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Flexible Pavement Evaluation: A Case Study

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Abstract: ***This study is a survey to evaluate the flexible pavement conditions to determine and specify the types of the failures in the pavement for the selected highway. It is very significant to evaluate and identify the causes of the flexible pavement failures and select the proper and best treatment and maintenance type. The study had two major and critical goals which covered by considering the following three tasks; the first was the visual evaluation and inspection of existing flexible pavement conditions including the failures, the second to determine and find out the actual causes of these failures in the pavement, and the third is to select the most and effective treatments and maintenance types. As a case study, Khanaqin-Kalar 2-way 2-lane rural highway was selected for evaluation and inspection purposes. The field evaluation works were achieved on the existing flexible pavement conditions of the selected rural highway. The results were most of the damages and failures in the pavement are serious and extreme surface deformation, cracks, disintegration, and surface defects. These damages and failures are caused by fatigue and other types of failures resulted from the movement of heavy vehicles and trucks, poor drainage design, unsuitable pavement layers thickness design, and improper pavement mix design and selected materials.***

Keywords: Flexible pavement, failure, deterioration, rural highway, evaluation survey.

1. INTRODUCTION

Ordinarily the term pavement only means the surface layer [1]. But in the designing of the highways, it means the pavement total thickness including wearing (surfacing) course, base course and sub-base course. It is hard and tough crust constructed over the natural subgrade in order to provide stable and leveled or flat surface for vehicles. It is a structure consist from overlies layers of materials over the natural subgrade which its primary and major function is to transfer and distribute the vehicles' axle loads to the subgrade. The structure of pavement should provide acceptable riding quality surface, sufficient skid resistance and minimum noise pollution [2].

For designing purposes and depending on structural function and behavior, the road pavements types are generally divided or classified into two types:

i. Flexible (bitumen) pavement.
ii. Rigid pavement.

Other pavement types include semi rigid or composite pavement and interlock (behartoon) cement concrete blocks pavement. These pavement types are less familiar than flexible and rigid pavement [1].

Flexible pavement design is the process and method of selecting the most effective and economical composition of flexible pavement courses or layers (taking in consideration the thickness of the pavement and type of selected materials) to fit the subgrade foundation. And cumulative traffic axle load to be carried and handled during the pavements' design life. Flexible pavement structure design is different from building design and the bridges because of the fact that the design of pavement until today is based on semi-empirical or empirical method and there is no rationalistic design method. Flexible pavement design consists mainly from two steps or parts:

1- Material mix design to be used in each layer of the pavement.
2- Design the structure of the pavement (design the thickness of each layer with its component).

The main and major factors to be taken in consideration in the flexible pavement design are:

1- Traffic volume.
2- Climate and weather conditions along the year.
3- The road geometric design.
4- Position.
5- Soil or subgrade
6- Drainage.

Road maintenance is one of the significant components of the complete road system. Even if the highways are designed and constructed in a good way, they may still require maintenance, the range that will depend on several factors which include the type of pavement [3].

A flexible pavement consists from several layers of granular materials covered with bituminous material (waterproof), and as its name mean, it is considered to be flexible. The flexible pavement will bend (flex) under the applied load of the tyre. The objective of designing a flexible pavement is to avoid extreme flexing of any of the layers, failure or un-ability to achieve its cause over stressing of a layer, which finally will cause the failure of the pavement. In the flexible pavements, the distribution pattern of load changes from one pavement layer to another, because the strength of each pavement layer is different. The least flexible and strongest material is in the top layer and the most flexible and weakest material is in the lowest layer. The reason for that is at the surface the wheel load is applied over small area, the result will be high stress level, and deeper down in flexible pavement, the load will be applied over a

larger area and the result will be lower stress levels, consequently enabling the use of less quality or weaker materials [4].

