Wadi AlShatti University Journal for Pure and Applied Science

مجلة جامعة وادي الشاطئ للعلوم البحتة والتطبيقية

Volume 1, No. 1, July-December 2023

المجلد 1، الاصدار 1، يوليو - ديسمبر 2023

CIVIL ENGINEERING

Effect of Polymer Modification Bitumen on Performance of Flexible Pavement in Hot Arid Area in Libya

Hassan Awadat Salem[1,*]

[1] Civil Engineering Department, Faculty of Engineering, Wadi Alshatti University, Brack, Libya.

ARTICLE HISTORY

Received 17 September 2023
Revised 02 October 2023
Accepted 10 October 2023
Online 12 October 2023

KEYWORDS

Asphalt; Superpave;
Polymer Modified Asphalt;
Concrete;
SBS; Dry Process;
Libyan roads

ABSTRACT

Premature rutting of flexible pavements is a significant problem faced by Libya, which has over 83200 km of national highways. Bituminous surfacing as a wearing course is commonly used for flexible pavements in Libya. This study aims to evaluate the effectiveness of polymer modification using Superpave and European mix design methods. The study includes binder characterization, PG determination, and several mechanical tests such as Water Sensitivity, Wheel Tracking, and Stiffness Modulus. The "Dry Process" SBS-modified mixture showed better results than the traditional unmodified asphalt concrete. The study shows that using more PR FLEX 20® increases the high-temperature PG value and reduces the rutting phenomenon. The study also proposes guidelines for implementing Polymer Modified Asphalt (PMA) concrete in Libya and suggests that Superpave technology can be adopted to design flexible pavement in the country.

تأثير تعديل البوليمر على أداء الرصفات المرنة في المناطق الحارة القاحلة في ليبيا

حسن عويدات سالم[1]

الملخص

تعد ظاهرة التخدد المبكر للرصف المرن أحد أكبر مشاكل الرصف التي تواجهها شبكات الطرق. تمتلك ليبيا شبكة طرق يبلغ طولها أكثر من 83200 كيلومتر. تستخدم الأرصفة المرنة ذات الأسطح البيتومينية على نطاق واسع في ليبيا. كان الهدف من هذه الدراسة هو تقييم فعالية تعديل البوليمر بواسطة طريقة الخلطات الإسفلتية عالية الأداء بالطريقة الحجمية والطرق الأوروبية لتصميم الخلطة. بالإضافة إلى توصيف المادة الرابطة بما في ذلك تحديد معدل الاداء الاسفلتي، شملت الدراسة أيضًا بعض الاختبارات الميكانيكية: حساسية الماء، اختبارات تتبع العجلات ومعامل الصلابة. أظهر الخليط المعدل بمادة ستايرين بوتادين ستايرين المحضر بالطريقة الجافة نتائج أفضل مقارنة بالخرسانة الإسفلتية التقليدية غير المعدلة. لقد تبين أنه كلما زادت كمية المادة المحسنة المضافة ، كلما زادت قيمة معدل الأداء الأسفلتي لدرجات الحرارة المرتفعة وقلت ظاهرة التخدد. تم اقتراح مبادئ توجيهية لتنفيذ الخرسانة الإسفلتية المعدلة بالبوليمر في ليبيا. يمكن اعتماد تقنية الاداء العالي لتصميم الرصف المرن في ليبيا.

الكلمات المفتاحية

الأسفلت
الاداء العالي
التخدد
خرسانة أسفلتية معدلة بالبوليمر
الخلط الجاف
ستايرين بوتادين ساترين
الطرق في ليبيا

Introduction

Premature rutting of flexible pavements is a significant issue faced by Libya, which has more than 83200 kilometres of national highways. In Libya, bituminous surfacing is commonly used as a wearing course for flexible pavements. This study aims to evaluate the effectiveness of polymer modification using both Superpave and European mix design methods. The study includes binder characterization, PG determination, and several mechanical tests such as Water Sensitivity, Wheel Tracking, and Stiffness Modulus.

