Academic Journal of Science and Technology,
Jun, 2025, vol.5, No.1, p253-260

A Review of the Superpave Performance Grade Classification System for Asphalt Binders by Temperature

. Asmaiel Naiel [1], Jaafir Omar Deerh [1],. Hassan Awaidat Salem [2]

1. Department of Civil and Architectural Engineering, Libyan Academy for Graduate Studies
2. Department of Civil Engineering, Wadi Al-Shati University

ABSTRACT

Asphalt roads are one of the most important elements of infrastructure in any country, as they play a vital role in achieving comprehensive development and economic growth. They provide safe and reliable means of transportation for citizens and companies, which develops trade, contributes to the development of industry, and expands the investment base. In addition, asphalt roads contribute to enhancing tourism and developing the infrastructure of cities and rural areas. Therefore, it is necessary to invest heavily in the construction and maintenance of asphalt roads to ensure economic growth and social stability.

The Superpave system is an important development in the field of paving, as it contributes to improving the design of hot asphalt mixes and evaluating the performance of paving facilities. This system relies on precise standards to evaluate the quality of asphalt mixes, which leads to improving the durability of the pavement and its efficiency in withstanding different traffic loads. This system is also the result of field and laboratory research and studies included in the Strategic Highway Research Program in the United States of America. Due to the importance of this system, we present this study to examine previous studies on the classification of asphalt binders in the high-performance asphalt paving system (Superpave) and to identify the significance of classifying the binder in this system.

KEYWORDS: *asphalt; Superpave; pavement; temperature; performance*

* *Corresponding author: : asmaiel.naiel@academy.edu.ly*

INTRODUCTION

The asphalt binder plays a vital role in road engineering, serving as an essential component in binding aggregates and enhancing the durability of asphalt surfaces. It also possesses water-resistant properties, reducing aging in roads and extending their lifespan. The asphalt binder is a fundamental part of the asphalt mixture used in paving roads, aiding in withstanding heat, pressure, and traffic movement. This binder is added to the asphalt mixture according to specific standards and guidelines to resist external effects such as wear, cracking, and aging. The asphalt mixture comprises raw asphalt, aggregates, and filler materials, mixed in precise proportions to achieve optimal properties that ensure its ability to bear vehicle loads and protect roads from environmental influences and temperature variations. The composition of asphalt mixtures varies based on the intended use, with specific mixtures designed to meet distinct requirements, such as those for roads with light traffic and others for roads with heavy traffic.

One of the most significant advancements in pavement technology over the past two decades is the emergence of the Superior Performance Asphalt Pavement (Superpave) system. This system is used to design hot asphalt mixtures and evaluate the performance of asphalt structures. It resulted from field and laboratory research conducted under the Strategic Highway Research Program (SHRP) in the United States of America. One of the key outcomes of this research was the development of an integrated and advanced system for designing asphalt mixtures, known as the Superior Performance Asphalt Pavement system. This new system classifies asphalt binders based on performance, earning the designation Performance Grades (PG). The classification relies on the maximum and minimum pavement temperatures, which depend on climatic conditions and the thermal properties of the pavement layers.

The Superpave system uses the term "asphalt binder" instead of "asphalt" because it encompasses both modified and unmodified asphalt. Through this paper, we will present previous studies on the classification of asphalt binder and the Superpave system.

LITERATURE REVIEW

This paper presents a collection of previous studies highlighting the progress made in the classification of asphalt binders within the Superpave system.

One study, conducted by Abdul-Moti Al-Hemali and others [1], focused on suitable aggregates meeting standard specifications for use in asphalt mixtures within the Superpave system in the area extending between the cities of Ajdabiya and Jalu .

The study also emphasized analyzing the properties of aggregates available in the region's quarries and assessing their compliance with the approved standard specifications. A series of laboratory tests was performed to determine the physical and chemical characteristics of the aggregates, ensuring that the materials used meet the necessary standards for effective asphalt mixture performance. This reflects the significance of scientific research in advancing Libya's construction sector.