Pavement failure and deterioration process starts immediately after opening the road to vehicles (traffic). The process of failure and deterioration starts very patiently therefore it may not be noticeable, and over the time it get faster and accelerates at quicker rates. To minimize premature failure and deterioration, it is vital to implement the best method in planning, the designing, construction and maintenance of the highway or the road. It can be accomplished by testing and inspecting pavements that have early failed. The focus was to determine the causes of failure and deterioration in order to be prevented in the future. The biggest understanding of flexible failures which can be gained from detailed evaluation and investigation could be significant in reducing the costs related to pavement failures and deterioration in the future. In many cases the failure and deterioration of flexible pavement structure can be directly justified by insufficient maintenance and insufficient programs of evaluation. Under a limited budget it is very important to reduce and minimize the maintenance costs. For the mentioned purpose it is very important to consider and select a simple way or method for inspection (surveying) and evaluation of flexible pavement failures [5].

Flexible pavement (bituminous) failure and deterioration generally occurs due to combined action of traffic volume and load, weather conditions and changes, drainage and environmental agent. Generally the flexible pavement fail and deteriorate at very fast rate when compared to rigid pavement because the mentioned above factors. Flexible pavements continue to fail and deteriorate at slow rate even without vehicles (traffic) movement on the flexible pavement surface as a result of the weather and environmental factors action. Rate of failure and deterioration of flexible pavement (bituminous pavement) rapidly increase when water is hold in the void spaces of the flexible pavement layers. Oxidation and aging of asphalt (bituminous) binder also lead to the failure and deterioration of the asphalt (bituminous) surfacing [1].

2. LITERATURE REVIEW

Transportation system takes a special role in the economical development of any country. By the good transportation system means; comfortable, safe, rapid, and convenient, the people communication becomes possible and which is fundamental for various goods distribution in the country that is important and basic for its economic, industry and environment. The good highway system is very significant for the developing country to get the way to the modern society. In order to have good transportation system, various factors of failure and deterioration of the highway or road should be taken in consideration. Highway maintenance is very important for the traffic management as a whole. The various defects in the roads resulted from weak maintenance of transportation system are the main accident causes. Therefore a successful and good engineer is a person whose is not only able to design the highway or roads, but also have sufficient skills to maintain the highways and roads [6].

A flexible pavement (bituminous) failure and deterioration is defined by consistence of ruts, cracks, potholes, settlements, localized depression, etc. normally the localized depression is followed with rising in the proximity (vicinity). The sequence creates waves in the surface of the pavement. The failure or deterioration of any one or more of flexible pavement structure components creates the corrugation and waves on the surface of the pavement or rutting and shoving. Unleveled (unevenness) flexible pavement may itself consider as a failure and deterioration when it is excrescent. The flexible pavement failure and deterioration subject is considered to be complicated as several factors participate to its failure and deterioration. The oxidation and aging of asphalt (bituminous) films cause the failure and deterioration of flexible pavement (bituminous pavement). Destructive actions in flexible pavement are quickly increased when surplus water is retained in the flexible pavement void spaces [3].

Flexible pavement failure and deterioration can be considered as functional, structural, materials failure, and a combination of the mentioned factors. Structural failure and deterioration is losing the ability of carrying load, when the flexible pavement not any more able to absorb, transmit and distribute wheels load through the road structure without causing extra or more failure and deterioration. Functional failure is a boundary (border) term which may refer to the loss of any function of the flexible pavement such as structural capacity, skid resistance, and serviceability or passenger comfort. Material failure result from the loss or disintegration of material characteristics of any of pavement component materials [7].

Flexible pavement deterioration and failure is defined as a decreasing in the serviceability resulted from the development of surface failure and deterioration such as rutting, cracking and potholes [8]. It was reported that the highway engineers should look into the causes of flexible pavement (bituminous pavement) before going into the strategies of the maintenance. It was found that deterioration and failure of flexible pavement are resulted from combination or many of reasons. It has been noticed that only three factors; rutting, unevenness index and cracking are considered while other failures have been neglected while going to maintenance [5].