The "Dry Process" SBS-modified mixture showed better results than traditional unmodified asphalt concrete. The study demonstrates that using more PR FLEX 20® increases the high-temperature PG value and reduces the rutting phenomenon. The study also proposes guidelines for implementing Polymer Modified Asphalt (PMA) concrete in Libya and suggests that Superpave technology can be adopted to design flexible pavement in the country.

This research aims to identify the possibility of improving the physical and mechanical characteristics of asphalt concrete in Libya by introducing polymer additives. The modifier considered in this research is the PR FLEX 20® commercialized by PR INDUSTRIE, a highly concentrated SBS-modified bitumen in solid pellets.

Section 2 considers some practical issues, such as introducing the modifier at the mixing plant, while Section 3 discusses the selection of a bituminous binder that can withstand Libya's climatic conditions. Section 4 determines the amount of additive required to meet the different sets of specifications.

Asphalt concrete preparation according to the "dry" process

Polymer Modified Bitumen (PMB) is widely known for its benefits, whether based on elastomer or plastomer. However, in some countries like Libya, there is a lack of PMB binder

*Corresponding author: has712002@yahoo.co.uk

plants, which results in long-distance transportation of PMB products to reach their destination, the asphalt mixing plant. Additionally, depending on the bitumen SBS copolymer compatibility, there is a risk of property loss due to the phase separation of the PMB binder.

To overcome these issues, the "Dry Process" of adding the modifier at the mixing plant is much more convenient. In this process, the modifier in pellets is directly poured onto the pre-heated aggregate during the mixing process before bitumen batching. The modifier should be explicitly designed for this process to allow a fine dispersion of the additive during the short mixing time, resulting in high-quality Polymer Modified Asphalt (PMA) concrete [2].

Fig.1, illustrates the principle of the "Dry Process" approach, which is more convenient than the "Wet Process" represented by the PMB technology. Both of these methods have the same objective of producing high-performance asphalt concrete. However, the "Dry Process" approach is more advantageous because it eliminates the need for a PMB production facility and simplifies the logistic chain.

Determination of low / high pavement temperatures in Libya.

Climate variability and change have physical impacts on infrastructure networks [3]. Temperature is a significant environmental factor affecting asphalt mixtures' mechanical properties. To build roads that are resilient to these impacts, the properties of the binder should be related to the conditions under which the asphalt concrete is used [4]. The Superpave Performance Grading (PG) system is the first attempt to directly relate the measured physical properties of bituminous binders to field performance, considering pavement conditions. This approach significantly advances the traditional penetration and viscosity grading systems [5].

The Superpave PG system reports using two numbers. The first indicates the average seven-day maximum pavement temperature, and the second indicates the minimum pavement design temperature expected to be experienced. For example, a PG 58-22 is intended for use where the average seven-day maximum pavement temperature is 58°C, and the expected minimum pavement temperature is -22°C. It is important to note that these numbers are pavement temperatures and not air temperatures.

In a previous study [6], high and low pavement temperatures were estimated (Table 1) based on information collected from eight Libya weather stations in 2012 and 2013. The pavement temperatures for a Wearing course and a Binder course differ because the Wearing course is more exposed to sun radiation than the Binder course.

In some cases, Grade Bumping may be necessary to artificially require a higher PG than required based on temperature considerations alone to offset higher than typical traffic volume and slower than typical traffic speed [7].

When the gap between high and low-temperature specifications becomes more extensive, some modification is generally required. We will discuss this point later.

Experimental

Material and sample preparation.

In this paper, we examine the PR FLEX 20® modifier, which is produced by PR INDUSTRIE and shown in Fig. 1. The product is composed of several ingredients, with Styrene Butadiene Styrene (SBS) block copolymer being the primary component. During the compound manufacturing process, the polymers are mixed with the bitumen and swell in hot liquid bitumen. This maturation step and unique composition enable the PR FLEX 20® to be directly introduced into the plant mixer using the “Dry Process.”

