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RESEARCH ARTICLE OPEN ACCESS

Causes of Failure of Asphalt Pavements in Hot Countries (Kuwait)

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ABSTRACT
Asphalt pavement deteriorates in a variety of ways depending on the quality of mix design, loading conditions and environmental conditions. The extreme climatic conditions with regards to temperature coupled with improper mix design accelerates the rate of failure of asphalt pavements in Kuwait. Asphalt pavement failure for instance rutting, fatigue cracks and raveling are exacerbated in high temperature, excessive traffic loads and high humidity levels as is common in Kuwait. This study analyzes the impact of these features in general and then with particular emphasis on the conditions present in Kuwait.

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I. INTRODUCTION

1.1 Background

Pavement failure is the development of distresses in a pavement structure due to the effect of a combination of environmental conditions or traffic loading. This phenomenon leads to reduction of riding quality, loss of serviceability and hampering of road safety. Naturally, due to continued use, newly constructed roads deteriorate with time and therefore need to be continuously maintained to satisfy safety, durability and quality standards. This deterioration takes place slowly during the initial lifetime of a road (between the first and fifteenth year) and then accelerates following that. The most experienced types of failures are; potholes, cracks, damaged edges, depressions, raveling and rutting.

Asphalt pavement is a widely used pavement material in highway construction. It offers benefits in comfort, ease of maintenance, high flatness, sturdiness and wear resistance alongside its skid resistance and durability. Just like any other pavement, asphalt pavements also experience diseases such as cracks, water damage, potholes and oil spills.

1.1.1 Types of pavement failures

Failure type	Mode of occurrence
Cracking	Fatigue cracking, edge cracking, reflective cracking, slippage cracking, longitudinal cracking, block cracking
Surface deformation	Corrugations, swell, rutting, shoving, depressions
Disintegration	Patches and potholes
Surface defects	Bleeding, polishing, raveling, delamination

Cracks
These appear during construction or during the service life of a road section. They can be structural, longitudinal or horizontal. They are caused by environment, climate, axle loads and floor strength differentials.
Potholes
It is uncommon for asphalt pavements to experience water damage in the early years or their construction due to the advancements in asphalt technology. However, temperature expansion and contraction paired with repeated wheel loading ruts and cracks the road surface, enabling water to erode the asphalt layer.
Rutting and oil flooding
The latter is caused by high petroleum content in bitumen which reduces its porosity while rutting is caused by repeated wheel actions.

Raveling
This is the dislodging of particles of coarse aggregate due to poor quality of mix, inadequate asphalt binder, insufficient compaction, stripping or segregation.

1.2 Research Objective

1.2.1 Overall objective

To investigate the causes of asphalt pavement failure in Kuwait

1.2.2 Specific objectives

- Determine causes of asphalt pavement failure
- To investigate specific conditions in Kuwait that cause asphalt pavement failure

II. LITERATURE REVIEW

2.1 Causes of Asphalt pavement failure

2.1.1 Raveling

This is the disintegration of the surface layer of hot mix asphalt due to dislodging of aggregates. This causes loose debris hence increased surface roughness that provides a zone for water collection which leads to vehicle hydroplaning and reduced skid resistance. Raveling hastens the development of further distresses such as potholes and fatigue cracks.

Raveling rate is stimulated by the following factors;

- Lack of quality control during construction. Improper regulations on properties such as moisture content of asphalt mix, aggregate quality, and compaction beyond optimum temperatures, inadequate compaction and incorporation of contaminated materials such as dust filled aggregates.
- Poor asphalt mix quality. Inadequate binder amount, excessive air filled voids and coarse aggregates inhibit the design properties of the mixture.
- Influence of heavy and concentrated traffic loads.
- Extreme changes in weather conditions. The influence of cyclic changes of moisture are magnified during evaporation or freezing.

(Liantong Mo, et al., 2009) Has posited the theory that associated raveling with stripping from moisture damage. This stripping is related to either poor adhesion between aggregate particles and the asphalt binder or cohesive failure of the asphalt mastic. This cohesion failure is associated with high temperatures and can be due to continuous traffic loads that cause recurrent confining stresses. The former, adhesive failure is associated with low temperatures. It forms at the stone-binder interfacial layer and is synonymous with strains. These strains are of tensile type and are accelerated by thermal contraction and deflection of the asphalt pavement.

(Jr, et al., 2003)Related several properties of the asphalt binder that influence the pavement susceptibility to stripping. A highly viscous binder indicates a greater concentration of large polar molecules, enhancing adhesion. A lowly viscous binder implies low asphalt concentration which encourages stripping.

2.1.2 Temperature

Temperature changes within a pavement structure cause distress and failure. Daily variations in temperatures and gradients across the depth of the pavement can lead to the following issues;

- Cracking due to large temperature differentials between exterior and interior environment
- Loss of strength due to concrete freezing prior to achieving maximum strength
- Loss of strength due to excessively high interior temperatures.

2.2 Making the case for hot climates (Kuwait)

Kuwait is located in Western Asia, experiencing extreme climatic and traffic loading conditions in the form of very high temperatures and high traffic loads.