The major types of flexible pavement failures are failure of surface texture or deformation failure. Deformation failures and deterioration include rutting, shoving, depression, corrugation and potholes. These failures and deterioration may result from traffic volume (load associated) or environmental influences (non-load associated). It might reflect serious problems in materials or

underlying structure that may cause cracking. Failure in the surface texture includes polishing, bleeding, cracking, raveling and stripping. These failures in the flexible pavement show that while the road pavement could be structurally sound, the surface is not functionally performing which designed for, which normally providing skid resistance, water tightness and smooth is running surface. Other various types of flexible pavement failures and deterioration include patching, edge defects and roughness [5].

The evaluation survey and assessment of the flexible pavement roads and highways is advantageous for transportation engineers because the reasons in the following:

1- It gives and provides accurate reason of flexible pavement failure and deterioration which makes the maintenance works easy.
2- Will provide good knowledge about flexible pavement failure and deterioration, which make the transportation engineers able to design and make high quality and performance roads and highways flexible pavement.
3- Study the failure and deterioration 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.

The objective of current study can be summarized in the following:

1- Visual evaluation and inspection of existing flexible pavement conditions including the failures and deterioration.
2- Determine and find out the actual causes of these failures and deterioration in the flexible pavement.
3- Select the most proper and effective treatments and maintenance types.

3. FACTORS EFFECTING AND INFLUENCING THE FLEXIBLE PAVEMENT PERFORMANCE

The major factors that influencing the flexible pavement performance [4]:

3.1. Traffic Volume and Load

It is the most significant and influential factor effecting and influencing flexible pavement performance. The flexible pavement performance is mostly affected and influenced by the traffic load magnitude, loading configuration, and heavy vehicles load repetitions number.

3.2. Moisture or Water

Moisture is considerably and significantly affect the flexible pavement by weaken the natural gravel materials especially the subgrade support strength. Moisture or water enter the flexible pavement structure through holes and cracks in pavement surface, laterally (horizontally) through subgrade soil and from the water table (underlying) by the action of capillary. The results of moisture or water entry are lubrication of particles, interlock loss between the particles and later particles displacement which cause flexible pavement failure and deterioration.

3.3. Subgrade Soil

Subgrade is the flexible pavement underlying soil that support and handle the applied vehicles wheel loads. Too weak subgrade will fail to support and handle the vehicles wheel loads, which cause the pavement to flex extremely which finally cause the failure of the flexible pavement. If the flexible pavement designer not taking the difference in natural composition of subgrade soil in consideration, significant and important differences in the flexible pavement performance will be witnessed.

3.4. Construction Quality

Failure to provide adequate compaction, inappropriate moisture content or conditions during the pavement construction, materials quality, and providing accurate flexible pavement layers thickness (after the compaction is finished) all mentioned conditions will effect directly on the performance of the flexible pavement. It is very important and significant to provide skillful staff, good and adequate inspection and a procedure of quality control during the construction works.

3.5. Maintenance

Regardless how well the flexible pavement is built, it will start to deteriorate and fail over the time. The performance of flexible pavement depend on what type of maintenance, when to be done and how to be performed.

4. TYPES OF FLEXIBLE PAVEMENT FAILURE OR DETERIORATION

The common types of failure or deterioration in flexible pavement are classified in to the following four major groups [1]:

i. Surface deformation
   - Corrugations
   - Rutting
   - Shoving
   - Shallow depressions
   - Settlement and Upheaval
ii. Cracking
   - Fatigue Cracking
   - Transverse Cracking
   - Longitudinal Cracking
   - Edge Cracking
   - Reflective Cracking
iii. Disintegration
   - Potholes
   - Patches
iv. Surface defects
   - Raveling
   - Bleeding

The common types of flexible pavement failure or deterioration and its expected or possible causes are listed in Table 1 [8] [3] [4].