Additionally, the study presented a map provided by the Libyan Roads and Bridges Authority in 2010 [18], showing the classification of asphalt binders in Libya. The classification divided Libya into two zones: a coastal zone classified as PG64-10 and a desert zone classified as PG70-10. Figure 1 illustrates the distribution of asphalt binder classifications in Libya.

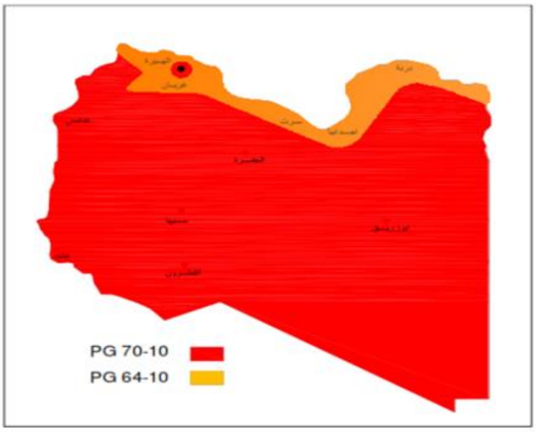

Figure :(1) Distribution of Asphalt Binder Classification in Libya [18]

Hassan Awaidat Salem [7], in his study on the thermal zoning of the Libyan desert, noted that the classification system used in Libya for asphalt binders is the penetration system. In this system, a penetration test is conducted at a temperature of 25°C. This test serves as an experimental measure of consistency and is used as an indicator for classifying asphalt binders. However, it does not correlate with pavement performance under varying thermal conditions.

The Superpave system for asphalt mixture design aims to improve the performance of materials used in pavement. It classifies these materials based on the climatic conditions they will face after paving. The first step in the Superpave

* *Corresponding author: : asmaiel.naiel@academy.edu.ly*

system involves a comprehensive and detailed study of the high and low temperatures at the paving site. From this, the required performance grades (PG) for the asphalt binder are determined, enabling the design of a Superpave asphalt mixture tailored for those regions.

In this study, temperature classifications in Libya were conducted using temperature data obtained from eight weather stations. The SHRP and LTPP prediction models were used to forecast pavement temperatures, revealing a significant difference between the predicted pavement temperatures from the two models. The SHRP model provided higher temperature estimates, which offer additional protection against cracking. Since cracking is the most common issue in flexible pavements in Libya, this study recommends using the SHRP models at a reliability level of 50%.

Accordingly, the performance grade for asphalt binders in the Libyan desert was classified into three zones, as illustrated in Figure 2. The study highlighted that relying on the penetration system for asphalt binder classification should be a concern for road projects in Libya.

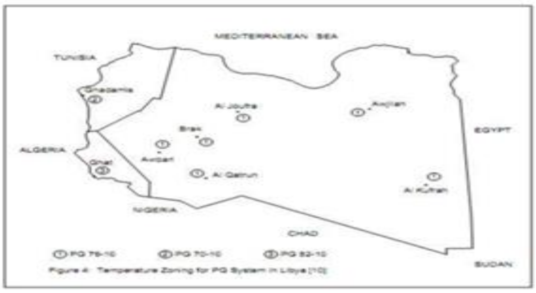

Figure 2: The Thermal Division of the Libyan Desert

Hassan Awidat Salem [8] also indicated in another study presented at the International Conference on Developments in Materials and Predicting Pavement Performance, which focused on the development of polypropylene to bind asphalt on the Libyan desert road network. The road area in the Libyan desert (surface layer) was divided into two regions, with region (1) requiring PG 70-10 temperature

Table1: Performance division of asphalt binder in the Libyan desert

and region (2) requiring PG 76-10 temperature, as illustrated in Table No. (1) Table 1 outlines the division of the performance of the binding material in the Libyan desert.

