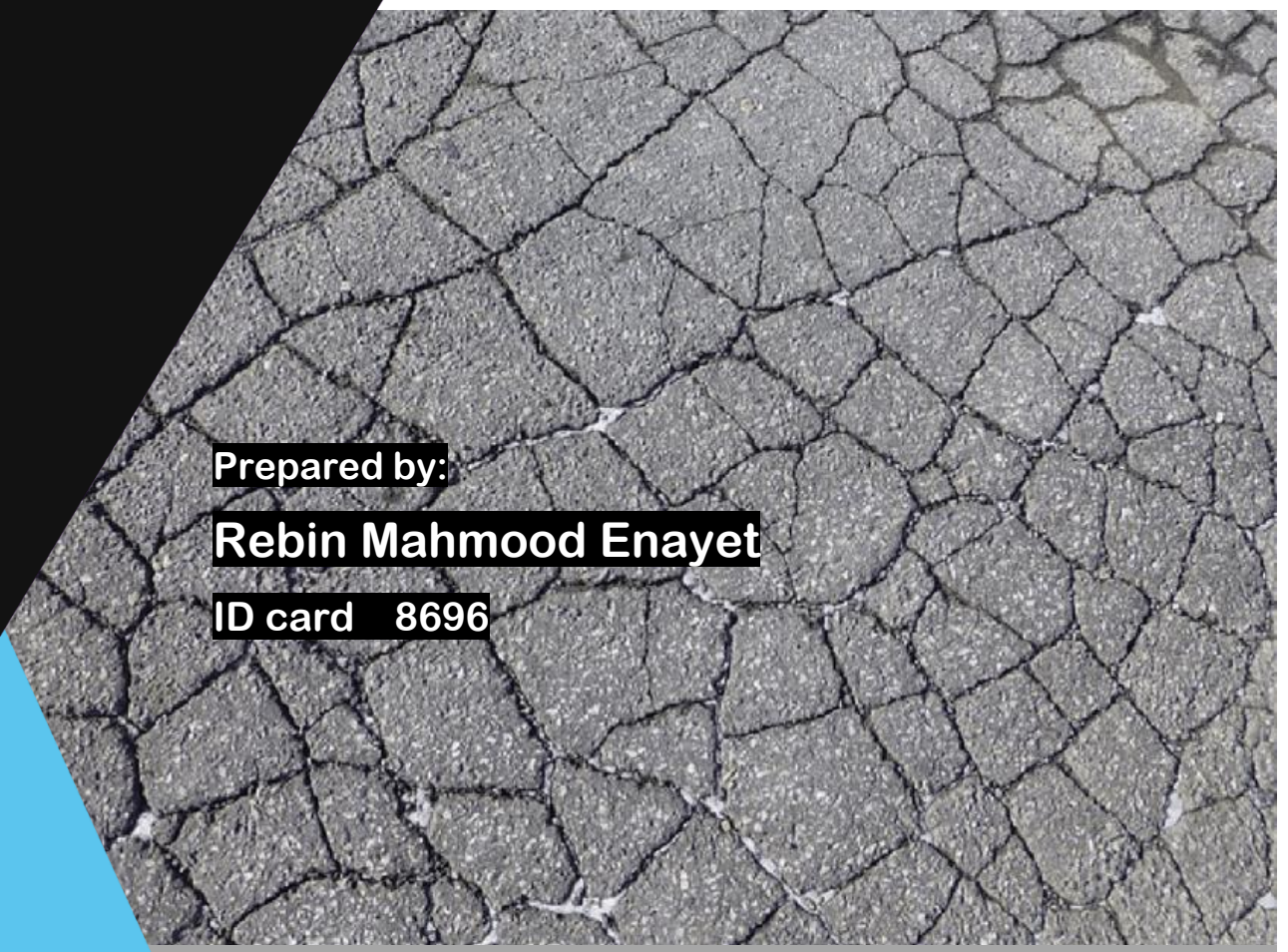
Flexible Pavement Distresses in Sulaymaniyah City

The Purpose of Preparing this Research is to Change the engineer's address to consultant title



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Abstract

Distresses of the pavement is a defect that appears in the top layer of the road, most of the flexible pavement structures are subjected to heavy traffic loadings with repetitions and temperature changes which causes to pavement cracking, deformation and deterioration. The existence of cracking, deformation and deterioration in the road make it uncomfortable and unsafe while driving, so it should be determined and treated in a proper way. This research is conducted in order to identify the most common types of flexible pavement distresses which occur in the Sulaymaniyah city as well as to find out the different reasons that causes pavement distress, finally suggest suitable way for maintenance. The work was achieved in locations that is subjected to passenger cars and heavy truck loadings. The data collection was done in the Malik Mahmood ring road in the Sulaymaniyah city/Iraq. Field surveying shows that the most common flexible pavement distresses are of various types of cracking, rutting, corrugation, shoving, patch and potholes that occur in the selected area. Finally, recommendations of maintenance method are provided to support the government and Sulaymaniyah municipality to have a promising repairing practice for the road network.

