

PRACTICAL FIELD INVESTIGATION TO INDICATE COMMON FLEXIBLE PAVEMENT DISTRESSES THAT OCCUR IN THE MALIK MAHMOOD RING ROAD-SULAIMANIYAH CITY

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(Accepted for Publication: December 8, 2020)

ABSTRACT

When the top layer of the road defects with time, it is called distresses of the pavement. The causes for this pavement distress vary as most of the flexible pavement structures are subjected to repeated heavy traffic loadings and high temperature changes which causes pavement cracking, deformation and deterioration. The existence of these defects on the road surface makes it uncomfortable and unsafe for the users, therefore, it should be determined and treated in appropriate ways. This research is conducted to identify the most common types of flexible pavement distresses which occur in the Sulaimaniyah city, Iraq, and to find out different reasons behind those distresses along with proposing suitable ways for their maintenance. The data collection was done in the Malik Mahmood ring road in the Sulaimaniyah city. The work study is carried out in locations that are subjected only to passenger cars and heavy truck loadings. Field surveying shows that the most common flexible pavement distresses occurred in the selected area are various types of cracking, rutting, corrugation, shoving, patches and potholes. Finally, recommendations on maintenance method are provided to guide the Sulaimaniyah governorate and municipality on solving the distresses and to have a promising repairing practice for the road network.

KEYWORDS: Flexible Pavement; Distresses, Cracks; Deformation; Deterioration

1. INTRODUCTION

The development of the countries relies on several factors including the economic, cultural and social. Roadway network system out of all the other methods of transportation is also regarded as a vital need for any country to improve their development. In some developing countries such as Iraq, the most frequent used mode of transport is regarded to be roadways. Therefore, their safety has to be continuously monitored and guaranteed. However, as most types of the paved roads in Iraq is flexible pavement, and they are considered as vulnerable when it comes to defects.

The main reason for the defects of flexible pavement is the level of the stresses on the pavement and it causes various types of distresses and cracks. Other factors such as rate of temperature change and the extra weight put on the roads can have impacts in creating cracks and defects on the surface of the roads. These

defects will be obstacles for the road users as they progress to create unsafe environment for the motorists and cyclists. Therefore, to increase the life span of the road, maintenance is inevitable in most of the cases despite of the cost of it as it might be expensive.

To perform the regular maintenance for the roads, regular inspection is required, therefore, the advantages of regular assessments for flexible pavement can be noticed that before the maintenance stage. That evaluation of the distresses gives precise causes of the pavement defects which makes the process of the maintenance easy. Moreover, to achieve a better, safer, and more effective design of the flexible pavements, a thorough investigation is needed on the failures of the roads.

This study is about a field investigation to indicate the common flexible pavement distresses that occur in the Sulaimaniyah city. This research is carried out to specify the most frequent types of flexible pavement distresses which happen in one of the main roads in the

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Sulaimaniyah city (Malik Mahmood ring road). It tries to find out the various scientific reasons in the literature that leading to those pavement distress. Finally, it suggests suitable methods for maintenance of the indicated problems based on the previous works that done on this topic area.

2. STATE OF THE ART

Two of the major factors that leads to pavement deterioration which develops to distresses in flexible pavement are high traffic loads combined with the effects of the environment on it. Aging and supporting layers are another factors that contributing in an increase in the amount of deterioration due to the frequent usage of the roads which aggravates the deterioration. That pavement deterioration influences most of the aspects of the road such as its serviceability, safety and the quality of riding of the road. Therefore, the maintenance of the road is crucial to increase the serviceability of the road. It is generally accepted that road deteriorates within time which means the probability of the new roads to deteriorate is very low as it is a slow process in the early ages of the road up to reaching fifteen years old. The deterioration takes place more rapidly after that age if proper and frequent maintenance are not carried out for the deteriorated road (Paterson, 1987). If the regular maintenance is not carried out for a deteriorated road, the consequences would be fatal. Those consequences start with losing the attractiveness of the road surface to losing lives due to accidents along with leading to several other fatal problems such as delaying the traffic flow unnecessarily and damaging the property and the vehicles (Ogundipe, 2008). They can lead to premature failures affecting both quality of riding and the road's safety.