A study conducted by Mohamed Al-Zawam [3] focused on the design of asphalt mixtures utilizing the Superpave system in place of the Marshall method (Hassan, 2015). The researcher noted that the Marshall method predominated in most countries, including Libya, for the design of flexible asphalt mixtures in road construction. He highlighted that numerous roads are affected by issues such as bleeding and cracking, attributed to high traffic volumes from both motor and commercial vehicles, as well as significant variations in daily and seasonal temperatures. These factors induce thermal stresses, resulting in premature thermal cracks and grooves within the asphalt road network. The study identified the reliance on the Marshall method as a critical challenge for Libya’s road infrastructure, thereby necessitating the adoption of modern technologies like the Superpave system for asphalt mixture design. Additionally, the study performed a comparison of the volumetric properties and traffic loads of asphalt mixtures designed through the Marshall method versus those utilizing the Superpave system. Findings indicated that the optimal asphalt content in the Superpave design was lower than that determined by the Marshall method, leading to reduced costs for binding materials. Furthermore, the air void percentage in Superpave mixtures at optimal asphalt content was lower compared to that in the Marshall method, which contributes to delaying the aging process and decreasing maintenance costs.

Tarrad et al [12] Where the study was, titled "Establishing an Asphalt Performance Map in Egypt Based on the Superpave Program", the objective was to create a map for classifying binding materials utilizing the Superpave system in Egypt. To achieve this, data from 60 meteorological stations, alongside recorded high and low temperatures over 30 years from the Egyptian Meteorological Authority, were collected. The collected data and standard deviation were employed to determine pavement temperatures for 21 stations representing diverse climatic regions in Egypt. The resulting classification of binding materials is depicted in Figure 3, illustrating the classification map for binding materials in Egypt..

Type	PG	City
Zone 1	70-10	alkafra
Zone 1	70-10	Ghadames
Zone 1	70-10	Al-Jafra
Zone 1	70-10	alshaati
Zone 2	76-10	algatron
Zone 2	76-10	Ubari
Zone 2	76-10	Ghat

* Corresponding author: : asmaiel.naiel@academy.edu.ly

Academic Journal of Science and Technology,
Jun, 2025, vol.5, No.1, p253-260

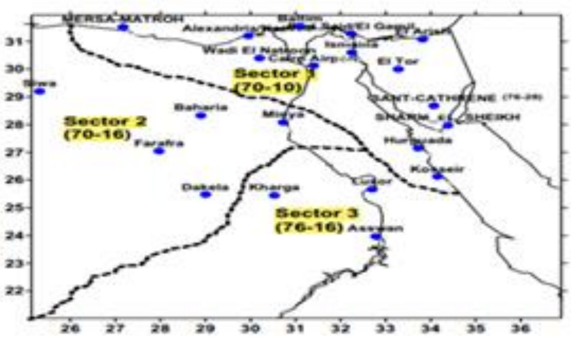

Figure 3: Classification of Asphalt Binder Types in Egypt

Shamsin et al [9], in his study on improving asphalt mix design using Superpave and comparing it with the Marshall method, emphasized that the primary goal of asphalt mix design methods is to determine the optimal asphalt content. This optimal content ensures the asphalt mixtures meet the essential requirements for stability and durability.

Several mix design methods are employed worldwide, with the Marshall method being one of the most widely used traditional techniques. Recently, since 2000, the Superpave method has gained prominence. The study also focused on designing asphalt mixtures using the Superpave system in Syria, based on the properties and materials of the mixtures. Furthermore, it examined the impact of torque on the volumetric properties of asphalt mixtures.

The research determined the optimal asphalt content and compared it with the Marshall method. The findings revealed that the optimal asphalt content using the Marshall method was 5.2%, while it decreased to 4.8% using the Superpave method. The stability value at the optimal asphalt content using Superpave was 1225 kg, meeting the flow criterion as per specifications. Air void results were within the required limits, and the outcomes at the optimal asphalt content using Superpave satisfied the design criteria, with aggregate voids at 14.2%, filled voids at 72.4%, and dust-to-binder ratio at 0.77. The study also indicated that the indirect tensile strength at the design asphalt content achieved the moisture sensitivity criterion, reaching 84.2% compared to 78.7% using the Marshall method.

