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Performance evaluation of SUPERPAVE and Marshall asphalt mix designs to suite Jordan climatic and traffic conditions

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Abstract

Due to the empirical nature and the drawbacks of the Marshall mix design procedure, the Strategic Highway Research Program (SHRP) has developed a Superior Performance asphalt Pavements (SUPERPAVE) mix design procedure. In this research a comprehensive evaluation of the locally available aggregate usually used in the asphalt concrete mixtures was carried out to ensure that these materials conform to the new mix design procedures developed by SUPERPAVE. A performance grading map was generated to the Hashemite Kingdom of Jordan. In this map the country was divided into different zones according to the highest and lowest temperature ranges that the asphalt might be subjected to. Using local materials, loading and environmental conditions, a comparative study of the performance of two mixes designed using SUPERPAVE and Marshall mix design procedures was carried out in this research. Samples from both mixes were prepared at the design asphalt contents and aggregate gradations and were subjected to a comprehensive mechanical evaluation testing. These tests included Marshall Stability, Loss of Marshall Stability, Indirect Tensile Strength, Loss of Indirect Tensile Strength, Resilient Modulus, Fatigue Life, Rutting, and Creep. In all the performed tests SUPERPAVE mixes proved their superiority over Marshall mixes. Therefore, serious plans should be set up in Jordan to shift from the presently used Marshall mix design procedure to SUPERPAVE mixture specifications.
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1. Introduction

The major properties to be incorporated in bituminous paving mixtures are stability, durability, flexibility and skid resistance (in the case of wearing surface). Traditional mix design methods are established to determine the optimum asphalt content that would perform satisfactorily, particularly with respect to stability and durability. There are many mix design methods used throughout the world e.g. Marshall mix design method, Hubbard-field mix design method, Hveem mix design method, Asphalt Institute Triaxial method of mix design, etc. Out of these only two are widely accepted, namely Marshall Mix design method and Hveem mix design method [1]. In Jordan, Marshall mix design procedure (ASTM D 1559) [2] is used for designing the asphalt concrete mixes.

In Jordan, roads were built to the best international standards. After a short period of service, some of these roads have shown signs of major distresses due to the harsh environmental conditions and traffic loading [3]. Another reason which is contributing to these early distresses is the continuation of the use of Marshall mix design procedure for asphalt mixtures. The Marshall mix procedure is empirical and suffers the limitation of accuracy in determining the full effects of variations in environmental and loading conditions, and material properties and types on the pavement performance. It cannot identify the mixes with high degree of shear susceptibility. In addition, the impact method of compaction in the Marshall mix method does not simulate densification that occurs under traffic in a real pavement [4]. Therefore, due to its drawbacks, it was

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dropped from the American Standard Testing Procedures in 1998 [5]. This situation calls upon the country, a leading country in the region, to adopt up-to-date mix design and evaluation procedures to alleviate these problems. Recent research and development efforts in the Strategic Highway Research Program (SHRP) have focused on the establishment of performance-based asphalt binder and asphalt mix specifications [4,6]. The main objective of SHRP Asphalt Program was to develop a mixture design method that incorporates a performance-based asphalt binder specification and an accelerated performance-based tests. The product that was designed by the new mixture design system was known as SUPERPAVE (SUperior PERformance PAVEments).

1.1. Current asphalt binder testing philosophy

The current philosophy that deals with asphalt binder evaluation in Jordan uses the traditional old fashion testing that deals mainly with the physical properties of the asphalt cement. It uses testing such as penetration, viscosity and ductility. These tests are performed at standard test temperatures. The results of these tests are used to determine if the material meets specification criteria.

Several limitations exist to the use of physical evaluation only. Limitations can be summarized as follows:

- Many of the current tests are empirical, i.e., the pavement performance experience is required to relate the test parameters with pavement performance.
- The tests do not give information about the entire range of typical pavement temperatures, for example, viscosity is an important property of asphalt binders, however, the viscosity gives an indication about the behavior of the material at high temperatures, viscosity does not provide any information about low and medium temperature behavior of asphalt binders.
- The current asphalt specifications can classify different asphalts with the same grading, when in fact these asphalts may have very different temperature and performance characteristics.

1.2. Development of the SUPERPAVE mix design procedure

Due to the drawbacks in both binder and mix specification, the US congress, in 1987, supported a five year research program to improve the performance and durability of the US roads and to make those roads safer to both motorists and highway workers. Part of this research funds were used for the development of performance-based asphalt specifications to directly relate laboratory analysis with field performance [7].

A bimodal grading system, which is based on rational performance indices, was established for both low temperature and high temperature pavement service. Thus, precise grade may be selected to accommodate the need to control low-temperature cracking, rutting or both in a particular construction project. In addition, it will address certain aspects of fatigue cracking [8]. For a given type of asphalt cement to satisfy performance criteria for a given temperature zone, it must satisfy SHRP performance tests which must be conducted at designated temperatures.

The suitability of a given asphalt binder to a certain area is determined by the extreme temperatures (average seven-day maximum pavement design temperature and the minimum pavement design temperature), required reliability, traffic level and speed anticipated to use the facility under consideration. The asphalt binder rheological properties related to both high temperature distresses such as rutting or shoving, and low-temperature cracking distress were specified and are required to satisfy a certain threshold value at the temperature regime in which the binder is expected to serve.

The SUPERPAVE system consists of three interrelated areas: (1) a performance graded (PG) asphalt binder specification and tests that are based on the range of temperatures experienced by the pavement; (2) aggregate criteria and tests; and (3) a mixture design system utilizing both a volumetric mixture design with a Superpave gyratory compactor (SGC) and an analysis/performance prediction element [4]. SGC (1.25°, 30 gyration/min and 0.6 MPa ram pressure for 150 mm mold) is used for the evaluation of volumetric properties and strength of compacted mixes [9]. Sousa et al. [10] found that the SGC is capable of producing laboratory specimens whose volumetric and engineering properties adequately simulate those of field specimens from a wide variety of pavements.

In this research, a performance grading map showing the required asphalt binder grades for the different parts of Jordan was generated. Representative aggregate and asphalt samples were collected. A comprehensive evaluation of the collected materials was carried out to ensure that these materials conform to the SUPERPAVE mix design procedures considering country specific conditions of traffic and environment. Marshall and SUPERPAVE mix design procedures were performed using the collected asphalt and aggregate samples. Comparison between the two mix design procedures included optimal asphalt content, aggregate gradation, and mixes mechanical performance. Mechanical performance evaluation consisted of Marshall Stability, Loss of Marshall Stability, Indirect Tensile Strength, Loss of Indirect Tensile Strength, Resilient Modulus, Fatigue Life, Rutting Behavior, and Creep Performance.

2. Experimental procedure

Fig. 1 shows a flow chart of the experimental procedure followed in this investigation. The work started with a literature review of available literature related to the investigation. Required amounts of aggregate and asphalt were collected and characterized according to the locally

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