1. Introduction

One of the most using modes of transportation systems in Iraq is roadways, a roadway network system is one of the most important necessities for the economic, cultural and social development of any country, especially regarding with the developing countries.

The flexible pavement roads are 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 need proper maintenance as a result of affected over load, temperature change rate, Impact of climate 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, so 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.

The evaluation survey and assessment of the flexible pavement roads are advantageous for highway engineers so that it gives and provides accurate reason of flexible pavement distresses which makes the maintenance works easy, finally study of the failure and defects of flexible pavement in specific area helps in improving the design of flexible pavement which can be more effective in term of safety, quality, and performance in the area.

This study is about practical field investigation to indicate the common flexible pavement distresses that occur in the Sulaymaniyah city. This research is done in order to identify the most common types of flexible pavement distresses which occur and to find out the different reasons that causes pavement distress, finally suggest suitable way for maintenance.

2. State of the art

Pavement deterioration is the process by which distresses develop in pavement under the combined effects of traffic loading and environmental conditions. Deterioration of pavement greatly affects safety, serviceability, and driving quality of the road. After construction, roads deteriorate with age as a result of use and therefore, they need to be maintained to ensure that the requirements for safety, efficiency and durability are satisfied. Normally, new paved roads deteriorate very slowly in the first ten to fifteen years of their life, and then go on to deteriorate much more rapidly unless timely maintenance is undertaken (Paterson, 1987).

Deterioration of highway pavement is a very serious problem that causes unnecessary delay in traffic flow, distorts pavement aesthetics, damages of vehicle and most significantly, causes road traffic accident that had resulted into loss of lives and properties (Ogundipe, 2008). Pavement surface deformation affects the safety and riding quality on the pavement as it may lead to premature failures. A variety of factors contribute to pavement deterioration were investigated by many researchers (Okigbo, 2012), (Omer at el., 2014), (Sargious, 1975), (Abhijit and Jalindar, 2011), (Little et al., 1995), (Sebesta, 2002a), some of the factors that cause highway failure has been identified. They include poor design, construction and maintenance, use of low-quality construction materials, poor workmanship and poor supervision of construction work and the applying of heavy traffic that were not meant for the road. Furthermore, they also suggested that the following will lead to highway failure; poor highway facilities, no knowledge base, inadequate sanction for highway failure, no local standard of practice, poor laboratory and in-situ tests on soil and weak local professional bodies in highway design, construction and management.

Maintenance is a series of activities designed to keep a road network serviceable by reducing the deterioration of pavements. Pavement maintenance includes routine, preventive and corrective interventions (Rohde, 1995), (Johanns and Craig, 2009). Routine maintenance is usually performed annually and includes interventions such as crack sealing and filling, patching and pothole filling. Preventive maintenance is usually performed to improve the functional surface properties without significantly changing the structural properties of the pavement. The best time to apply the interventions is considered to be before

significant distress is exhibited (Hicks et al., 2000). So, maintenance of a road network involves a variety of operations, i.e., identification of deficiencies and planning, programming and scheduling for actual implementation in the field and monitoring. The essential objective should be to keep the road surface and appurtenances in good condition and to extend the life of the road assets to its design life. Broadly, the activities include identification of defects and the possible cause there off, determination of appropriate remedial measures; implement these in the field and monitoring of the results (Rashid and Gupta, 2017).

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 (Alaamri et al., 2017).

This research investigation was carried out to identify different types of distresses in the Malik Mahmood ring road-in the Sulaymaniyah city/Iraq, to find out the different reasons that cause defects and cracks, and finally to suggest suitable maintenance methods.

3. Factors that may cause pavement distresses

Through this section, major factors that causes pavement distresses are discussed.

Heavy Traffic: One of the defects caused by heavy traffic on the road is the deformation of the pavement surface due to overloading that is more than the design load. As stated by (Croney and Croney, 1991), that deterioration of pavements arises from deformation generally associated with cracking under heavy commercial vehicles. The increased traffic loading will then cause failures such as cracks and depressions on the pavement (Omer et al., 2014).