Table 1: The common flexible pavement failure types and their expected or possible causes [3] [4] [8] .

Failure Type	Expected or Possible Causes
Alligator cracking	• Fatigue failure due to flexible/brittle base. • Inadequate pavement thickness.
Block cracking	• Reflection of joints cracking in underlying base.
Longitudinal cracking	• Reflection cracking. • Poor paving lane joint. • Pavement widening. • Cut/fill differential settlement. • Fatigue failure of asphalt concrete.
Transverse cracking	• Reflection of shrinkage cracking. • Construction joints.
Rutting	• Inadequate pavement thickness. • Post construction compaction. • Instability of base surfacing.
Shoving	• Poor bond between layers. • Lack of edge containment. • Inadequate pavement thickness.
Depression	• Settlement of service trench or embankment. • Isolated consolidation. • Volume change of subgrade
Corrugation	• Instability of asphalt concrete or base course.
Edge drop	• Inadequate pavement width. • Erodible shoulder material (lack of plasticity).
Edge break	• Inadequate pavement width. • Inadequate edge support. • Traffic travelling on shoulder edge drop. • Weak seal coat/loss of adhesion.
Raveling	• It is a result of insufficient adhesion between the asphalt cement and the aggregate. • Initially, a fine aggregate break loose and leaves small, rough patches in the surface of the pavement.
Potholes	• Potholes are often located in areas of poor drainage. • Potholes are formed when the pavement disintegrates under traffic loading, due to inadequate strength in one or more layers of the pavement, usually accompanied by the presence of water.
Polishing	Caused by traffic movement (vehicles movement).
Patches	• Filling the holes with asphalt concrete without cleaning and preparing and doing the required works for maintenance. • Filling the holes without doing proper leveling and compaction.

5. METHODOLGY

The deformation response of flexible pavements under traffic loading is characterized by recoverable deformations and permanent deformations. The permanent deformation is much smaller than the recoverable deformation and, as the number of load repetitions increases, the plastic strain due to each load repetition decreases. The deformation of materials is the result of three mechanisms: the consolidation mechanism (the change in the shape and compressibility of particle assemblies); the distortion mechanism characterized by bending, sliding, and rolling of the particles; and the crushing and the breaking of the particles occur when the applied load exceeds the strength of particles [9].

This study conducted to estimate and predict the flexible pavement road failure rate with particular references to cracking and other types of failures and deteriorations using available data. Data for the study was collected from related government departments (data related to the history of the selected highway and its construction) and an exploratory evaluation survey of the selected highway. The exploratory survey is a method employed in road performance modeling and is chosen in this study in order to scientifically evaluate the road.

The adopted methodology is as follows:

1. Identification and selecting the proposed study area.
2. Review of the performance, behavior, failure and deterioration of flexible pavements exposed and subjected to traffic and local climatic conditions.
3. Collection of relevant data from related government departments.
4. Analyzing the collected data in order to create clear and scientific evaluation of the selected highway.
5. Discuss the suitable and appropriate solutions based on the pavement failures and deteriorations.

6. THE CASE STUDY AND STUDY AREA

For the purposes of this study Khanaqin-Kalar 2-lane 2-way rural highway selected. This rural highway is connecting Khanaqin City the center of Khanaqin District with Kalar City the center of Kalar District. The length of this rural highway is 33 Km of flexible pavement, and it is one of the very important highways because it is working as a connecting link between Diyala Governorate with Sulaimaniya and Kirkuk Governorates from the northeast of Iraq in addition to that it is leading to Iraq-Iran border (see **Figure 1 and 2**).

In 2005 Kurdistan Ministry of Rehabilitation and Housing\ Garmian Directorate of Roads and Transportation, established this 2-lane 2-way rural highway by repaving existing two sections (marked with red color in **Figure 1**) by new asphalt layer and connected them by constructing new section (marked with green color in **Figure 1**), and since then this highway is maintained only one time during its life but still suffering from severe types of failure and deterioration.