The first step of the amendment of the deteriorated road is to verify the type of the defect prior to suggesting possible solutions. To do so, a thorough investigation is required to be carried out all across the roads taking notes all types of the failures happened on the surface of the pavement. After that, implementing the necessary tools to carry out the amendment of the defects (Rashid and Gupta, 2017). The maintenance has to be carried out using suitable tools and solutions with continuous monitoring. Maintenance, which is considered as a sequence

of actions performed on a road to extend the life span of it, is essential in reduction of the defects and preventing them in their future life time. It includes several interventions that has to be consistent, preventive, and correct, (Rohde, 1995), (Johanns and Craig, 2009).

There are some types of treatments for the road that needed to be carried out annually therefore, they are called Routine maintenance. They include several actions including filling potholes and patching them along with filling and sealing cracks annually. The second type of treatment involves enhancing the functional properties of the road surface; however, they might slightly influence structural properties but not greatly, therefore, they are referred to as Preventive maintenance. The last type of the maintenance is called corrective which involves a major change in the structural properties of the road. All three types serve the purposes of the road which is mainly increasing the life span of it.

It is quite unfortunate that in some countries, particularly in developing countries, maintenance either neglected or poorly carried out and managed. This has caused continuous appearing of rapid defects on the road surfaces and leading to failure eventually (Alaamri et al., 2017). Sulaimaniyah is located in Iraq which is considered as a developing country; therefore, the same statement is true for this location. In the Sulaimaniyah city the same study was not done previously, so this research investigation tries to identify and indicate different types of defects in the Malik Mahmood ring road-in the Sulaimaniyah city. It also, tries to find out the possible reasons behind the failures and defects on that road in the literature. Finally, it suggests some reasonable methods of maintenance to be carried out urgently to increase the life time of this major road in the city.

3. FACTORS THAT MAY CAUSE PAVEMENT DISTRESSES

Many researchers, in the literature, investigated the possible reasons and factors behind pavement distresses (Okigbo, 2012), (Omer et al., 2014), (Sargious, 1975), (Abhijit and Jalindar, 2011), (Little et al., 1995), (Sebesta, 2002a), (Kadhim and Mahdi, 2017). They reported several factors which includes

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designing the roads poorly in early stages, using low quality materials, supervising the work inappropriately during the construction stage, and applying loads with higher magnitudes that it was expected in the design on the road during the operation stage. Moreover, they added insufficient number of tests for the soil and the materials along with inappropriate monitoring for the road can lead to failure and distress of the pavements in general.

Hereafter, the following paragraphs will discuss the major factors that causes pavement distresses regardless of the stage of the road.

The first major factor is heavy traffic loads which happens when the estimated design loads are less than the actual applied traffic loads on the roads that forces the surface of the pavement to deform. It is confirmed that heavy loads from commercial vehicles lead to initiation of the cracks which can lead to a failure if extended for a long period of time (Croney and Croney, 1991) and (Omer et al., 2014).

The second major factor is an obvious change in climate which varies from the amount of rainfall to the changes in temperature annually or the combination of both. The rate of rainfall has influences on pavement distresses as the amount of the moisture balances alter from a season to another. While, the change in temperature affects the age of the bitumen. This can cause cracks on the surface of the pavement as it will embrittlement due to the considerable change in temperature (Wee and Teo, 2009).

Poor drainage system, such as not having a reliable surface, culverts, drains and shoulders, is another factor affecting the level of damage on the surface of the roads. Some of the researchers investigated the effects of poor drainage on asphalt pavements. (Little and Jones, 2003) found out that water can cause a loss of cohesion between the films of the asphalt leading to a substantial loss in strength. They reported another factor that the water can cause debonding between the asphalt and aggregate this leading to a significant loss of the strength. Finally, they also asserted that water can disturb the gradation of the aggregate especially when subjected to a cyclic freezing and thawing. Other researchers investigated the method of deterioration of the moisture. For example, (Khosla et al., 1999) confirmed that the damage initiates at the very bottom layer of the asphalt

which leads to localized failure in forms of potholes or rutting and raveling. The other researchers such as (Stuart, 1990) attributed the bleeding or flushing to the migration of the pavement to the surface during a moisture ingestion in the bottom layers.