Anderson's et al [6] Study on Aggregate Gradation Evaluation for Asphalt Mixtures Using the Superpave System. Anderson's research highlighted that asphalt mixture design is a complex process requiring precise material ratios to meet the volumetric and mechanical properties of the mix. A significant portion of the design process involves evaluating and selecting aggregate gradations to meet project requirements.

The latest requirement system for asphalt mixtures is the Superpave system, developed under the Strategic Highway Research Program. This system encompasses material selection, evaluation of trial aggregate structures, selection of binder content, moisture sensitivity, and, in some cases, determining performance properties for specific aggregate-asphalt blends. The selection of aggregate structure ensures sufficient resistance to permanent deformation, bleeding, and thermal cracking within the volumetric mix design process under the Superpave system.

The study also emphasized the challenge of achieving voids in the mineral aggregate (VMA), one of the most demanding tasks for mix designers. It provided guidelines to meet VMA requirements for Superpave mix designs.

Al-Khatib et al [14] and Others' Study on Performance Grading in the Superpave System, This study stressed the critical role of asphalt binders in improving resistance and performance. The rheological properties of asphalt binders, which define the relationship between stress and strain, must be thoroughly characterized before field application. Classification systems are typically used to evaluate and select appropriate asphalt binders. Al-Khatib's study emphasized that the Superpave Performance Grading (PG) System represents the first attempt to directly link the measured physical properties of asphalt binders to field performance while considering pavement conditions. This approach marks a significant advancement over traditional penetration and viscosity grading systems.

The Superpave system's laboratory tests simulate the conditions that asphalt mixtures experience during and after pavement placement. New tests and specifications in the Superpave system were designed to meet performance demands. Al-Khatib's research reviewed the Superpave system in relation to workability, rutting resistance, fatigue cracking resistance, and thermal cracking resistance. While the Superpave system is theoretically superior to traditional grading methods, certain shortcomings have been reported regarding testing methods and evaluation metrics.

The study noted that addressing these shortcomings could further enhance the Superpave system. It also explored recent developments in performance-based testing methods for asphalt binder classification and suggested that performance-based specification tests could be integrated into the Superpave system to improve its efficiency.

Khan et al [16] Study on Developing a Superpave Performance Grading Map for Pakistan. Kamran Khan's research highlighted the critical role of asphalt binders in pavement performance, underscoring their significance in the asphalt industry. Binder classification systems are based on physical properties. Pakistan faces significant issues with asphalt pavement deterioration due to harsh weather conditions and heavy traffic loads.

* Corresponding author: : asmaiel.naiel@academy.edu.ly

The study aimed to characterize asphalt binders in line with the requirements of the Superpave system. Performance grades for asphalt in Pakistan were determined by collecting and analyzing air temperature data. The country was divided into seven performance zones based on temperature data collected over 20 years from 30 meteorological stations. The results and recommended grades are illustrated in Figure 4, where asphalt binders in Pakistan were classified according to Superpave performance requirements.

Figure 4: Classification of Asphalt Binders in Pakistan

Ntirama et al. [11] Study on Selecting Asphalt Binders Using the Superpave System for Asphalt Mix Design in Ghana.

Simon Ntirama's study focused on selecting asphalt binders using the Superpave System for asphalt mix design in Ghana. The research highlighted that the Superpave asphalt pavement system, encompassing asphalt binder classification, mix design, and performance evaluation, has been in existence for nearly 30 years. It has been implemented or evaluated for potential adoption in many countries to address issues such as fatigue cracking and thermal cracking caused by temperature variations.

The study emphasized that the Superpave system reduces pavement costs compared to other systems, which often result in higher maintenance expenses and increased safety risks. Currently, Ghana faces common issues of cracking, premature deterioration, and asphalt bleeding in its roads. The study noted that the binder classification system used in Ghana is primarily viscosity-based. However, a small number of projects have experimented with the Superpave system, with challenges arising in determining the most suitable performance grade (PG) for specific regions.