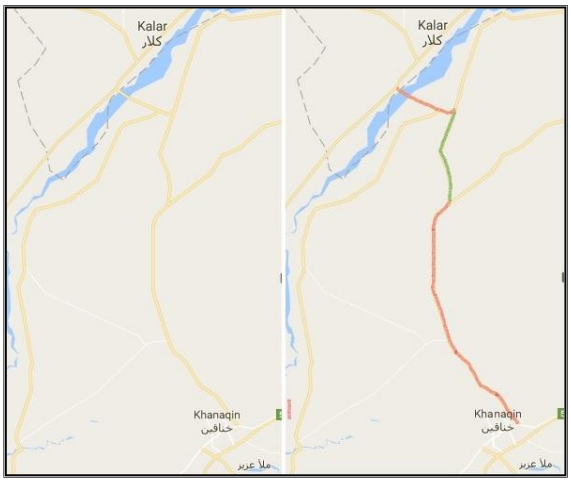

Figure 1 Khanaqin-Kalar 2-lane 2-way rural highway route location (Google Map)

Figure 2 Khanaqin and Kalar locations in the northeast of Iraq (Google Map)

7. RESULTS OF THE EVALUATION SURVEY AND ASSESMENT

As mentioned above Khanaqin-Kalar 2-lane 2-way rural highway, established in 2005 by Kurdistan Ministry of Rehabilitation and Housing\ Garmian Directorate of Roads and Transportation. This highway consists of three sections with the following information (see **Figure 3**):

- Section 1: from Khanaqin city to Sauz-Balakh village (20 Km length). It was existed flexible part re-paved in 2005 with new layer of asphalt.
- Section 2: from Sauz-Balakh village to Saleh Agha villages (8 Km length). It completely new construction in 2005.
- Section 3: from Saleh Agha village to Kalar city (5 Km length). It was existed flexible part re-paved in 2005 with new layer of asphalt.

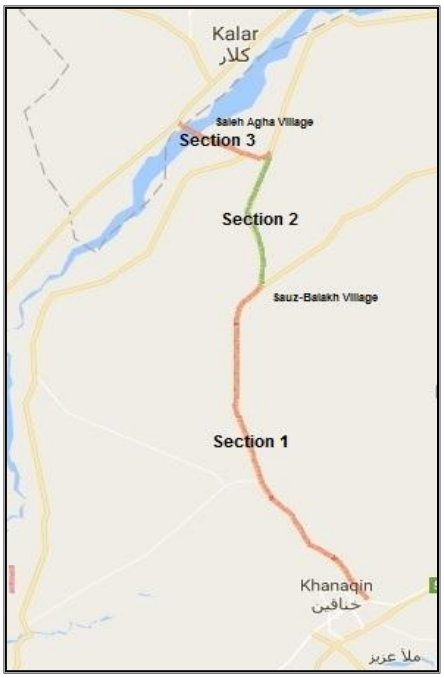

Figure 3 Khanaqin-Kalar rural highway three sections (Google Map)

In order to determine and evaluate the existing conditions of the selected rural highway, a several field assessment survey conducted on the three sections of the highway. The results of the evaluation filed assessment survey showed that the pavement of this rural highway is suffering from the following types of failure and deterioration:

- Rutting (see **Figure 4**)
- Cracking (alligator cracking, block cracking and edge cracking) (see **Figures 5, 6, 7, 8, 9, 10, 11 and 13**).
- Potholes (see **Figures 9, 10, 12 and 13**)
- Polishing (see **Figures 9, 11 and 12**)
- Depression (see **Figures 6, 10 and 11**)
- Raveling (see **Figures 9 and 10**)
- Patching (see **Figure 10 and 13**)

Figure 4 Rutting in the pavement of Khanaqin-Kalar rural highway

Figure 5 Severe blocking cracking failures in the pavement of Khanaqin-Kalar rural highway