Climatic Changes: Climatic factors include rainfall and annual variations in temperature are an important consideration in pavement deterioration. Climatic changes in temperature and rainfall can interact together. Rainfall can alter moisture balances and influence pavement deterioration while the temperature changes can affect the aging of bitumen resulting in an increase in embrittlement of the bitumen which causes the surface to crack (Wee and Teo, 2009).

Poor Drainage: The highway drainage system includes the pavement and the water handling system which covers pavement surface, shoulders, drains and culverts. Researchers (Little and Jones, 2003), investigated moisture damage in asphalt pavements due to poor drainage. They found that the loss of strength and durability due to the effects of water is caused by loss of cohesion (strength) of the asphalt film, failure of the adhesion (bond) between the aggregate and asphalt, and degradation of the aggregate particles subjected to freezing.
Moisture damage generally starts at the bottom of an asphalt layer or at the interface of two asphalt layers (Khosla et al., 1999). Eventually, localized potholes are formed or the pavement ravels or ruts. Surface raveling or a loss of surface aggregate can also occur, especially with chip seals. Occasionally, binder from within the pavement will migrate to the pavement surface resulting in flushing or bleeding (Stuart, 1990).

Construction with Low Quality Materials: The use of low-quality materials for construction adversely affects the performance of the road. This sometimes occurs in the form of the improper grading of aggregates for base or subbase and poor subgrade soil of low bearing strength. The use of marginal or substandard base materials for pavement construction will affect pavement performance (Rollings, 1988).

Expansive Subgrade Soil: Expansive soil as road subgrade is considered one of the most common causes of pavement distresses. Longitudinal cracking results from the volumetric change of the expansive subgrade, is one of the most common distresses forms in low volume roads. This type of cracking is initiated from the drying highly plastic subgrade (PI>35) through the pavement structure during the summer (Sebesta, 2002a), (Sebesta, 2002b). Other forms include fatigue (alligator) cracking, edge cracking, rutting in the wheel path, shoving, and pop outs.

4. Common Types of Flexible Pavement Distresses

Based on reference (Miller and Bellinger, 2003), there are a wide range of flexible pavement distresses. Table 1 Shows the most common types of crack and defects of asphalt concrete pavements.

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		
a) Rutting	mm	No
b) 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

5. Experimental Work and Data Surveying

Malik Mahmood Ring Road is located in the province of the Sulaymaniyah City/Kurdistan Region/Iraq. It is estimated that the length of the road is about 22 km and it's a two-way six lane road with a frontage road in each side. Malik Mahmood road is a service ring road around Sulaymaniyah city, serving industrial and commercial areas, educational institutions and large residential communities. The surface of the road had been constructed more than 20 years ago. The road has received some major repairs or modifications to some of the affected areas.

The visual examination of the pavement surface was conducted by a foot walking along the selected road. Frequently stops were made near locations where severe distresses were witnessed. Drainage features at and/or near these locations were inspected to determine if improper drainage was a contributing factor to the distress. In addition, photographs of the distressed pavements were taken at these locations and the severity levels were measured when applicable. Firstly, we divided the Malik Mahmood ring road (see Fig.1) into three zones as follows:

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

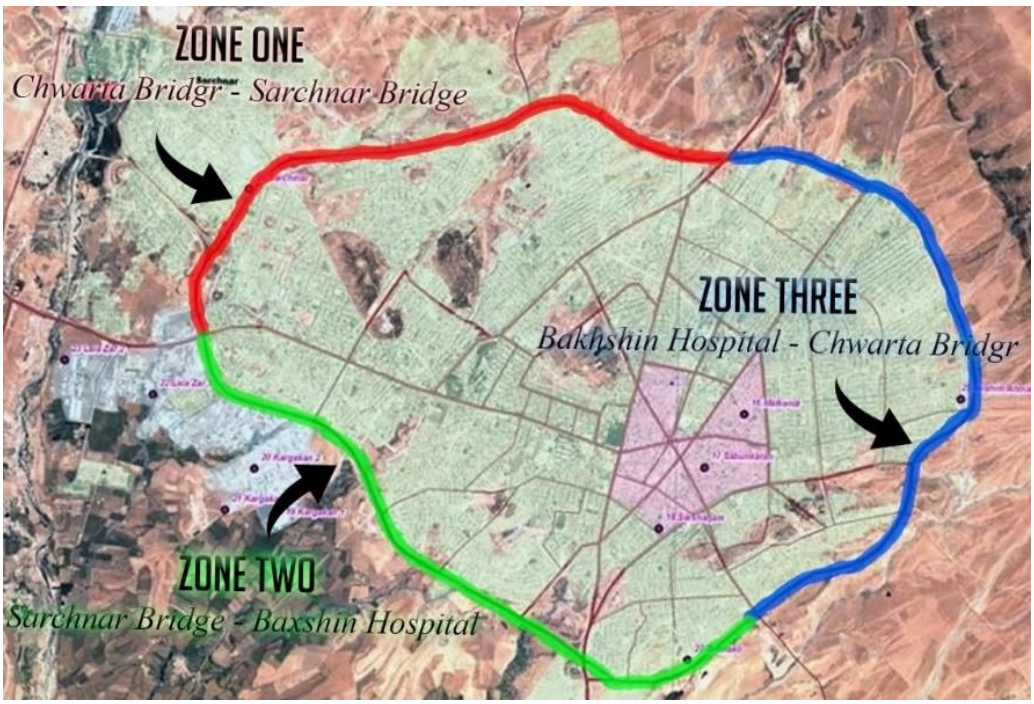

Figure1. Malik Mahmood Ring Road- Sulaymaniyah City/ Iraq

The field survey shows that these types of distresses were available in the selected location (fatigue cracking, longitudinal cracking, transverse cracking, patching, potholes, corrugation and shoving, polished aggregate, rutting and raveling).

6. Results and Discussion

a) **Fatigue Cracking:** Figure 2 Is the photo of the fatigue cracking on the existing road. It is a series of interconnected cracks in early stages of development. Develops into many-sided, sharp-angled pieces, usually less than 0.3 meters (m) on the longest side, characteristically with a chicken wire/alligator pattern, in later stages. [Note: in all tables, L=Low, M=medium and H=high].

Figure 2. Fatigue Cracking

Table 2. Fatigue Cracking and their severities

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

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 on the Malik Mahmood ring road. The possible causes of these cracks are due to the excessive amount of axle loading, age of the road, weak surface or base or sub grade and poor drainages. The suggested maintenance methods for repairing this defect are based on the severity levels, for low severity levels use suitable amount of sealant 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 Is the photo of the longitudinal cracking on the existing road. It is a crack which is predominantly parallel to pavement centerline.

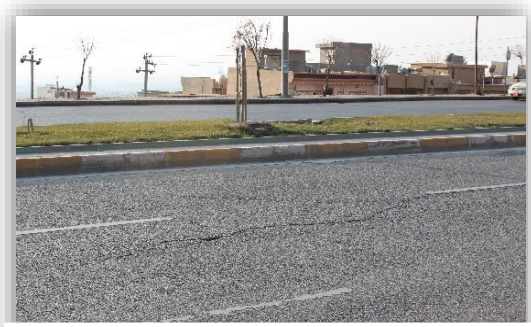

Figure 3. Longitudinal Cracking

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

The availability of longitudinal cracking and their severities are shown in Table 3 and it is indicating that there are a wide range of longitudinal cracking with a variety of severities on the Malik Mahmood ring road. The possible causes of these cracks are due to poorly constructed paving joint cracks. These joints are usually least dense area, shrinkage of the asphalt layer due to daily temperature cycling or hardening of asphalt and longitudinal segregation caused by the improper operation of the paver. The suggested maintenance methods for repairing this type of distress are upon the severity levels, the existing pavement have low to high severity levels, so improve drainage by removing the source that traps the water seal crack or fill with asphalt emulsion slurry or light grade of asphalt mixed with fine sand and provide side drainage ditches.

c) **Transverse Cracking:** Figure 4. Is the photo of the transverse cracking on the existing road. It is a crack which is predominantly perpendicular to the pavement centerline.

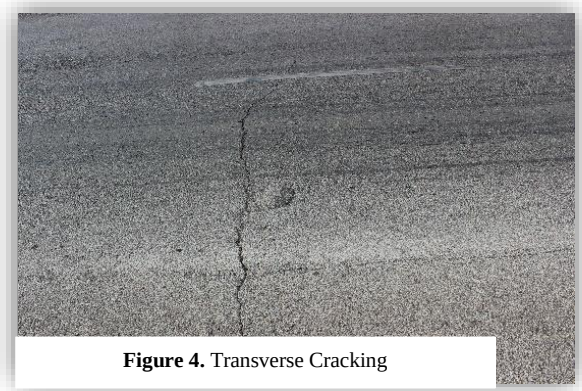

Figure 4. Transverse Cracking

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

The transverse cracking and their severities on Malik Mahmood ring road are shown 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 levels. The possible causes and the suggested maintenance methods of these cracks are the same as transverse cracking with a little difference.

d) **Patching:** Figure 5. Is the photo of the patching on the existing road, Patching is a part of the pavement surface greater than $0.1m^2$ that have been removed and replaced with additional materials applied to the pavement after the original construction.