The research anticipated that the adoption of the Superpave system for road projects in Ghana would become increasingly important in the future. However, there is currently no official government-endorsed map for asphalt binder classification under the Superpave system. This study aimed to bridge this gap by providing a guidance document to facilitate the selection of appropriate performance grades.

Using 42 years of air temperature data (1979–2020) collected from 24 meteorological stations across Ghana, the study analyzed asphalt pavement temperatures to determine optimal performance grades for asphalt binders under the Superpave system. It proposed a performance grade map for Ghana and suggested dividing the country into two regions for binder grade selection:

Northern Savannah Region: PG 10-70

Transitional/Forest/Coastal Region: PG 10-64

These base binder grades, determined at a 98% reliability level, account only for climatic conditions and must be further adjusted based on traffic conditions at project sites.

The study emphasized the importance of developing a localized model for selecting binder performance grades and recommended that the chosen binder grades be validated through laboratory testing. Accurate binder selection is essential for designing and constructing effective asphalt pavements in Ghana.

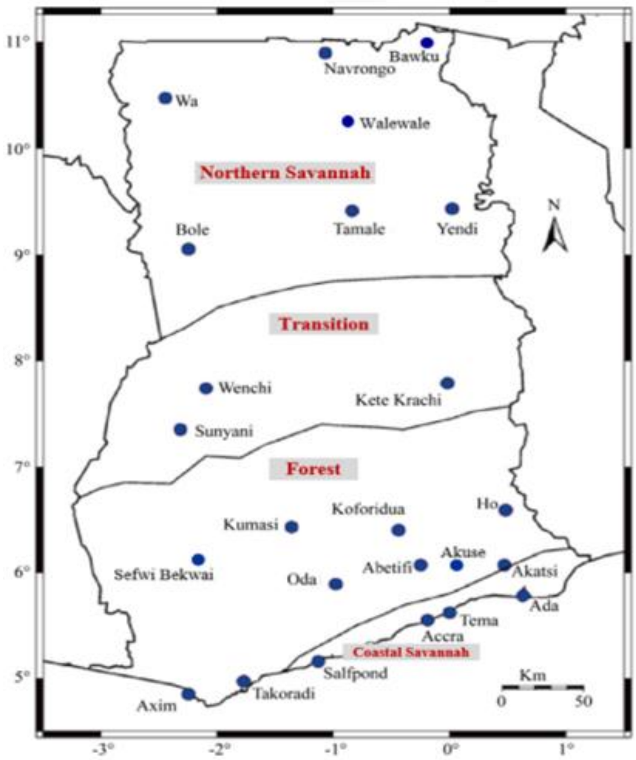

Figure 5: Classification of Asphalt Binders in Ghana

Lee et al .[5] Where the study was on Asphalt Binder Performance Grading in North Korea for Superpave Mix Design.

* Corresponding author: : asmaiel.naiel@academy.edu.ly

This study aimed to determine the performance grades (PG) of asphalt binders in North Korea to design asphalt mixtures capable of resisting rutting and cracking problems caused by seasonal temperature variations. The first step in the study was to identify the performance grades by determining the high and low temperatures for specific locations. Since asphalt binders are viscoelastic materials sensitive to temperature, temperature classification was crucial.

To develop a PG map, the study utilized 26 years of temperature data from the World Meteorological Organization (WMO) for 27 cities in North Korea. The temperature data and asphalt binder reliability were analyzed to ensure binder performance under varying conditions. Three models were used to predict pavement temperatures throughout the study.

At the conclusion, reliability levels of 98% and 50% were applied to define performance grades. Given that the Superpave equation includes latitude as a dependent variable, reflecting the geographic characteristics of northern regions better than other models, the study ultimately adopted the SHRP Superpave model for asphalt binder performance grading.

The study combined Superpave models with reliability analyses and produced a performance grading map. The performance grades of asphalt binders for North Korea are illustrated in Figure 6.

