting

Asphalt rutting remains one of the leading forms of flexible pavement distress and is classified as a longitudinal surface depression located along the wheel path. There is no exact severity levels defined for this type of distress, instead measurements of surface depressions are used for analysis. These measurements are then classified as low, moderate and severe, and reflect which repair methods are applied. Rutting occurs in the wheel path as a permanent deformation impacting any pavement layers or subgrades. Consolidation or lateral movement of materials usually leads to rutting. Rutting shows up in wheel paths because traffic loads apply the most pressure here leading to reoccurring stress.

i. Severity Levels

Low: the depth < 6.5mm to 12.5mm

Moderate: the depth between 12.5 mm to 18.5 mm. High: the depth > 18.5 mm.

The extent of rutting is the full length of the segment in the wheel path. Measurements should be taken from as many locations as possible and then averaged out. If rutting becomes extreme the surrounding pavement layers can become raised. In most cases, rutting forms progressively right along the wheel path, and eventually reaches a maximum depth at the center of the path. These ruts are most notable post-rain because they fill up with water. Wear is another key term associated with rutting that refers to the surface depression of the wheel path, caused by tire abrasion.

ii. Types of rutting

There are two types of rutting: mix rutting and subgrade rutting.

Mix rutting results when the subgrade does not rut but the pavement surface shows depression marks in the wheel path as a result of compaction and/or mix design problems. Subgrade rutting is classified by the subgrade showing depression marks along the wheel path as a direct result of loading. As a result, the pavement settles into the subgrade ruts creating a sunken appearance in the wheel path.

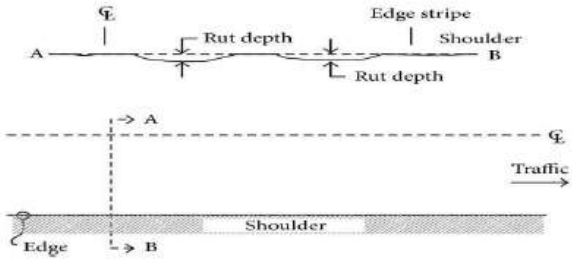

Figure 7: Schematic representation of rutting.

iii. Possible causes

Some common causes of asphalt rutting include: Improper compaction of HMA layers in the construction process may cause pavement to continually become denser when placed under the pressure of traffic loads. This is why proper construction techniques with adequate compaction remain fundamental to quality asphalt. A number of issues relating to the mix design or manufacture, such as excessive mineral filler, too high asphalt content or insufficient angular aggregate particles in the mix. The actual wearing away of surface particles due to consistent traffic. Inadequate pavement structure leading to subgrade rutting. Plastic deformation is when the material fails and the mix becomes displaced and tends to hump up along the outside of the wheel path. This occurs because the mix does not have the strength needed to hold up under constant stress imposed by loaded vehicle tires. In cold climates where it snows ruts are more likely to form due to studded snow tires. While damage remains the same, it is related to mechanical dislodging caused by wear and tear as opposed to pavement deformation.

iii. Possible engineering solutions

Some of the causes of rutting can be prevented with good construction practices, settlement will probably continue to play a part in causing rutting well into the future. Even with the breakthroughs in compaction technology, rutting will likely continue to be a challenge that engineers face into the future. With improved industry standards, quality control, and technology, the roads of the future might one day be, roads without ruts.

c. Fatigue cracking

A series of interconnected cracks caused by fatigue failure of the HMA surface under repeated traffic loading. As the number and magnitude of loads becomes too great, longitudinal cracks begin to form (usually in the wheel paths). After repeated loading, these longitudinal cracks connect forming many-sided sharp-angled pieces that develop into a pattern resembling the back of an alligator or crocodile.

i. Severity levels

Low: An area of cracks with no or only a few connecting cracks; cracks are not spalled or sealed; and pumping is not evident. Moderate: An area of interconnected cracks forming a complete pattern; cracks may be slightly spalled; cracks may be sealed; and pumping is not evident.

High: An area of moderately or severely spalled interconnected cracks forming a complete pattern; pieces may move when subjected to traffic; cracks may be sealed; and pumping may be evident.