Figure 6 Severe Edge cracking and breaking, alligator cracking and depression failures in the pavement of Khanaqin-Kalar rural highway

Figure 7 Severe edge cracking and breaking, block cracking, and alligator cracking failures in the pavement of Khanaqin-Kalar rural highway

Figure 8 Edge and block cracking failures in the pavement of Khanaqin-Kalar rural highway

Figure 9 Severe edge break and cracking, block cracking, alligator cracking, potholes, polishing, raveling and polishing failures in the pavement of Khanaqin-Kalar rural highway

Figure 10 Severe potholes, raveling, alligator cracking Depression and bad patching failures in the pavement of Khanaqin-Kalar rural highway

Figure 11 Polishing, Depression and alligator cracking failures in the pavement of Khanaqin-Kalar rural highway

Figure 12 Polishing and pothole failures in the pavement of Khanaqin-Kalar rural highway

Figure 13 Bad patching, block cracking, alligator cracking, and pothole failures in the pavement of Khanaqin-Kalar rural highway

The results of the evaluation survey and assessment for Khanaqin-Kalar rural highway total length and its three sections are illustrated in **Table 2** and **Figures 14, 15, 16 and 17.**

Table 2: The results of the evaluation survey and assessment for Khanaqin-Kalar rural highway as a whole and its three sections

Type of the Failure or Deterioration	**Percentage of the Damage in the Highway Based on the Failure Type (%)**			
	Section 1 (20 Km)	**Section 2 (8 Km)**	**Section 3 (5 Km)**	**Total Length of the Highway (33 Km)**
Rutting	15	0	100	24.24
Alligator Cracking	27	5	0	17.57
Block Cracking	20	2	0	12.6
Edge Cracking	15	2	2	9.87
Potholes	42.5	50	5	38.63
Polishing	35	90	40	49
Depression	30	1	1	18.57
Raveling	20	50	0	24.24
Patching	3	2	2	2.6

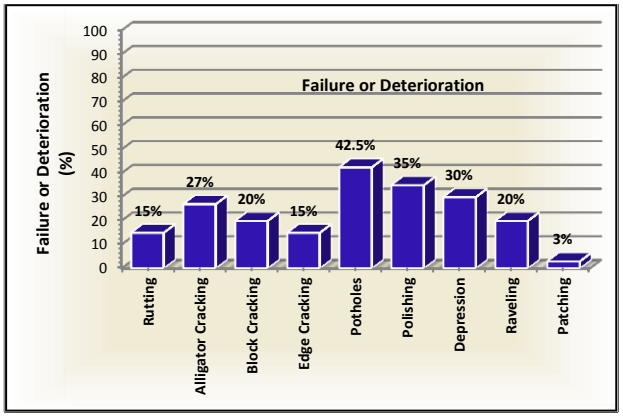

Figure 14 The results of the evaluation survey and assessment for section 1 of Khanaqin-Kalar rural highway

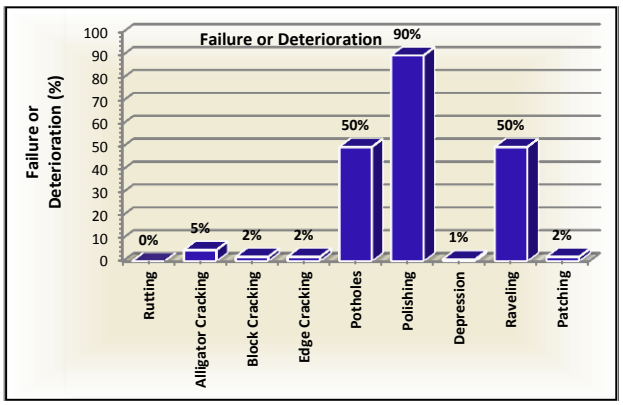

Figure 15 The results of the evaluation survey and assessment for section 2 of Khanaqin-Kalar rural highway