Low quality of the materials in the construction stage is considered as another major factors in pavement distressing as it adversely effects on the whole performance of the road. (Rollings, 1988) stated that, using such material might be in form of using improper grading of the aggregates for both courses of base and subbase and using low strength material in the subgrade levels.

The last major factor is the usage of expansive subgrade soil. Some of the roads in the Sulaimaniyah city were made on that type of soil. As they work as a foundation for the road so expansive soils are not suitable to be used as most of the distresses are attributed to them. They cause longitudinal cracking, fatigue cracking or (alligator), shoving, popping outs, rutting and edge cracking due to the volumetric change of the expansive soil beneath.

4. COMMON TYPES OF FLEXIBLE PAVEMENT DISTRESSES

The Study was conducted by referring to the procedures that is suggested by Federal Highway Administration (FHWA). In the Distress identification manual (Miller and Bellinger, 2003), and it contains a wide range of flexible pavement distresses most of them are presented in Table 1.

Table (1): The most common pavement distresses

Distresses	Unit of Measure	Defined Severity Levels
1. Cracking		
a) Fatigue Cracking	m ²	Yes
b) Block Cracking	m ²	Yes
c) Edge Cracking	m	Yes
d) Longitudinal Cracking	m	Yes
e) Reflection Cracking at Joints	Not Measured	No
f) Transverse Cracking	No, m	Yes
2. Patching and Potholes		
a) Patch Deterioration	No, m ²	Yes
b) Potholes	No, m ²	Yes
3. Surface Deformation		
c) Rutting	mm	No

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d) Corrugation and Shoving	No, m ²	No
4.Surface Defects		
a) Bleeding	m ²	No
b) Polished Aggregate	m ²	No
c) Raveling	m ²	No
5.Miscellaneous Distresses		
d) Lane to Shoulder Drop-off	Not Measured	No
e) Water Bleeding and Pumping	No, m	No

effectively. Its age is more than 20 years with some major repairs or amendments to some of its areas that were severely affected.

The road is examined using visual investigation. The whole road is surveyed on foot. Any observation of abnormality of the road is recorded with recording the existence of effective drainage in the affected vicinity. To reassure the quality of the drainage in the affected areas, inspections carried out for that purpose. Additionally, photographs of each distressed area are taken marking their locations accompanied with measuring the level of damage where possible. Firstly, the Malik Mahmood ring road is divided into three zones, as shown in Figure 1, as follows:

5. EXPERIMENTAL WORK AND DATA SURVEYING

Malik Mahmood Ring Road is located in the province of the Sulaimaniyah city in Kurdistan Region of Iraq. The estimated length of the road is 22 km. It is a two-way six lane road with a frontage road on each side. Malik Mahmood road is a service ring road in the Sulaimaniyah city, which has a variety of functions such as serving the industrial and commercial areas along its coverage area. Also, it serves the educational institutions and large residential communities by connecting them together

- 1. ZONE ONE:** Chwarta Bridge to Sarchnar Bridge
- 2. ZONE TWO:** Sarchnar Bridge Bakhshin Hospital
- 3. ZONE TTREE** Bakhshin Hospital to Chwarta Bridge