The paper includes binder and asphalt concrete tests. The laboratory mixing procedure to prepare PR FLEX 20® modified binders is as follows: the bitumen is heated to 185°C, and the PR FLEX is added to the binder. Good agitation is required for 60 to 90 minutes at 175-185°C using a Low Shear Mixer to prepare the asphalt concrete at the laboratory; the PR FLEX 20® modifier is introduced into the mixture as follows: the additive is dumped on the mineral materials, which are heated to 180°C. After “dry” mixing for 30 seconds, the bitumen is poured into the mixer. The modified mixture is ready after a 3-minute “wet” mixing phase, and its temperature typically ranges from 175-180°C.

Binder testing devices

Asphalt concrete comprises two primary ingredients: asphalt binders and mineral aggregates. Therefore, laboratory assessments are required to determine binder properties and overall mixture behaviour to evaluate asphalt concrete. These evaluations will determine the adequacy of the asphalt concrete's performance in the field under local climatic conditions and traffic loads (Table 1).

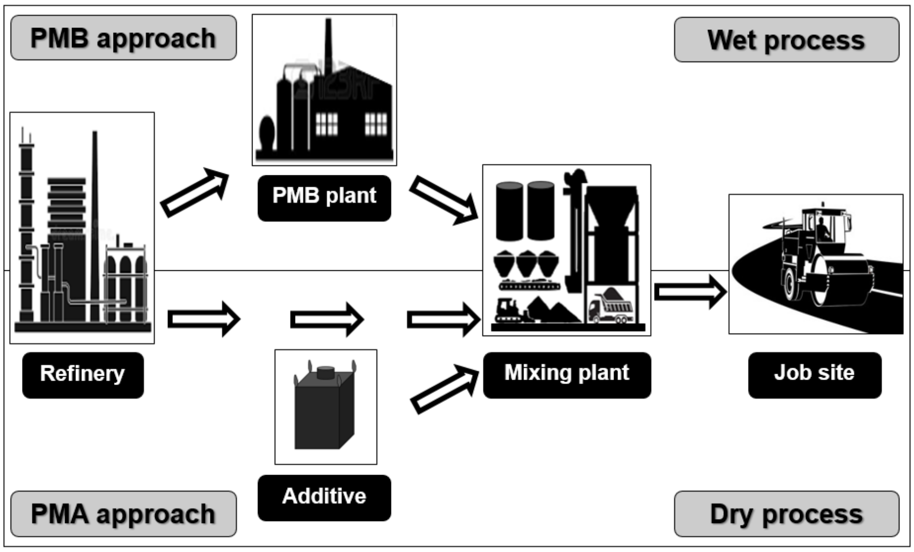

Figure 1: Presentation of the “Dry” and “Wet” processes [8]

Table 1: PG temperature zoning across Libya's desert area

Region	Wearing course	Binder course
1. Al Kufrah	PG 64-10	PG 64-10
2. Awjilah	PG 70-10	PG 64-10
3. Al Jufroh	PG 64-10	PG 64-10
4. Ghadamis	PG 70-10	PG 64-10
5. Ghat	PG 76-10	PG 64-10
6. Brak	PG 64-10	PG 64-10
7. Awbari	PG 64-10	PG 64-10
8. Al Qatrun	PG 64-10	PG 64-10

Several empirical physical property tests are available to characterize bituminous binders, and highway agencies commonly use the most frequently used ones listed in Table 2, along with some advanced equipment.

As explained in Figure 2, the PG determination following AASHTO M320 requires two ageing steps and two unique pieces of equipment: The Dynamic Stress Rheometer and the Bending Beam Rheometer.

The Rolling Thin Film Oven Test (RTFOT) simulates asphalt ageing during the blending and agitation in the hot mixing facility and during construction. This procedure exposes thin binder films to heat and air in a designated test environment. An asphalt binder film is oxidized by rotating a carriage assembly at 163°C (325 °F) for 75 min. The effects of ageing are determined from changes in physical test values as measured before and after the oven treatment.

The Pressure Aging Vessel (PAV) test covers the accelerated ageing (oxidation) of asphalt binders using pressurized air (2.10 MPa) and elevated temperature (generally 100°C) for 20 hours. It simulates the pavement's in-service oxidative ageing of asphalt binders due to the combined effects of time, traffic, and environment. This system comprises a pressure vessel, a pressure and temperature-controlling device, and a vacuum system. After the PAV process, the asphalt binder residue is vacuum degassed.