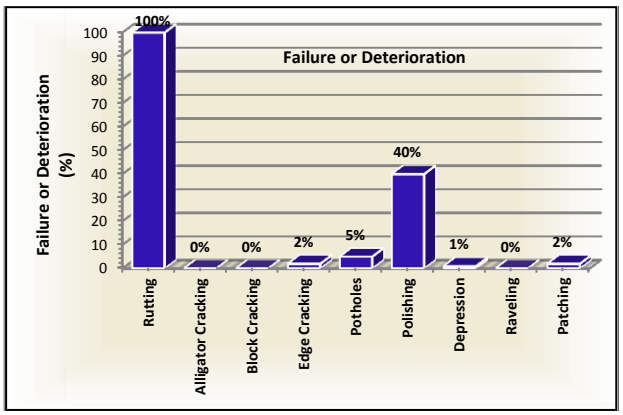

Figure 16 The results of the evaluation survey and assessment for section 3 of Khanaqin-Kalar rural highway

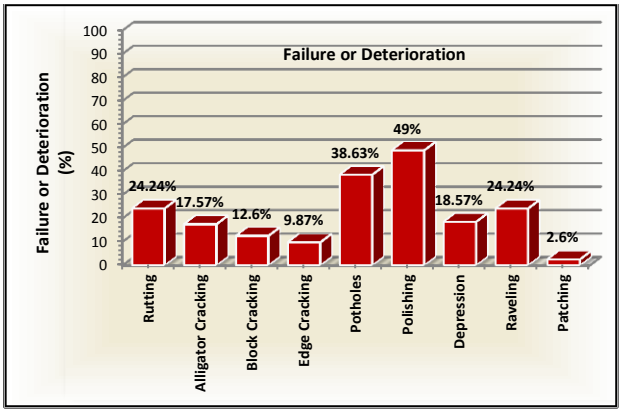

Figure 17 The results of the evaluation survey and assessment for the total length of Khanaqin-Kalar rural highway

8. DISCUSSION

The results of the evaluation survey and assessment showed that Khanaqin-Kalar rural highway suffer from several types of pavement failures or deteriorations. Each section of the three sections of the rural highway is evaluated separately, as sections 1 and 3 were existed parts and re-paved and section 2 was completely new construction in establishing Khanaqin-Kalar rural highway in 2005.

The results of evaluation survey and assessment for the three sections of Khanaqin-Kalar rural high clearly indicated that there are number of severe failures and deteriorations in the pavement of these sections as in the following:

I. Section 1: a significant percentage of the length and area of this section of the rural highway suffer from most of the types of pavement failure and deterioration (see **Table 2** and **Figure 14**). The types of the failures with its percentages in section 1 and the expected causes of the failures are listed in below:
   - Rutting (15% of section 1): the expected cause of this failure is in 2014 the highway used as alternative way by big number of traffic with heavy axel load resulted from big trucks, big trailers and military trucks and machines due to closing Kirkuk-Baghdad highway because of military operations (war against ISIS terrorist groups). The thicknesses of pavement layers of this section were not designed to carry such big number of traffic and heavy axel loads, therefore rutting failure occurred.
   - Alligator cracking (27% of section 1): the expected causes are fatigue failure and un-adequate pavement layers thickness to carry un expected traffic loads (in 2014 the highway used by big number of traffic with heavy axel load resulted from big trucks, big trailers and military trucks and machines due to closing Kirkuk-Baghdad highway because of the military operations of the war against ISIS terrorist groups).

