https://dx.doi.org/10.24001/ijaems.3.7.6 *ISSN: 2454-1311*

Evaluation of Flexible Pavement Failures-A Case Study on Izki Road

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Abstract— *Pavement is a multi-layer system that distributes the vehicular 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. Cracking of pavement is a defect that appears in the top layer of the road. Pavement can be under compression and tension at the same time, but in different directions. While a tire compresses a pavement downward, it forms a deflection basin which causes the pavement to go into tension in both horizontal directions. If the pavement is not strong enough, the asphalt is stretched too far, which separates and a crack forms in the wheel track. A crack may also form between the wheel tracks. The maintenance of roads means protecting, restoration and strengthening of all elements of the road to maintain sustainability of the road. Road maintenance also includes additional work that is necessary in order to raise the level of performance and reach the best level of safety and comfort for the road users. 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. The aim of this Study is to identify the most common types of cracks and defects which occur in Izki road and suggest suitable option for maintenance. The objectives are to identify different types of cracks & defects, to find out the different reasons that cause defects and cracks in Izki road and to suggest suitable maintenance methods. A 2km length of the road was selected for the study. Survey was carried out and the reasons for cracking and other failures in pavement were studied. Finally, the required maintenance solution for each type of failures was identified and the best maintenance option was selected.*

Keywords— Crack, Pavement distress, road maintenance, Pavement deterioration.

I. INTRODUCTION

The asphalt road is exposed to many distresses due to of the high stress on the pavement so it causes cracks and a lot of defects. These defects cause a lot of problems for road users such as discomfort and the road will not be safe. All kinds of pavement needs proper maintenance as a result of affected over load, temperature change rate, Impact of climate (rains) and others factor. If cracks occur on the surface of the road due to one of the factors affecting it, it requires maintenance work but sometimes the maintenance is expensive to treat cracks or to reconstruct.

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 cracks & defects in Izki road.
- To find out the different reasons that cause defects and cracks in Izki road.
- To suggest suitable maintenance methods.

Scope of Work*:*

This study is about the Identification of Defects and Cracks and Maintenance of roads: Case Study on Izki Road. In this study the most frequently occurring types of cracks and the defects on Izki 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,

https://dx.doi.org/10.24001/ijaems.3.7.6 *ISSN: 2454-1311*

the best maintenance option for each type of cracks and defects will be selected.

Literature Review

Khaing.H. & Htwe.T, (2014) explain that for good system of highway the factors that cause road degradation should be considered. Road maintenance is very important to traffic management. If the maintenance system is weak, road defects will appear and the defects will be the main causes of accidents and the road will be unsafe. So, to be a successful engineer, a person should not only able to design the road, but also skillful to maintain the road. Flexible pavement fails due to any one of the sub-grade failure, sub-base or base course failure and wearing course failure. The deterioration of pavement is not only the 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 consist 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. So, deflection and stress subjected on the highway are calculated by using structural characteristics of the 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. The pavement design consists mainly of two parts: (i) Design of mixture materials, to be used in each layer composed of pavement; (ii) Design of the pavement structure (Thickness design and type of different component layers). The main factors that be considered during pavement design are: climate, road geometry, traffic, and position, soil and drainage.

Nega. A., Nikraz. H., Herath. S. & Ghadimi. B, (2015) conclude that the level of tensile strain in asphalt depends on the temperature and can be considered this effect in terms of the effect of temperature on the hardness of the mix.

Tarawneh. S. & Sarireh. M, (2013) Emphasized that deteriorate of the flexible pavements caused by under traffic loads and climate effects. This effect depends on the technology and materials that used for road construction, but the biggest effects depend on traffic loads and volumes. 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. Knowledge of traffic volume and size (In particular for overload) contributes to road safety and can minimize the deterioration of the road. The author found that cracks, edge defects, drilling and slowness are important road defects. At the same time he stressed that traffic, age, engineering, road construction, climate, drainage and quality of materials used to construct the road, must be taken into account to design a good pavement. Road maintenance policy also plays a key role in road degradation.

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. The origin of the cracks varies in form, composition, loading capacity, movement and deformation rate. 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) conclude 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.