2.2.1 Mix design and materials used in Kuwait

Mix design

The Marshall Mix design procedure is the official mix design method. This old method has contributed to the severe raveling experienced on Kuwaiti roads. This empirical design procedure does not have a measure of shear strength. The Ministry of Public Works places the cause of premature raveling on the rainy season and poor asphalt binder properties.

(Ahmed, et al., 2023) Investigated the strength of three types of asphalt pavement concrete mixes with thicknesses and properties determined using the following methods; the newly introduced super pave asphalt mix, the widely used Marshall Mix and the mix method designated in AASHTO Guide to the Design of Pavement Structures. The results showed that the recently introduced super pave mix design was better in resistance to fatigue cracking and rutting. However the pavement from AASHTO guide still needs improvement like increased thickness to withstand longer design periods exceeding 20 years of 30 MESALS of traffic. The Pavement design using Marshall Method proved inadequate for both fatigue resistance and strength against 30 MESALS of traffic for a 20 year design life.

2.2.2 Raveling

(Ahmed, et al., 2021)Performed both laboratory and field evaluation on asphalt pavements in Kuwait to investigate the causes of raveling and its effect on Hot Mix Asphalt pavement performance. The study covered the four functional road classes in Kuwait; Local roads, collector roads and arterial roads. Results showed that newly laid pavements with less

than 3 years of regular maintenance experienced premature raveling at sufficiently serious levels to warrant pavement performance description as low. An appreciable percentage of pavements considered had low moisture damage resistance and permanent deformation. This increased the likelihood of raveling of pavements.

Kuwait lacks access to binder grades and is therefore only uses bitumen of 60/70 penetration grade for all mixes. The high temperatures greater than 500C in summer (Michaelson, 2) age the asphalt binder significantly faster than expected. This shows that asphalt binder properties are heavily influenced by Kuwait's high temperatures.

(Kandhal, et al., 1996) Related Asphalt film thickness to aging properties of the mix. There is positive correlation between the film thickness and the short and long term asphalt binder properties for instance complex modulus, penetration and viscosity. On comparing the optimum film thickness of between 9 and 10 micrometers and those calculated from the (Ahmed, et al., 2021)studies, the following observations were made;

- Sections with a higher film thickness value than the optimum accelerated the rutting amount
- Sections with lower film thickness than the optimum contributed to increased rate of aging in those sections.

These factors meant that Kuwait pavements have poor adhesion between asphalt binders and the aggregates. This inadequate adhesion allows moisture interaction with the asphalt at the binder-aggregate interface. This increases the susceptibility to moisture damage during repeated loading with causes stripping failure.

2.2.3 Temperature

(Bisssada, 1972) Studied the effect of Kuwait temperatures on asphalt pavements. The research showed that the asphalt surface course suffered significant temperature extremes. A 9 hour summer day saw temperature fluctuations between 32^0C and 74^0C with a yearly minimum and maximum of 50^oC and 74^oC.

On flexible pavements, temperature dictates the asphalt grade to be used and the traffic load allowable. The four asphalt binder performance grade that can be used within the temperature ranges of gulf countries' climate are; 58-10, 64-10, 76-10 and 70-10.

III. DISCUSSION

Asphalt pavements performances are affected by the following factors; mix design quality, environmental conditions such as temperature and moisture effects, amount of traffic loading and pavement thickness. Several conditions exist in Kuwait that serves to increase the likelihood of asphalt pavement failure. This includes the high temperature regularly experienced in the country. High temperature mix design is different from low temperature mix design due to its influence on the stiffness modulus of asphalt. Lowered stiffness reduces the modulus of resilience as radial stresses develop in the base course under the asphalt layer. The stability and load-spreading properties of the pavement are affected by this (Bissada, 1999). The widely used mix design method in Kuwait does not consider these effects. Successful asphalt pavements design considers the range within which the pavement will be subjected. In desert climates such as Kuwait, surface and pavement temperatures range between 3^0C and 72^oC for coastal slabs and 4^oC to 65^oC for inland slabs. This causes a wide variation in asphalt concrete modulus that is not addressed in the mix design method most widely used in Kuwait.

From a review of available data, most Kuwaiti pavements are under-equipped for actual traffic levels experienced, ranging from 3, 10 to 30 MESALS. This is exacerbated by the frequent fatigue cracking failures which further hinder the pavements' durability in the course of their design lives. The weak support layer brought about by the type of materials used for instance type of binder, is also at fault for early pavement fatigue cracks. These cracks encourage moisture intrusion while the influence of widely varying temperature on the intruded water decreases the fatigue life of the pavements.

IV. CONCLUSION

In hot countries such as Kuwait, it is often the extreme temperatures and their duration that demand special attention in the design and analysis of asphalt pavement performance. However, this study shows that several other conditions such as the widespread use of outdated mix design methods and use of binders of insufficient quality also accelerate asphalt pavement failure. In particular, surface cracking and raveling are the most common forms of failure. There has, however, been recent progress in improving the quality of asphalt mixes in the form of the newly introduced super pave mix.

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