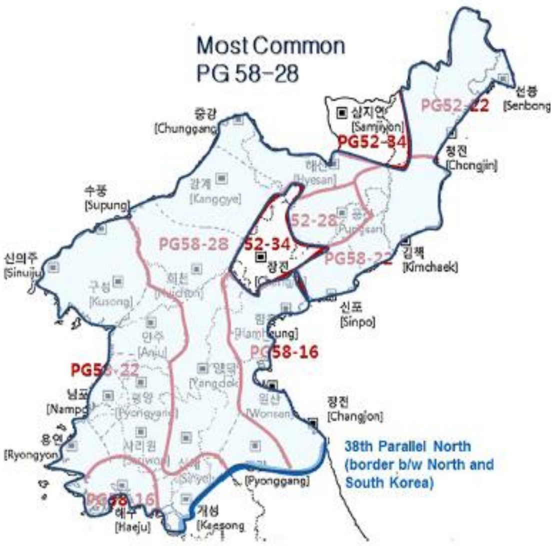

Figure 6: Classification of Asphalt Binders in North Korea

Lee et al. [5] Study by Jong Sub Lee and Others on Asphalt Binder Performance Grading in North Kore for Superpave Mix Design .

This study aimed to determine the performance grades (PG) of asphalt binders in North Korea to design asphalt mixtures capable of resisting rutting and cracking problems caused by seasonal temperature variations. The first step in the study was to identify the performance grades by determining the high and low temperatures for specific locations. Since asphalt binders are viscoelastic materials sensitive to temperature, temperature classification was crucial.

To develop a PG map, the study utilized 26 years of temperature data from the World Meteorological Organization (WMO) for 27 cities in North Korea. The temperature data and asphalt binder reliability were analyzed to ensure binder performance under varying conditions. Three models were used to predict pavement temperatures throughout the study.

At the conclusion, reliability levels of 98% and 50% were applied to define performance grades. Given that the Superpave equation includes latitude as a dependent variable, reflecting the geographic characteristics of northern regions better than other models, the study ultimately adopted the SHRP Superpave model for asphalt binder performance grading.

The study combined Superpave models with reliability analyses and produced a performance grading map. The performance grades of asphalt binders for North Korea are illustrated in Figure 6.

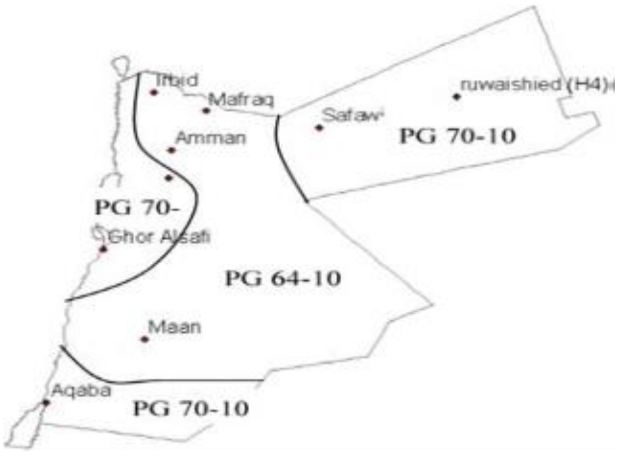

Figure 7: Classification of Asphalt Binders in Jordan

Senta et al. [17] Where the study was to create a Performance Grade Map in Nepal Using the Superpave System .

This study emphasized the critical role of asphalt binder performance in overall pavement performance, noting that one of the primary causes of pavement failure is the improper selection of asphalt performance grades. Consequently, performance grading of asphalt binders is essential for specific temperature and climatic zones.

* Corresponding author: : asmaiel.naiel@academy.edu.ly

The study aimed to determine the performance grades of asphalt binders for different temperature regions in Nepal. It collected 21 years of daily maximum and minimum temperature data from 70 meteorological stations. These data were analyzed to classify temperature ranges. The performance grading of asphalt binders was conducted using predictive models from the Strategic Highway Research Program and the Long-Term Pavement Performance programs.