Abubakar.S, (2016) found the 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.

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.

II. METHODOLOGY

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

A. Select 2km length of the road which will be under the study to carry out survey.

- Divide the road into four sections A, B, C and D.
- The length for each section will be 0.5 km / 500m.
- Notes taken by two methods.

i. By car "Taking Notes while driving".

ii. By visual inspection, the cracks and defects were

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identified and measured.

B. Get knowledge about the reasons which cause defects in the roads.

- Through the notes, select the reasons which cause defects.
- Through the journals.
- Interviews.
- Traffic Volume Studies.

C. Select the best maintenance option.

- Best maintenance method will be suggested for each defects or cracks identified.

Fig.1: the sections selected for the study in Izki road

Information about Izki road

Izki Road is located in the province of the Ad-Dakhiliyah, Izki, which is about 123.5 km from the capital Muscat. It is estimated that the length of the road is about 35 km and its two way road. The width of the road without shoulders is 618 cm. Izki Road is a service road, serving industrial and commercial areas, educational institutions and large residential communities. The road has been constructed more than 10 years ago. The road has not received any major repairs or modifications except for "Patching" to some of the affected areas.

Fig 2: the traffic in Izke road

Fig 3: Izki road

Soil:

Soil is the basic material for road construction. Soil 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. Before constructing the road, physical properties of the soil must be determined. The supporting soil beneath the pavement is called sub grade. Compacted sub grade is the soil 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 municipal projects they used inexpensive soil such as wadi soil because it's available in Oman. The type of soil used in the construction of Izki road is wadi soil.

The most common types of defects and cracks are:

Table 1: type of distress

NO	Type of distress	Description
1	alligator cracking	Series of interconnected cracks caused by fatigue failure under repeated traffic loading
2	Block cracking	Interconnected cracks that divide the pavement up into rectangular blocks (approx. 0.1 m2 to 9 m2)
3	Longitudinal cracking	Cracks parallel to the pavement's centerline direction
4	Patching	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	Raveling	Asphalt raveling is the progressive disintegration of a hot mix asphalt layer from the surface downward as a result of the dislodgement of aggregate particles.

The Measurements (Based on the study and literature)

Table 2: Measurements of the distress in Izki road

Section	Type of distress	Length (mm)	Width (mm)	Depth (mm)
Section A	Longitudinal cracking	1958	5.7	
	Edge failure	2570		
	Patching	452	6180	
	Pothole	456		11.2
	Edge failure	1258		
	Raveling	1748	6180	

Section	Type of distress	Length (mm)	Width (mm)	Depth (mm)
Section B	Pothole	810		60
	Raveling	885	3090	
	Edge failure	1641		
	Pothole	295		45
	Longitudinal cracking	2065	13.1	
	Longitudinal cracking	1460	2.6	

https://dx.doi.org/10.24001/ijaems.3.7.6 *ISSN: 2454-1311*

Section	Type of distress	Length (mm)	Width (mm)	Depth (mm)
Section C	Longitudinal cracking	1657	5	
	Patching	570	150	
	Edge failure	610		
	Pothole	150		23.25
	Patching	963	6180	
	Block cracking	782	4.2	

Section	Type of distress	Length (mm)	Width (mm)	Depth (mm)
Section D	Pothole	470		40.5
	Longitudinal cracking	1040	4.4	
	Raveling	2540	6180	
	Edge failure	1315		
	Block cracking	1723	8.16	

(Based on field study)

The possible causes and suitable maintenance of the defects and cracks:

Alligator cracking:

Table 3: Alligator cracking

NO	Possible Causes	Suggested Treatment
1	Inadequate pavement thickness	Strengthen the pavement or reconstruction
2	Low modulus base	Strengthen the base or reconstruction
3	Poor base drainage	Improve the drainage and reconstruct
4	Brittle base	Base recycling or reconstruction

(Based on the study and literature)

Edge cracking:

Table 4: Edge cracking

NO	Possible Causes	Suggested Treatment
1	Inadequate pavement width	Widen the pavement
2	Seepage and heavy rainfall	Proper and efficient drainage
3	no shoulder	construct shoulders

