# Gap Analysis and Roadmap for Improvement of Asphalt Pavements in Kuwait

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ABSTRACT: This paper documents the findings of a study conducted by the Kuwait Institute for Scientific Research (KISR) to identify primary factors contributing to low ride quality, performance, and durability of asphalt pavements in Kuwait. The study was motivated by the initiation of major rehabilitation and reconstruction projects that aim to rectify major distresses in asphalt pavements. The study conducted detailed gap analysis of factors that have potential to adversely affect the performance of asphalt pavements in Kuwait. Consequently, the study outlined the main elements of a roadmap that aims to improve specifications, material selection, mixture design, mixture testing, mixture production, construction operations, evaluation, preservation and rehabilitation techniques.

## 1 INTRODUCTION

There have been several studies and reports in recent years documenting problems with severe raveling in Kuwait. This problem was compounded following heavy rainy seasons (Ahmed et al. 2021). Almutairi and Alfadhli (2023) attributed such distresses to a combination of factors, including lack of quality control during construction, poor mixture design in terms of low bitumen (or asphalt binder) content and high air voids, unregulated axle loading, and rain intensities higher than the typical rates recorded in previous years. A review of several investigation reports by government committees highlighted poor quality control and quality assurance procedures in relation to all asphalt mix production & paving operations, and furthermore major shortcomings when using a thin open graded asphalt wearing course mix type locally known as Plant Mix Seal (PMS) as the preferred rehabilitation solution on motorway & high speed roads. Details of the PMS composition are described in section 409 of Kuwait Specifications (Ministry of Public Works Administration 2012) and key attributes summarized in Table 1. This mix has a higher bitumen content than other mixture designs in Kuwait and the region. It is also specified to have a minimum air void of 15%, which is very high for hot climate regions that do not typically have high rain intensities. Some of the technical committees the Ministry of Public Works formed indicated existing mixtures did not incorporate antistrip additives, weakening the resistance to moisture damage in heavy rain seasons.

Additionally, Kuwait Institute for Scientific Research conducted a study to evaluate prevalent asphalt pavement maintenance practices (Al-Owmi et al., 2024). This study identified several gaps, such as the lack of a comprehensive local maintenance and rehabilitation guide, inadequate machinery calibration, and limited personnel certification programs. The outcomes of this study highlighted the need to adopt international standards to enhance local maintenance practices and pavement management systems to improve quality and durability in Kuwait's pavements.

Table 1: Composition of Plant Mix Seal, extract from Kuwait General Specifications 2012 (Ministry of Public Works Administration 2012).

| Sieve Size | Percent passing by weight | Maximum Allowable Tolerances from the Job Mix Formula |
|---|---|---|
| 1/2 inch | 100 | 0 |
| 3/8 inch | 95 - 100 | ± 5 |
| No. 4 | 30 - 50 | ± 7 |
| No. 8 | 5 - 15 | ± 3 |
| No. 200 | 3 – 6<br>Gradation may include hydrated lime | ± 2 |
| Asphalt Cement (% by weight of aggregate) | 5.5 to 7.5 | ± 0.4 |
| Antistripping Additive (% by weight of bitumen) | 1.5 Maximum | - |

## 2 OBJECTIVES

The primary objectives of this preliminary study were to:

- Conduct a gap analysis of the various technical factors that may have contributed to Kuwait's poor performance of asphalt pavements.
- Review current specifications used in Kuwait and recommend improvements to various as-

pects of material selection, testing, quality control/acceptance, construction specifications, and rehabilitation practices.

- Outline the main elements of a roadmap to improve asphalt pavement design, construction operations, and performance.