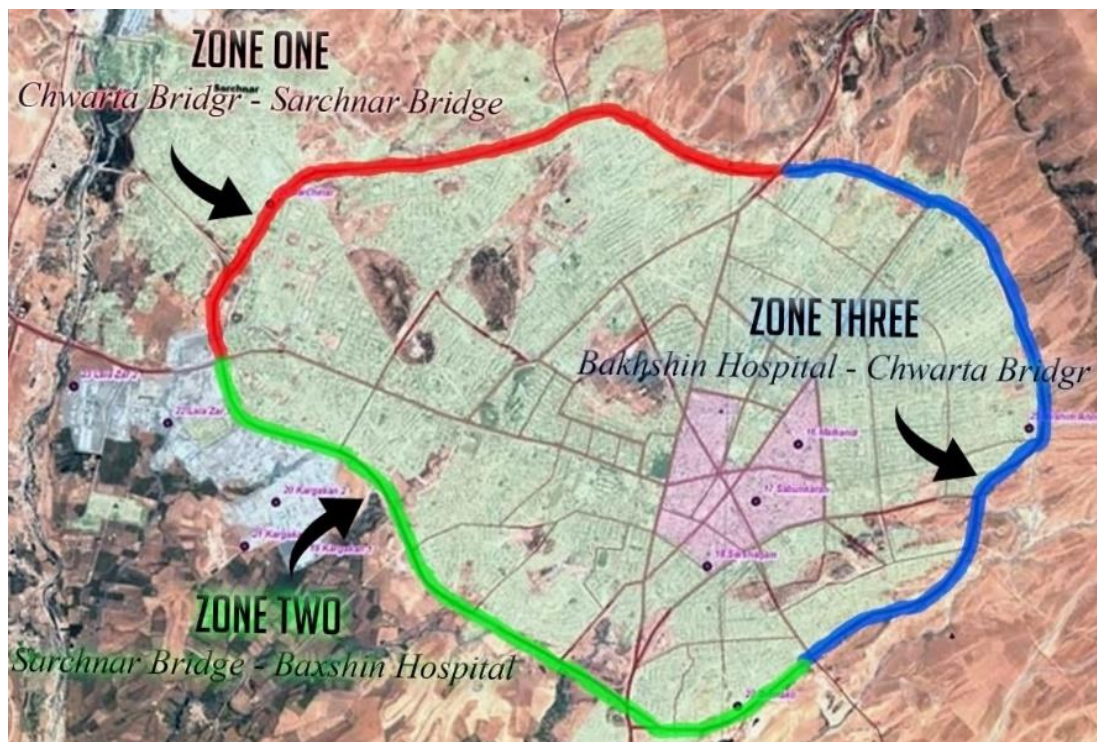


Fig.(1): Malik Mahmood Ring Road- Sulaimaniyah City/ Iraq [taken from <https://sleanimuseum.org/Gallery.aspx#gallery-21>]

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6. RESULTS AND DISCUSSION

a) **Fatigue Cracking:** Figure 2 shows an example of a fatigue cracking on the existing road. It looks like the back of a crocodile or an alligator that is why it is called an alligator cracking where a series of interconnected cracks



Fig. (2): Fatigue Cracking

The presence of fatigue cracking and their severities are presented in Table 2. Results show that there are a lot of fatigue cracking with a variety of severities levels on the Malik Mahmood ring road. The possible causes of these cracks were mentioned in the literature can be the excessive amount of axle loadings, aging of the road, weak surface or base or sub grade and poor drainages. The suggested maintenance methods for repairing this defect is based on the

together. It starts with small cracks in early stages and then develops into many-sided wider cracks with an area of less than 1 m². Table 2. Shows the distribution of this type of cracking with noting that L=Low, M=medium and H=high]

Table (2): Fatigue Cracking and their

Zones	Severity Levels		
	L (m ²)	M (m ²)	H (m ²)
1	73	30	200
2	58	55	154
3	52	92	97
Total	183	177	451

severity levels. For instance, for low severity levels suitable amount of sealant can be used to prevent water entering in to the road layers and for moderate and high severity levels full depth patch is effective.

b) **Longitudinal Cracking:** Figure 3 shows an example of longitudinal cracking on the selected road. It is a crack that is usually parallel to centerline pavement regardless of the thickness of the crack.