(Based on the study and literature)

Longitudinal cracking:

Table 5: Longitudinal cracking

NO	Possible Causes	Suggested Treatment
1	Reflection of shrinkage cracks	Cut and patch
2	Displacement of joints at pavement widening	Reconstruction of joints

(Based on the study and literature)

Potholes:

Table 6: Potholes

NO	Possible Causes	Suggested Treatment
1	Loss of surface course due to heavy rainfall	Patching
2	Moisture entry to base course through a cracked pavement surface	Cut and patch

(Based on the study and literature)

Raveling:

Table 7: Raveling

NO	Possible Causes	Suggested Treatment
1	Insufficient bitumen content	Thin bituminous overlay
2	Deterioration of aggregate	Thin bituminous overlay
3	construction during wet weather	Thin bituminous overlay

(Based on the study and literature)

Patching:

Table 8: Patching

NO	Possible Causes	Suggested Treatment
1	Weak, loose layer immediately	Reconstruction of weak layers
2	Seepage of water through asphalt, especially in cracks, to break the bond between surface and lower layers.	Reconstruction of weak layers

(Based on the study and literature)

III. RESULTS AND DISCUSSIONS

Izki Road is located in Ad-Dakhiliyah, starts from Izki and ends at Nizwa. It is estimated that the length of the road is about 35 km and its two way road. The width of the road without shoulders is 618 cm. the thickness of asphalt is 55 mm. Izki Road is a service road, serving industrial and commercial areas, educational institutions and large residential communities. The road has been constructed since more than 10 years ago.

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Fig.4: Road thickness

The most common types of defects and cracks in Izki road:

1. 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 m^2 to 9 m^2. 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:

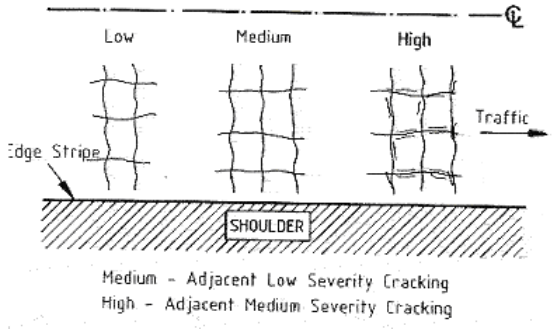

Fig.5: Severity Levels [Paul, T., 2003]

i. Severity Levels

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

Table 9: Severity Levels in Block cracking

Section	Type of distress	Length (mm)	Width (mm)	Severity Levels
Section C	Block cracking	782	4.2	Low
Section D		1723	8.16	Moderate

(Paul, T., 2003)

ii. 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

iii. Suggested maintenance methods

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

2. Longitudinal Cracks

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

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

Table 10: Severity Levels in Longitudinal cracking

Section	Type of distress	Length (mm)	Width (mm)	Severity Levels
Section A	Longitudinal cracking	1958	5.7	Low
Section B		2065	13.1	Moderate
		1460	2.6	Low
Section C		1657	5	Low
Section D		1040	4.4	Low

(Paul, T., 2003)

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).

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Fig.6: Longitudinal Cracks

iii. Suggested maintenance methods

The longitudinal cracking in section A, B, C and D 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.

3. Edge Cracking

Edges cracking generally are parallel to the edge of the pavement. The shape of cracks is crescent or fairly continuous cracks. Edge cracks are increased due to excess traffic loads.

Fig.7: Edge Cracking

i. Severity Levels

- Low: Cracks with no breakup or loss of material.
- Moderate: Cracks with some breakup and loss of material for up to 10% of the length of the affected portion of the pavement.
- High: Cracks with considerable breakup and loss of material for more than 10% of the length of the affected portion of the pavement.

Table 11: Severity Levels in Edge Cracking

Section	Type of distress	Length (mm)	Severity Levels
Section A	Edge Cracking	2570	Moderate
		1258	Low
Section B		1641	High
Section C		610	High
Section D		1315	Moderate

(Paul, T., 2003)

ii. Possible Causes

Edge cracks appear due to the weakness of the base or subgrade layer near the edge of the pavement, lack of lateral support, heavy traffic and Poor drainage.

iii. Suggested maintenance methods

Improve drainage. Remove vegetation close to edge. Reconstruct of the edge and support the edge with paving stones.