The Superpave concept, representing high-performance asphalt pavement, was adopted for the analysis. It involves a new analysis system based on pavement layer performance characteristics. The study determined asphalt binder grades for Nepal based on air temperature and subsequently predicted pavement temperatures. Seven performance grade zones were identified using SHRP models, and four zones using LTPP models. The study compiled the data and created a performance grading map for asphalt binders in Nepal.

Abtan et al. [13] The study of Abdul Malik Abtan and Others. The impact of future temperature changes on the selection of asphalt binder and simulation of pavement performance in Sharjah. indicates that climate change is an urgent global issue with far-reaching impacts on the environment, including its impact on infrastructure such as roads and sidewalks. With the rise in temperatures, it has become necessary to consider the selection of asphalt binder performance grades to ensure the long-term and reliable performance of asphalt pavements in Sharjah. The study also indicated that the penetration classification system for classifying the binder is empirical and does not take into account daily and seasonal temperature fluctuations. In contrast to the Superpave system, which explicitly takes into account daily and seasonal temperatures while allowing for the incorporation of future temperature changes, the objectives of the study by Abtan et al. were to evaluate the impact of future temperature changes on the performance of the asphalt binder required in Sharjah and the resulting impact on the performance of the pavement simulated by AASHTO Ware Pavement ME Design. Abtan's study also confirmed that performance simulations are of great importance for the accurate selection of the asphalt binder in the Superpave system, as it has been proven that the most appropriate selection of the binder classification increases the service life of the asphalt pavement.

Carriz et al.[4] Where the study was on the importance of switching to the classification of binder material according to the Superpave system in Western Canada, confirmed that most of North America has adopted the classification of asphalt binder according to the Superpave system. The study also confirmed that the classification of binder material according to the penetration system is still in place and used in Western Canada, and that the study area has an excellent history in producing high-quality asphalt, so there was no need to change the classification specifications. However, the use of polymer-modified asphalt or the Superpave system is increasing in some states in Western Canada. The study confirmed that there is an urgent need to switch to the classification of asphalt binder according to the Superpave system and to choose the optimal classification for the binder within the states in Western Canada. The study showed that in recent years, some western Canadian states have adopted Superpave specifications for the selection of paving grades. One of the objectives of this study was to compare the asphalt specifications of a relatively large group of asphalt distilled from crude oils produced in western Canada with the penetration-based specifications and the Superpave system specifications. The ability of both systems to predict basic rheological behavior was also analyzed. The study also addressed the analysis of the effect of low temperatures on the Superpave specifications in paving by some states.

Rodrigo et al. [10] which was on the impact of climate change on the choice of the Superpave binder in Chile, showed that one of the relevant effects of climate change resulting from human activity is the abnormal increase in temperature at the surface of the earth, and that in the context of pavement engineering, materials exposed to heat can be affected by these changes, for this reason the potential effects of global warming on the choice of asphalt binder in Chile were studied. This study also addressed the calculation of future temperature increase projections, where the estimated temperature changes for the period 2030-2059 were calculated for 94 meteorological stations that previously used Superpave in Chilean regions. In this study, three pavement temperature models were used with new air temperature databases, and the results were compared with SHRP, LTPP 2.1, and LTPP 3.1. With the original superpave areas obtained with the same models, a large number of stations underwent a change in pavement performance grade over the forecast period, and most of the predicted changes in high temperature pavement performance grade were increased.

The study of Anadelis Alonso et al. [2] on the determination and classification of the performance grade of asphalt for Cuba according to the Superpave system, confirmed that traditional methods of classifying asphalt binders depend on their penetration or viscosity, and this method is a problem in itself as these methods can classify different types of asphalt with the same grade at a certain temperature, while in fact they have different behaviors at high or low temperatures, and the performance of the pavement cannot be predicted in the face of changes in loads and temperatures. To solve this problem, the Superpave system design method was created, as this system takes into account new specifications for classifying asphalt according to the performance grade of the asphalt

* Corresponding author: : asmaiel.naiel@academy.edu.ly

binder according to the Superpave system. The performance grade system is based on the idea that the properties of the asphalt binder must be related to the conditions in which it is used, including the expected climatic conditions and pavement temperature in addition to the aging conditions that the asphalt must have in the study area. One of the most important objectives of this designed in Cuba.