Fig. (3) Longitudinal Cracking

The availability of longitudinal cracking and their severities are showed in Table 3. It indicates that there are a wide range of

Table 3. Longitudinal Cracking and their severities

Zones	Severity Levels		
	L (M.L)	M(M.L)	H (M.L)
1	163	123	175
2	85	373	266
2	26	42	68
Total	274	538	509

longitudinal cracking with a variety of severity levels on the Malik Mahmood ring road. The possible cause of these cracks were explained in

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detail in the literatures and in the distress identification manuals, and it is attributed to poor construction paving joint which are usually least dense area. Another factor contributing to this kind of crack is change of the temperature which leads to the shrinkage of the asphalt layer. Otherwise, the reason might be interpreted as the paver might have not worked properly causing the longitudinal segregation of the asphalt. The suggested maintenance methods for repairing this type of distress is upon the severity levels, the existing pavement have low to high severity

levels. It can be performed in the following stages. First, the existed cracks have to be sealed or filled with a mixture of light grade asphalt and fine sand or with emulsion slurry. After that proper drainage has to be assured to avoid future failures in that areas.

c) **Transverse Cracking:** Figure 4 shows a typical transverse cracking on the road. It is a crack which its direction is usually perpendicular to the direction of the longitudinal crack or the pavement centerline



Fig. (4): Transverse Cracking

The transverse cracking and their severity levels of the Malik Mahmood ring road are showed in Table 4. It can be clearly seen that there are a lot of transverse cracking with presence of severity levels from low to high. The possible causes and the suggested maintenance methods of these cracks are the same as longitudinal cracking with a little difference.

Table 4. Transverse Cracking and their severities

Zones	Severity Levels		
	L (NO.)	M (NO.)	H (NO.)
1	244	324	327
2	244	530	219
3	83	136	144
Total	571	990	690

d) **Patching:** Figure 5 shows the patching on the existing road. Patching takes place after repairing performed on the road where the original surface is replaced with added materials to the surface. The usual size of it, is more than 0.1m².



Fig. (5): Patching

The presence of patching and their severity levels are presented in Table 5. Results indicate that there are a wide range of patching with a

Table 5. Patching and their severities

Zones	Severity Levels		
	L (m ²)	M (m ²)	H (m ²)
1	157	183	223
2	10	98	156
3	41	77	67
Total	208	358	446

variety of severities on the Malik Mahmood ring road. They usually cause a rough pavement that leads to cracks in the joints. The possible causes

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of these cracks are due to combination of several types of previous cracks that had been treated or replaced with new pavement and may lead to patching distresses. Those treatments include the treatment of potholes, removal of fatigue cracking, shoving and corrugation patching. The suggested maintenance methods for repairing this defect is as treatment with removal or placement of new overlay as patches are repair actions in themselves.

e) **Potholes:** Pothole, as shown in Figure 6, is a hole in a road surface that is created naturally to penetrate to the base course of the pavement from hot mix asphalt layer. The frequency of potholes and levels of severity are presented in Table 6. It can be seen that there are a lot of potholes with a variety of severities on the selected area. This type of distress causes the pavement to allow moisture to infiltrate the layers and causes roughness which can cause serious damage to vehicles going at high speed.



Fig. (6): Potholes

The possible causes of these defects are generated where the severe alligator cracking that is not treated. The alligator cracks leave small and weak chunks of pavements on top of the surface of the pavement which are vulnerable to repeated loads as they will be dislocated to new places and a hole will be created. The other possible reasons of pothole might be having weak points in either the base course or subgrade layer. The most effective method that is

suggested as a maintenance for repairing this type of distress is to remove dislodged chunks and then patch it.

f) **Rutting:** Rutting (shown in Figure 7) is a form of distress, which is a permanent surface deformation along the path of the wheel. The availability of rutting and their severities are presented in Table 7. This type of distress tend to pull vehicles into the rut path which inflicts vehicle damage.

Table (6): Potholes

Zones	Severity Levels		
	L (m ²)	M (m ²)	H (m ²)
1	108	285	220
2	23	26	31
3	32	46	47
Total	163	357	298



Fig. (7): Rutting

The possible causes of rutting include heavy truck loading during high-temperature climates, lateral movement of materials or consolidation and problems in mix design such having inadequate quantity of pointed aggregate and unnecessary asphalt content or mineral filler all of them were proved in past . The most effective method that is suggested as a maintenance method for repairing this type of distress is based on the severity levels of the rutting, if the depth of the rutting is too small it can be left untreated otherwise deep ruts should be removed and replaced by new layer of pavement.