4. 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.

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)

Fig.8: Raveling

Table 12: Severity Levels in Raveling

Section	Type of distress	Length (mm)	Width (mm)	Severity Levels
Section A	Raveling	1748	618	Not applicable
Section B		885	309	
Section D		2540	618	

(Paul, T., 2003)

ii. Possible Causes

The possible Causes of raveling are Heavy traffic volume (in Izki 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).

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iii. Suggested maintenance methods

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

(* Overlay is any operation that consists of laying of Hot Mix Asphalt (HMA) over an existing pavement structure. This is different than a total replacement of the structure, and is typically done when there is only minor to modest damage to the existing pavement structure).

5. Pothole

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 (thickness of Izki road is 55mm).

i. Severity Levels

- Low: the depth < 25 mm.
- Moderate: the depth between 25 mm to 50 mm.
- High: the depth > 50 mm.

Table 13: Severity Levels in Pothole

Section	Type of distress	Length (mm)	Depth (mm)	Severity Levels
Section A	Pothole	456	11.2	Low
Section B		810	60	High
		295	45	Moderate
Section C		150	23.25	Low
Section D		470	40.5	Moderate

(Paul, T., 2003)

Fig.9: Pothole

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 and heavy traffic volume (traffic action accelerate potholes).

iii. Suggested maintenance methods

The suitable maintenance for pothole in section A and C is fill-depth but for section B and D is patching.

6. 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 14: Severity Levels in Patching

Section	Type of distress	Length (mm)	Width (mm)	Severity Levels
Section A	Patching	452	618	High
Section C		570	150	Low
		963	618	Moderate

(Paul, T., 2003)

ii. Possible Causes

Possible causes of faulty patching are excessive traffic loads (Izki road is not ready to cross heavy vehicles such as trucks and accommodate a large number of vehicles), poor quality of materials that are used to construction and poor implementation of asphalt.

iii. Suggested maintenance methods

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

Fig.10: Patching

https://dx.doi.org/10.24001/ijaems.3.7.6 *ISSN: 2454-1311*

IV. CONCLUSION

Pavement deterioration is the process by which distress (defects) develop in the pavement under the combined effects of traffic loading and environmental conditions. Some Causes of Road Cracks and Deterioration are Defects caused during construction due to poor construction quality, Structural failure of base, poor highway facilities, Poor maintenance policy, Poor supervision and others.

Pavement deterioration process starts very slowly so that it may not be noticeable, and over time it accelerates at faster rates, they must be implementation of the proper maintenance and repair work in suitable time; which will maintain the pavement in a safe and acceptable operational condition and helps to save cost of maintenance. 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 possible causes of deterioration on Izki road 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 Suggested maintenance for the cracks and defects in Izki road are Crack seal (fill the crack) to prevent moisture entering into subgrade through the cracks, Improve (construct) drainage system, Reconstruction of the edge and support the edge with paving stones and patching.

V. RECOMMENDATIONS/ FUTURE WORK

The importance of governorate of roads maintenance to maintain the level of road performance and ensuring safety for its users, Where is more than (60,000) km of paved roads in Oman is subject to regular maintenance and preventive. To reduce road defects in general, during the construction or maintenance of the road, the municipality must ensure that the construction work are performed as properly and required. Also to construct the roads that have high traffic volume must be increase the thickness of the asphalt layer must be increased more than 70 mm (To avoid defects that are due to high traffic volume) and the level of the asphalt layer should be at the same level of the soil beside the road. It is recommended to use the soil derived from rock breakage as an alternative to wadi soil that was used for Izki road.

To reduce the spread of further defects and cracks on Izki road the following measures are suggested:

- Continuous periodic inspection of roads.
- Fill the cracks and repair minor defects on the road surface.
- Construct the shoulders and Repair Edge Cracking of the road.
- Construct a water drainage system.
- Reconstruct some parts of the road.
- Periodic cleaning of the road.

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