The Dynamic Stress Rheometer (DSR) measures the rheological properties (complex shear modulus G* and phase angle d) at intermediate to high temperatures experienced by the pavement in the geographical area for which the asphalt binder is intended. Permanent deformation is governed by limiting the G*/sin d at the test temperature to values greater than 1.00 kPa for the original binder and 2.20 kPa after RTFO aging. Fatigue cracking is governed by limiting G*/sin d of RTFO+PAV aged material to values less than 5000 kPa at the test temperature.

The Bending Beam Rheometer (BBR) is used to evaluate the properties of binders at low temperatures. The test measures how much a binder deflects or creeps under a constant load and at a fixed temperature. This temperature is related to the pavement's lowest service temperature. The test method uses beam theory to calculate an asphalt binder's flexural creep stiffness or compliance under a creep load. The test is performed on RTFO+PAV-aged samples to obtain the Flexural Creep Stiffness, S(t), and the ability of the binder to relax the stresses (m-value) as a function of loading time at a fixed temperature. Flexural Creep Stiffness is the ratio of the maximum bending stress in the beam to the maximum bending strain. The m-value is the absolute value of the slope of the logarithm of the stiffness curve versus the logarithm of time.

Asphalt concrete testing devices

This section is a reminder of some basic principles relating to the testing devices used in this study: The Hamburg Wheel Rut Tester (HWRT), Fig 3, is used to evaluate the rutting and moisture resistance of asphalt mixes. If necessary, the slab of hot-mix asphalt can be submerged in hot water, and a wheel is rolled across its surface. Two samples can be tested simultaneously in one HWRT run. The rubber wheels are 50 mm wide. The load applied to the wheels is 710 ± 1 N. The test path is 230 ± 10 mm long, and the average speed of each wheel is approximately 1.1 km/h (~53-wheel passes per minute). Colorado DOT recommends a maximum allowable rut depth of 4.0 mm at 10,000-wheel passes [10].

The French Laboratory Rut Tester (FLRT), Fig 4, is used in France, Belgium, Quebec and several African and Asian countries to evaluate asphalt mixes regarding rutting resistance. First, hot-mix asphalt samples (500 mm long, 180 mm wide and 50 mm or 100 mm high) are prepared in the slab compactor. In the FLRT, the repetitive load is applied by a pneumatic tire (400 mm diameter and 80 mm wide) passing on the slab's surface at a frequency of 1 Hz. Two slabs can be tested simultaneously in one run. The pressure of the tires is set at 600 ± 30 kPa, the applied load is 5000 ± 50 N, and the typical testing temperature is 60° C. The rut depth must be recorded at 100, 300, 1000, 3000, 10000 and 30000 cycles.

The Restrained Cooling Test (RCT) is designed to study the behaviour of asphalt concrete under the influence of temperature. Samples of asphalt concrete measuring 160 mm x 40 mm x 40 mm are glued to the upper and lower plates of the breaking device. The setup is introduced in a climatic chamber that can lower the temperature to -40°C. During testing, the length of the samples is kept constant, and the resulting forces are recorded. Two samples can be placed in the climatic chamber at the same time. One test lasts about 10 hours. The Water Sensitivity Test (WST) is a method to evaluate the loss of serviceability due to moisture. Asphalt concrete specimens are divided into two subsets and conditioned. One subset is maintained dry at room temperature, while the other is saturated and stored in water.