- Block cracking (20% of section 1): the expected causes are hot mix asphalt shrinkage and daily temperature changing (cycling). Generally caused by un-ability of asphalt binder to expand and contract with temperature changes (cycles) because of asphalt binder (bitumen) aging.
- Edge cracking (15% of section 1): caused by excess moisture resulted from bad drainage and lack of shoulders support due to weak materials.
- Potholes (42.5% of section 1): In general, potholes are the final result of alligator cracking. As alligator cracking becomes severe, the interconnected cracks create small blocks of pavement which displaced as vehicles pass over them. The remaining hole after the pavement block is displaced is called a pothole.
- Polishing (35% of section 1): caused by repeated big traffic volume on an aging flexible pavement. It can cause a dangerous low friction surface with a low skid resistance.
- Depression (30% of section 1): caused by subgrade settlement resulted by insufficient compaction during construction or soft (poor quality) subgrade.
- Raveling (20% of section 1): caused by inadequate adhesion between the asphalt (bitumen), filler and the aggregate. This type of failure typically occurs on an older pavement that has already oxidized, and it can be accelerated by the environmental conditions and traffic volume.
- Patching (3% of section 1): resulted from bad maintenance, where the damaged or failed pavement to cleaned or removed in proper way before laying the new pavement and also the new pavement is not leveled and compacted in proper and standard way.

II. Section 2: this section of the rural highway suffer from 8 types of failures (see **Table 2** and **Figure 15**), but in general most of the failures and deteriorations in this section are less severity than in section 1. The types of the failures with its percentages in section 2 are listed in below:
    - Alligator cracking (5% of section 2)
    - Block cracking (2% of section 2)
    - Edge cracking (2% of section 2)
    - Potholes (50% of section 2)
    - Polishing (90% of section 2)
    - Depression (1% of section 2)
    - Raveling (50% of section 2)
    - Patching (2% of section 2)

The causes of the failures and deteriorations in section 2 are the same as for section 1 of the rural highway.

III. Section 3: this section of the rural highway suffers from 6 types of failures (see **Table 2** and **Figure 16**). The percentages of 4 types of failures and deteriorations in this section are small (edge cracking, potholes, Depression and patching). The types of the failures with its percentages in section 3 and the expected causes of the failures are listed in below:
    - Rutting (100% of section 3): the expected causes of this failure are:
        - This section is carrying additional traffic which is going to and coming from Parwiz-Khan border point with Iran. All the additional traffic is heavy axel load vehicles (big trailers and truck).
        - In 2014 the highway used as alternative way by big number of traffic with heavy axel load resulted from big trucks, big trailers and military trucks and machines due to closing Kirkuk-Baghdad highway because of military operations (war against ISIS terrorist groups). The thicknesses of pavement layers of this section were not designed to carry such big number of traffic and heavy axel loads, therefore rutting failure occurred.
    - Edge cracking (2% of section 3)
    - Potholes (5% of section 3)
    - Polishing (40% of section 3)
    - Depression (1% of section 3)
    - Patching (2% of section 3)

Except the rutting failure, the causes of the failures and deteriorations in section 3 (edge cracking, potholes, polishing, depression and patching) are the same as for section 1 of the rural highway.

The result of the evaluation survey and assessment of the full length of Khanaqin-Kalar rural highway show that this rural highway suffers from serious problems. The pavement of this rural highway suffers from 9 types of failures and deteriorations (see **Table 2** and **Figure 17**).

9. CONCLUSION

1- Most the types of the failures and deterioration were found along the Khanaqin-Kalar rural highway.
2- The severity of the failures and deteriorations ranges from medium to high in the pavement of the rural highway.
3- The major causes of the failures and deteriorations in the selected rural highway are:
    - Additional traffic volume with high axel loads which were not taken in consideration during designing the pavement layers thicknesses of the selected rural highway.
    - Poor or absent of drainage design.
    - Unsuitable pavement layers thickness design.

- Improper pavement mix design and selected materials.

4- The suggested maintenance or treatments are:
   - The highway shoulder improvement.
   - Removing the heavily damaged or structurally destroyed pavement and patching its places.
   - Overlying with new layer of asphalt pavement with adequate thickness.

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Biography

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