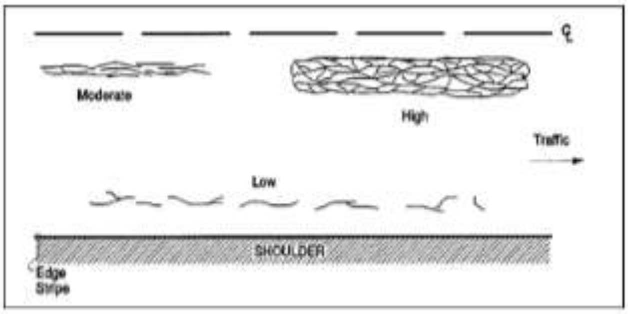

Figure 8: Fatigue cracking severity levels

iii. Possible causes
Inadequate structural support for the given loading, which can be caused by a myriad of things. A few of the more common ones are:
a. Decrease in pavement load supporting characteristics;
probably the most common reason is a loss of base, subcase or subgrade support from poor drainage, water under a pavement will generally cause the underlying materials to become weak and Stripping on the bottom of the HMA layer. The stripped depth contributes little to pavement strength so the effective HMA thickness decreases.
b. Increase in loading (i.e., the pavement is being loaded more heavily than anticipated in design)
c. Inadequate structural design (i.e., the pavement was designed too thin for the anticipated loads)
d. Poor construction (i.e., inadequate compaction)

iii. Possible engineering solutions
A fatigue-cracked pavement should be investigated to determine the root cause of failure. Any investigation should involve digging a pit or coring the pavement to determine the pavement's structural makeup as well as determining whether or not subsurface moisture is a contributing factor. Once the characteristic alligator pattern is apparent, repair by crack sealing is generally ineffective. Fatigue crack repair generally falls into one of two categories: Small, localized fatigue cracking indicative of a loss of subgrade support. Remove the cracked pavement area then dig out and replace the area of poor subgrade and improve the drainage of that area if necessary. Patch over the repaired subgrade and large fatigue cracked areas indicative of general structural failure. Place an HMA overlay over the entire pavement surface. This overlay must be strong enough structurally to carry the anticipated loading because the underlying fatigue cracked pavement most likely contributes little or no strength.

V. Conclusion

Asphalt concrete road deterioration is the process by which distress (defects) develop in the pavement under the combined effects of traffic loading and environmental conditions. There are various causes of defects in asphalt concrete roads amongst them are; poor construction quality, structural failure of base, poor highway facilities, Poor maintenance policy and poor supervision. Asphalt concrete roads deteriorate slowly after construction and handing over for use to be noticed, and over a period of time it accelerates faster hence there must be timely implementation of cost effective and sustainable maintenance and repair schedule which will the road segment sound to adequately meet its primary objective. Road maintenance is one of the important components of the entire road system. Even if the roads are well designed and constructed, they may require maintenance. Repair and maintenance procedures cannot overcome bad design problems but can help prevent these problems resulting from degradation. The most frequent distresses in asphalt concrete roads in Kenya are as follows in order of severity; Potholes, Rutting, Fatigue cracking, bleeding, longitudinal cracking, edge cracking, patching, transverse cracking and raveling, this was evident in both conditioning survey along the Voi – Maungu road and use of questionnaires. More over the and possible causes of distresses in asphalt concrete roads are firstly during implementation of road; Failure in the layers of the road (failure in Subgrade or other layers), the asphalt mixture arrival in the site is cold, the wrong way in the casting and compaction of asphalt and others. Secondly after implementation; Heat shrinkage of asphalt materials (change in temperatures and climate), High stress (Heavy traffic volume or increase vehicle weight), Lack of water drainage system and many more. Early detection and repair of road defects are important to maintain the permanence of road. The various distresses have various possible engineering solutions. For example, the raveling in Voi Maungu road; Raveling will entail removal of the damaged pavement and overlay. Bleeding; applying coarse sand to blot up the excess asphalt binder or cutting off excess asphalt with a motor grader or removing it with a heater planer. If the resulting surface is excessively rough, resurfacing may be necessary, use of pothole terminator for managing potholes, rutting can be prevented with good construction practices, settlement will probably continue to play a part in causing rutting well into the future and to minimize this information technology interventions is ideal and timely. For small fatigue cracking remove the cracked pavement area then dig out and replace the area of poor subgrade and improve the drainage of that area if necessary. Patch over the repaired subgrade and large fatigue cracked areas indicative of general structural failure. In addition to that weigh bridges should efficient and functional to avoid over loading the asphalt concrete roads. Road furnitures should be constructed as designed, for instances most of culverts along the Voi-Maungu road are not efficient as they are filled with soil and other solid material.

VI. Recommendations

Evaluation and assessment of road distresses is key and essential step in road segment maintenance and management. To minimize road distresses in Asphalt Concrete roads, during the construction or maintenance of the road, the road agencies must ensure the construction work is performed as per design specifications provided. More so construction of roads that has high traffic volume like the Voi – Maungu road the thickness of asphalt layer must be increased to more than 75mm. settlement is the most challenging issue in asphalt concrete distresses and contributes greatly to distress development, hence making it paramount to be monitored progressively for remedial measures to be under taken. Research should be done by infusing information technology to develop settlement model to assist in management of distress in concrete asphalt roads.

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