Fig. (8): Corrugation and shoving

The possible causes of corrugation and shoving include heavy truck loading on the road where excessive moisture presents in the structure of the pavement and a combination of poor mix design with unstable hot-mix asphalt layer. The effective maintenance method for repairing this type of distress affecting a small area is removing the distorted pavement and patch but if the area is large enough, it indicates the general HMA failure that needing the total removal of the area and overlay.

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Table (7): Rutting

Zones	Severity Levels		
	L (No.)	M (No.)	H (No.)
1	72	70	50
2	24	38	35
3	7	17	26
Total	103	125	111

g) **Corrugation and shoving:** Figure 8, shows corrugation and shoving on the Malik Mahmood ring road. Shoving happen when the surface of the pavement displaces longitudinally over a localized area. The presence of shoving and their severities are presented in Table 8. The recorded data show that there are a lot of shoving with a variety of severities on the selected road, these corrugation and shoving create a rough pavement surface which is uncomfortable for vehicles.

Table 8. Corrugation and shoving

Zones	Severity Levels		
	L (m ²)	M (m ²)	H (m ²)
1	95	120	62
2	16	22	8
3	18	16	15
Total	129	158	85

h) **Raveling and Polished aggregate:** Figure 9 and 10 show both the raveling and polished aggregate of the Malik Mahmood ring road. Raveling is loss of the main constituent material of the mix which is aggregate that can be fine or sometimes course. However, polished aggregate happens when the binder of the surface is worn away and only the course and some of the fine aggregates left exposed.



Fig. (9): Raveling



Fig. (10): Polished aggregate

Table (9): Polished aggregate and raveling

Zones	Severity Levels					
	Polished aggregate (m ²)			Raveling (m ²)		
	L	M	H	L	M	H
1, 2 and 3	365	288	522	90	344	363

The presence of raveling and polished aggregate with their severities are presented in Table 9. The recorded data show that there are a wide range of raveling and polished aggregate on the selected pavement. These raveling and polished aggregate collects water and will cause the loss of resistance to skid.

The possible causes of these types of distresses are heavy and repeated traffic volume, inadequate compaction during construction that leads to debonding between aggregate particles and the asphalt, and water ingestion. The effective maintenance method for repairing this type of distress is applying a skid resistant slurry seal after removing the defected area and patching or overlaying.

7. CONCLUSION

This study is a practical field investigation to indicate the common types of flexible pavement distresses that occur in a road in the Sulaimaniyah city/Iraq. The following conclusions can be drawn from it:

- 1) Based on the field investigation and data collection the common flexible pavement distresses that occur in the Sulaimaniyah city are fatigue, longitudinal and transverse cracking, rutting, shoving, raveling, polished aggregate, patching and potholes.
- 2) Pavements deteriorate under combination of some factors such as high traffic loading, change in climate condition, poor drainage system, improper materials of construction and decrease physical life of the pavement.
- 3) It can be concluded that knowing about various types of distresses and possible reasons behind them will allow all parts including government and private companies to work hand

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in hand in solving them and preventing them in the future. As a consequence, the life of the motorists will be saved along with the life of the roads.

4) The most effective methods of maintenance of the cracks with low severities in Malik Mahmood ring road are crack seal by a suitable sealants to prevent moisture entering into road layers through the cracks and for high severities use low grade asphalt mixed with fine sand and fillers to fill the cracks, improve drainage system and for other type of distresses full depth patching or mill the surface and applying on overlay.

5) The authors would like to recommend for further study on this topic area to indicate the causes of distresses of rigid and flexible pavements in our region and we prefer to follow the procedures that stated in ASTM D6433 "Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys".