## 3 GAP ANALYSIS OF MATERIAL SPECIFICATIONS

Following the significant problems of raveling in Kuwait in winter 2018, which affected both conventional and PMS type asphalt wearing courses, the Ministry of Public Works in Kuwait took the decision to adopt the Qatar Construction Specifications (QCS), issued in 2014. This decision was motivated by the fact that the QCS had originally been specifically designed for the road network in Qatar which has similar environmental and traffic conditions to Kuwait, and that the QCS has since undergone major reviews and updates. However, this study concluded that following almost 5 years of full adoption in Kuwait, certain aspects of the QCS were found to be lacking and that the QCS-2014 requires an update given taking into consideration the local & regional/international experiences and developments in over the past decade. The main issues that require updates are:

- The Marshall design specifications in QCS have restrictive gradation bands and relatively low binder contents. The aggregate gradation bands should be wider (less restrictive than the current bands) to facilitate more flexibility in achieving a balanced mix design. Consequently, more significant benefits from the properties of polymer-modified binders (PMBs) in terms of resistance to rutting can be expected while simultaneously achieving better resistance to fatigue cracking and thermal aging).
- QCS 2014 specifies polymer-modified binders (PMB) with grades of PG76S-10, PG76H-10, PG 76V-10, and PG 76E-10 based on AASHTO M332. This temperature grade is suitable for Kuwait's climatic conditions. Recently, MPW-Kuwait specified using PG 76H-10 for highways and other heavily trafficked roads (Ministry of Public Works 2307-2019). This recommendation is a major improvement since existing pavements in Kuwait were constructed primarily using unmodified asphalt binders (Pen 60/70, equivalent to PG 64-10).
- QCS has Quality Control (QC) specifications for relative density and in-place air voids. Relative density relates the density of the field core to the density of laboratory-compacted specimens of mixtures taken from the field. The specimens are compacted using the design number of blows in the Marshal method or the design number of gyrations in the Superpave method. Including both criteria (relative density and in-place air voids) could lead to conflicting results. Also, using relative density can lead to high air voids in the pavement that will negatively affect performance. It is therefore recommended that only percent air voids be used instead of relative density.
- The specifications of the Superpave mix design criteria require 125 gyrations for compaction under high traffic conditions (> 30 million ESLAs), which has generally led to dry mixes with low bitumen content. Lowering the gyration levels for high traffic is recommended to design more durable mixes.
- The QCS specifications do not include tests to achieve a balanced mix design between cracking and rutting resistance. It is recommended that mixture tests and associated specifications be included. This will lead to a more balanced mixture design. Figure 1 includes initial recommendations based on experiences gained in the performance of roads in regions in the United States with hot climatic conditions in the United States. Adopting such characterization tests will promote a more balanced mixture design that achieves improved resistance to both cracking and rutting. Following the adoption of QCS 2014 in 2018, the frequency & intensity of rutting related distresses across the network have been significantly improved whilst raveling has been almost completely eliminated, nonetheless several roads in Kuwait exhibited premature cracking, particularly fatigue and thermal induced cracking. This issue may be attributed arose due to high gyratory compaction levels (125 gyrations), restrictive gradation bands, and low bitumen content, resulting in relatively more stiff and brittle mixes. These specification limits will need to be updated based on tests conducted on mixtures in Kuwait.

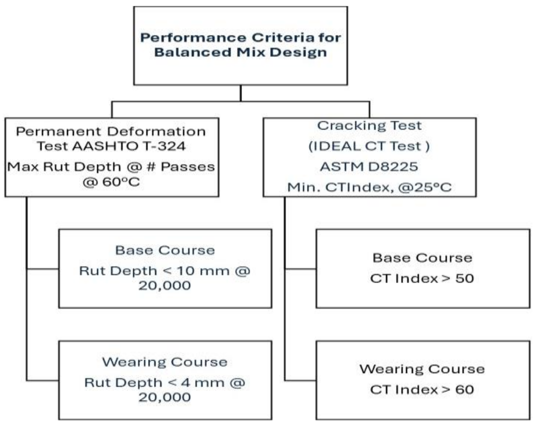


Figure 1. Preliminary recommendations for performance tests and criteria.

- Current specifications do not sufficiently cover the design of recycled asphalt pavements. In addition, the specifications must include guidelines and procedures for evaluating the performance of asphalt mixtures that include recycled materials.

It is recommended that the Superpave mix design criteria be adopted as the preferred methodology. While Superpave itself does not inherently increase binder content, this study recommends increasing binder content within the Superpave framework to improve mix durability and resistance to premature cracking in Kuwait's conditions. The increase in bitumen content combined with the use of PG 76-10 grade PMB and a strong aggregate structure will contribute to achieving a balanced mix design as part of the Superpave mix design framework.