Figure 5. Patching

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

The presence of patching and their severities are presented in Table 5. Results indicate that there are a wide range of patching with a variety of severities on the Malik Mahmood ring road. These patching causes the pavement more roughness and leads to joint cracks. The possible causes of these cracks are due to several types of previous cracks that have been treated or replaced with new pavement and may lead to patching distresses such as treatment of potholes, removal of fatigue cracking, shoving and corrugation patching and as a result of excessive traffic loads, poor quality of materials that are used to construction and poor implementation of asphalt. The suggested maintenance methods for repairing this defect are repair actions in themselves but they can be treated with removal or placement of new overlay.

e) Potholes: Figure 6. Is the photo of the patching on the existing road, Pothole is a hole in a road surface that penetrate the road through the hot mix asphalt layer down to the base course of the pavement. The availability of patching and their severities are presented in Table 6, which shows that there are a lot of patching 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.

Figure 6. Potholes

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

The possible causes of these defects are basically severe alligator cracking that is not treated. The interconnected alligator cracks create small chunks of pavement which will be dislodged as vehicles drive over them which forms the pothole and 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. The most effective method that is suggested as a maintenance method for repairing this type of distress is to remove dislodged chunks and then patched.

f) Rutting: Figure 7. Is the photo of the rutting on the existing road. Rutting is a form of distress, which is a surface depression in the path of the wheel. The availability of rutting and their severities are presented in Table 7, which shows that there are a lot of rutting with a variety of severities on the selected area. This type of distress tend to pull vehicles into the rut path which inflicts vehicle damage.

Figure 7. Rutting

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

The possible causes of rutting including heavy truck loading during high-temperature climates, consolidation or lateral movement of materials and problems in mix design such as excessive asphalt content, mineral filler, and insufficient amount of angular aggregate. 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 pavement.

g) **Corrugation and shoving:** Figure 8. Is the photo of the corrugation and shoving on the Malik Mahmood ring road. Shoving is a longitudinal displacement of a localized area of the pavement surface. The presence of shoving and their severities are presented in Table 8. The recorded data shows that there are a lot of shoving with a variety of severities on the selected road. These corrugation and shoving causes the pavement more roughness and discomfort for vehicles.

Figure 8. Corrugation and shoving

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

The possible causes of corrugation and shoving including heavy truck loading, excessive moisture in the pavement structure and an unstable hot-mix asphalt layer with poor mix design. The effective maintenance method for repairing this type of distress is for small localized areas of corrugation or shoving, remove the distorted pavement and patch and for large corrugated or shoved areas indicative of general HMA failure, remove the damaged pavement and overlay.

h) **Raveling and Polished aggregate:** Figure 9 and 10. Is the photo of the raveling and polished aggregate of the Malik Mahmood ring road. Raveling is loss of material that covered asphalt surface that ranges from loss of fines to loss of some coarse aggregate, while polished aggregate is the surface binder worn away to expose coarse aggregate.

Figure 9. Raveling

Figure 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 shows that there are a wide range of raveling and polished aggregate on the selected pavement, these raveling and polished aggregate, water collecting and loss of skid resistance.

The possible causes of these types of distresses are heavy and repeated traffic volume, water and loss of bond between aggregate particles and the asphalt binder as a result of inadequate compaction during construction. The effective maintenance method for repairing this type of distress is applying a skid resistant slurry seal, remove the defected area and patch or overlaying.

7. Conclusion

This study deals with the practical field investigation to indicate the common flexible pavement distresses that occur in the Sulaymaniyah city/Iraq. The following conclusions can be drawn:

1) Common flexible pavement distresses that occur in the Sulaymaniyah are (fatigue, longitudinal and transverse) cracking, rutting, shoving, raveling, polished aggregate, patching and potholes.
2) Pavements deteriorate under combination of some factors such as traffic loading, change in climate condition, poor drainage system, improper materials of construction.
3) It was pointed out that understanding the causes of pavement deterioration will significantly contribute to the proper selection of effective maintenance technique results in prolonged service life of roads and significant savings for the government.
4) The most effective methods of maintenance of the cracks with low severities in Malik Mahmood ring road are crack seal to prevent moisture entering into road layers through the cracks and for high severities use low grade asphalt mixed with sand to fill the cracks, improve drainage system and for other type of distresses full depth patching or mill the surface and applying on overlay.

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