REFERENCES

- Alaamri, R. S. N., Kattiparuthi, R. A., & Koya, A. M. (2017). Evaluation of Flexible Pavement Failures-A Case Study on Izki Road. *International Journal of Advanced Engineering, Management and Science*, 3(7).
- Abhijit, P., & Jalindar, P. (2011). Effects of bad drainage on roads. *Civil and Environmental Research*, 1(1), 1-8.
- Croney, D., & Croney, P. (1991). *The design and performance of road pavements*.
- Hicks, R. G., Seeds, S. B., & Peshkin, D. G. (2000). *Selecting a preventative maintenance treatment for flexible pavements*. Federal Highway Administration, Office of Asset Management.

¹Corresponding author: College of Engineering, University of Sulaimani, Kurdistan Region, Iraq

- Johanns, M., & Craig, J. (2002). Pavement maintenance manual. *Nebraska: Department of Road*, 5-10.
- Kadhim, Z. A., & Mahdi, Z. A. Z. (2017). *Evaluation of Asphalt Pavement Distresses in Main Roadways in Al-Diwaniyah City. Journal of University of Babylon for Engineering Sciences*, 26(1), 72 - 80. Retrieved from.
- Khosla, N. P., Birdsall, B. G., & Kawaguchi, S. (1999). *An in-depth evaluation of moisture sensitivity of asphalt mixtures* (No. FHWA/NC/2002-012,).
- Little, D. N., & Jones, I. V. (2003). Chemical and mechanical processes of moisture damage in hot-mix asphalt pavements. In *Moisture Sensitivity of Asphalt Pavements-A National Seminar California Department of Transportation; Federal Highway Administration; National Asphalt Pavement Association; California Asphalt Pavement Alliance; and Transportation Research Board*.
- Little, D. N., Scullion, T., Kota, P. B., & Bhuiyan, J. (1995). Identification of the structural benefits of base and subgrade stabilization (No. FHWA/TX-94/1287-2,).
- Miller, J. S., & Bellinger, W. Y. (2003). *Distress identification manual for the long-term pavement performance (LTPP) project*. FHWA-RD-03-031 (4th edition). Federal Highway Administration.
- Omer, O. G., Elsharief, A. M., & Mohamed, A. E. (2014). Failure Investigation for Recently Constructed Road in Khartoum State. *Journal of Geological Resource and Engineering*, 2, 20-31.
- Okigbo, N. (2012). Road maintenance in Nigeria, the way forward. *International journal of research in engineering science*, Pan African journal series, Accra, Ghana.
- Ogundipe, O. M. (2008). Road pavement failure caused by poor soil properties along Aramoko-Ilesha Highway, Nigeria. *Journal of engineering and applied sciences*, 3(3), 239-241.
- Paterson, W. D. (1987). Road deterioration and maintenance effects: Models for planning and management.
- Rashid, Z. B., & Gupta, R. (2017). Study of Defects in Flexible Pavement and its Maintenance. *International Journal of Recent Engineering Research and Development*, 2(6), 74-77.
- Rohde, G. T. (1995). Modelling Road Deterioration and maintenance effects in HDM-4. *Pavement Strength in HDM-4 with FWDs*.
- Rollings, R. S. (1988). Marginal Materials for Pavement Construction. *Final Report, Department of the Army Waterways Experiment Station Corps of Engineers, US. Vicksburg Mississippi*, 39180-0631.
- Sebesta, S. (2002a). Reworking base. In *Statewide Maintenance, " Conference, San Antonio, TX*.
- Sebesta, S. (2002b). *Investigation of maintenance base repairs over expansive soils: Year 1 report* (No. FHWA/TX-03/0-4395-1,). Texas Transportation Institute, Texas A & M University System.
- Stuart, K. D. (1990). Moisture damage in asphalt mixtures-a state-of-the-art report.
- Sargious, M. (1975). Pavements and surfacing for highways and airports.
- Wee, S. Y., & Teo, H. W. (2009). Potential modeling of pavement deterioration rate due to cracking. *Journal of Civil Engineering, Science and Technology*, 1(1), 1-6.

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