## 4 RECYCLED ASPHALT PAVEMENTS

Incorporating RAP into the hot mix production process is cost-effective and environmentally friendly. Specifically, RAP saves money in areas where high-quality aggregates are scarce or importing virgin aggregate is more expensive. Using RAP in rehabilitation and new pavement construction can also reduce the demand for landfills.

The study developed guidelines for RAP stockpiling, management, and plant processing to maximize its use. Multiple techniques exist to introduce RAP into the hot mix batch facility. The optimum process will vary depending on the condition of the RAP, the percentage to be added, and the plant layout. Minor variations to plant operations can achieve a 30% RAP mix addition; however, it will require some changes in the plant configuration. Even higher percentages can be achieved with significant changes to the plant.

Given the low bitumen content in the current Kuwaiti Marshall mixtures, it is recommended that the RAP content in the current mixes does not exceed 20% by weight. RAP used in small quantities only requires minor modifications to the asphalt mix design and moderate adjustments to production processes while providing economic and environmental benefits. Including more than 20% RAP in batch plants would require some modifications to control the RAP temperature and mixing of RAP and virgin aggregates. It is recommended that the Superpave mixture design process be used to accommodate a higher RAP content. This is because Superpave incorporates performance-based binder selection, blending charts, and mechanical performance tests, which allow better control of RAP binder stiffening effects. In contrast, the Marshall method relies primarily on volumetric properties, which can limit RAP usage. With time and experience, the RAP percentages can be increased to enhance economic and environmental benefits.

## 5 QUALITY ASSURANCE SYSTEM

The Quality Assurance (QA) system in the current QCS does not include clear and specific designation of responsibilities for quality control (QC), acceptance (A), and Independent Assurance (IA) operations. AASHTO R10 and AASHTO R42 guidelines are recommended for developing a QA/QC system and assigning responsibilities. Quality acceptance (A) must be included in the specifications. These tests would be at less frequency than the QC program. The recommended lot size per layer for the base course is a minimum of 2000 tons and a maximum of 4000 tons, with one test per 500 tons. The lot size for the wearing course is a minimum of 1000 tons and a maximum of 2000 tons, with one test per 250 tons.

The recommended specifications include specific material tests and tolerances. Adopting a statistical approach for analyzing Quality Control and Quality Acceptance data is also recommended. Such an approach will encourage the implementation of measures to reduce variation, which can also help output to remain within the specification limits. The concept of percent within limits (PWL) is highly suitable for data analysis and relating the results to pay factors for each lot.

## 6 ASPHALT PAVEMENT EVALUATION

Kuwait employs a process for evaluating asphalt pavement conditions based on ASTM D6433, which evaluates the Pavement Condition Index (PCI). The PCI is determined using visual surveys, which is similar to the distress identification manual by the long-term pavement performance program (Miller and Bellinger 2014). Automated surveying systems that incorporate cameras and lasers for pavement evaluation are needed.

It is not sufficient to assess only visual surface conditions to decide on the extent and severity of distress and damage in various layers and then subsequently select the proper optimum rehabilitation method. Lack of structural evaluation raises the risk of placing overlays on damaged layers, which is not a suitable strategy as damage will develop rapidly due to the existing damaged underlayers.

The study developed guidelines for using a combination of nondestructive evaluation methods (Dynamic Cone Penetrometer (DCP), Falling Weight Deflectometer (FWD), Ground-Penetrating Radar (GPR), roughness profilometers, and skid resistance and destructive methods (trenching and coring) should be used to assess the conditions of asphalt pavement layers.

## 7 ASPHALT PAVEMENT PRESERVATION TREATMENTS AND REHABILITATION

The study additionally developed guidelines for preservation treatments and rehabilitation of asphalt pavements. As defined by Hall et al. (2001), "pavement rehabilitation is defined as a structural or functional enhancement of a pavement that produces a substantial extension in service life by substantially improving pavement condition and ride quality. Pavement maintenance activities, on the other hand, are those treatments that preserve pavement condition, safety, and ride quality, and therefore aid a pavement in achieving its design life." The term pavement preservation is used in the literature to refer to preventive maintenance and some forms of minor rehabilitation and corrective maintenance (Peshkin et al. 2011).