REFERENCE

1- Abdelmuti Al-Taher Al-Humali. (2019, October 29–31). Design of asphalt mixtures using the Superpave performance pavement system for the road between Ajdabiya and Jalu-Ojlah. The Second Conference on Engineering and Applied Sciences.

2- Alonso Ainley, A. (2022, August 25). Determining and classifying asphalt performance grades for Cuba using the Superpave methodology. Journal of Engineering and Development, 400–419.

3- Emhamed Al-Zuwam, H. (2015). Design of asphalt mixtures using the Superpave system instead of the Marshall method. Tripoli, Libya: Libyan Academy for Graduate Studies, Janzour.

4- Carriz, P., et al. (2012, September 1). The importance of transitioning to Superpave binder grading in Western Canada. ResearchGate.

5- Lee, J. S., et al. (2018, July 7). Performance grading of asphalt binders in North Korea for Superpave mix design. International Journal of Pavement Research and Technology, 647–654.

6- Bahei, H., & Anderson, M. (1997, January 1). Evaluation and selection of aggregate gradations for asphalt mixtures using the Superpave method. Transportation Research Record Journal of the Transportation Research Board, 91–97.

7- Awidat, S. H. (2014, July 18). Thermal division of the Libyan desert for asphalt mixture classification. Trans Tech Publications, Switzerland, 638–640.

8- Awidat, S. H. (2018, April 16–18). Development of asphalt performance grading for pavement layers in desert roads in Libya. Advances in Materials and Pavement Performance Prediction (AM3P), Doha, Qatar.

9- Hanna, R., & Shamsin, M. (2020, July 19). Enhancing asphalt mixtures using the Superpave method and comparing it to the Marshall method. Tishreen University Journal, 42.

10- Delgadillo, R., et al. (2018, August 17). Climate change and Superpave binder selection in Chile. International Journal of Road Materials and Pavement Design, 607–622.

11- Ntirama, S., et al. (2022, August 24). Selection of asphalt binders using the Superpave system for asphalt mix design in Ghana. African Scientific Journal, 17.

12-Trad, S. M. (2011, November 14). Creating an asphalt performance grading system in Egypt using Superpave. Journal of Building and Construction Materials, 2248–2253.

13-Abtan, A., et al. (2022, March 7). Impact of future temperature changes on asphalt binder selection and

study was to determine the performance grade, and for this, three mathematical models and the climatic and geographical conditions of 52 meteorological stations were used. The results obtained from the models used were compared, and the model with the best consistency in the results was selected. With these results, a performance score map was

pavement performance simulation in Sharjah. Springer Journal of Innovative Infrastructure, Article 88.

14. Al-Khatib, G., et al. (2022, February 14). Review of the Superpave performance grading system and recent developments in performance-based testing methods for asphalt binder characterization. Journal of Building and Construction Materials, 319.

15. Al-Khatib, G., & Ghazlan, K. (2012, January 31). Selection and verification of performance grades for asphalt binders produced in Jordan. International Journal of Pavement Engineering, 116–124.

16. Khan, K. M., et al. (2013, October 7). Development of a performance grading map for Pakistan using the Superpave system. Journal of Life Sciences, 355–362.

17. Senta, K., et al. (2020, September 1). Development of a performance grade map in Nepal using the Superpave system. Khowpa Engineering College e-Journal, 8.

[18]مصلحة الطرق والجسور (اكتوبر, 2010). "دراسة تحديد المادة الرابطة الاسفلتية في ليبيا". تقرير المرحلة الأولى.

* Corresponding author: : asmaiel.naiel@academy.edu.ly