Hall et al. (2001) categorize rehabilitation treatments to the "4 Rs"– restoration, resurfacing, recycling, or reconstruction. Some Certain types of treatments may be carried out as part of a restoration or resurfacing effort. The guidelines developed in this study include the classification of various activities under maintenance and the 4Rs of rehabilitation, as shown in Table 2. Also included are guidelines for the various preservation and rehabilitation strategies depending on the type and severity of distress, as shown in Table 3.

Table 2. Classification of Different Pavement Treatments Under Preventive Maintenance and Rehabilitation.

| Pavement Activity | Preventive Maintenance | Rehabilitation | | | |
|---|---|---|---|---|---|
| | | Restoration | Resurfacing | Recycling | Reconstruc-tion |
| Structural Overlays | | | | X | X |
| Functional) Overlays | | | X | X | |
| Thin Overlays | | | X | | |
| Crack Sealing | X | X | | | |
| Fog Seal | X | X | | | |
| Slurry Seal | X | X | | | |
| Chip Seal | X | X | | | |
| Microsurfacing | | | X | | |

Table 3. Guidelines for Using Surface Treatments Based on Distress Type and Severity Level.

| | Crack Sealing | | | Fog Seal | | | Slurry Seal | | | Chip Seal | | | Microsurfacing | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Minor | Mod | Major | Minor | Mod | Major | Minor | Mod | Major | Minor | Mod | Major | Minor | Mod | Major |
| Fatigue Cracking | M | | | M | | | M | | | M | | | M | | |
| Linear & Block Cracking | E | M | | M | | | E | M | | E | M | | E | M | |
| "Stable" Rutting | | | | | | | | | | | | | E | M | |
| Raveling | | | | M | | | E | M | | E | E | M | E | E | M |
| Flushing/Bleeding | | | | | | | | | | E | | | E | M | |
| Roughness | | | | | | | | | | | | | E | M | |
| Friction Loss | | | | | | | E | E | E | E | E | E | E | E | E |
| Moisture Damage | E | | | E | | | E | | | E | | | E | | |
| Typical Traffic Volume | All | | | Low | | | Low | | | Low to Moderate | | | Moderate to High | | |
| Expected Performance (Treatment Life) (yr)* | 2-5 | | | 1-2 | | | 2.0-3.50 | | | 2-5 (single course)<br>3.5-7.0 (double course) | | | 2-4 (single course)<br>3-5 (double course) | | |
| Expected Performance (Pavement Life Extension) (yr)* | 2-5 | | | 1-2 | | | 4-5 | | | 5-6 (single course)<br>8-10 (double course) | | | 3-5 ((single course)<br>4-6 (double course) | | |

E: Efficient, M: Marginal

*Except for fog seal, data is according to SHRP2 Report S2-R26-RR1 (Peshkin et al. 2011). High traffic volume is defined as greater than 5,000 vpd for rural roads and greater than 10,000 vpd for urban roads.

## 8 CONCLUSIONS

This paper documents the primary outcomes of a strategic initiative to develop a comprehensive roadmap for asphalt pavement improvements in the State of Kuwait. The focus is creating practical, long-term solutions to improve construction quality, rehabilitation, and maintenance practices. The development of this roadmap began with identifying gaps in the current system, including technical, operational, and procedural shortcomings. Subsequently, the team developed a roadmap with specific deliverables and action items.

- Gap analysis with action items for improvements.
- Improved specifications for asphalt materials and construction methods.
- Guidelines for asphalt pavement evaluation, rehabilitation, and maintenance operations.
- Processing, stockpiling, and managing Recycled Asphalt Pavements (RAP) and a customized design procedure for asphalt mixes containing RAP.
- Establishment of training and certification programs for engineers and technicians.
- Integration of advanced technologies for real-time quality control and pavement assessment.

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