Table 2: Binder characterisation according to the American and European approaches

Property	**ASTM Test standards**	**AASHTO Test standards**	**EN Test standards**
Penetration @ 25°C, 1/10 mm	ASTM D05	AASHTO T49	EN 1426
Softening Point (SP) , °C	ASTM D36	AASTHO T53	EN 1427
Elastic recovery (ER), %	ASTM D6084-13	AASHTO T301	EN 13998
Viscosity (Brookfield) @ 135°C	ASTM D4402	AASHTO T316	EN 13702
Flash point, °C	ASTM D92	AASHTO T48	EN ISO 2592
RTFOT aging	ASTM D2872	AASHTO T240	EN 12607-1
PAV aging	ASTM D6521	AASHTO R28	EN 14769
Dynamic Stress Rheometer	ASTM D7175	AASHTO T 315	EN 14770
Bending Beam Rheometer	ASTM D6816	AASHTO T313	EN 14771

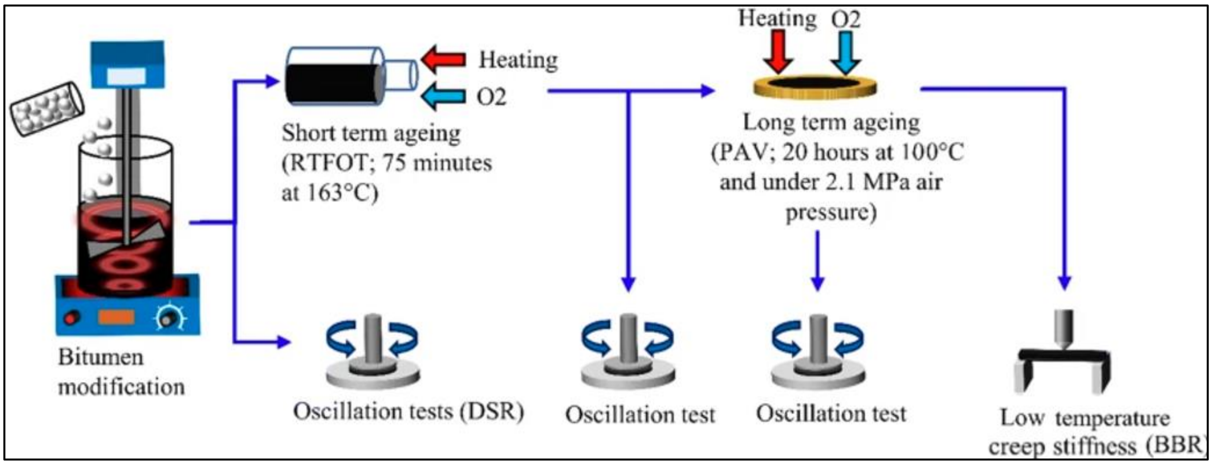

Figure 2: Superpave Testing methodology for PG determination [8]

After conditioning, the strength of each of the two subsets is determined at the specified test temperature. The ratio of the strength of the water-conditioned subset compared to that of the dry subset is determined and expressed in percent. Reduced water sensitivity means reduced maintenance requirements from layer delamination or water ingress.

There are multiple ways to determine the Stiffness Modulus (SM). These include bending tests direct and indirect tensile tests. The tests are conducted on compacted bituminous material under sinusoidal or controlled loading. Different types of specimens and supports are used in the procedure. The objective of the tests is to rank bituminous mixtures based on stiffness, which is used as a guide to estimate the relative performance of the mixture on the pavement. Additionally, the test data is used to estimate the structural behaviour of the road and to evaluate test data according to the bituminous mixture specifications.

Results.

Binder testing results

To handle intense traffic, a PG76-10 is required in the hottest regions of the Libyan Desert. To cope with the hottest climatic regions in the Libyan Desert, a PG70-10 is required, and even a PG76-10 when the traffic conditions are intense (Bumping).

In order to assess the performance of three different binders according to European and American test standards, tests were conducted on a straight run of 50/70 bitumen from TOTAL ENERGIES, as well as on two samples produced with the same base bitumen along with some PR FLEX 20® asphalt modifier. The final proportions of bitumen and PR FLEX 20® were 95/5 and 92.5/7.5, respectively. The results showed a decrease in penetration and an increase in SP, ER, and viscosity, typical of SBS modification. It was observed that a higher concentration of PR FLEX 20® led to a significant improvement in performance (SP and ER) when the loading was increased from 5 to 7.5%.

The modified samples were further tested according to AASHTO (Standard specification for Performance Graded asphalt binder), and it was found that while the base bitumen achieved PG 64, a modification with 5.0% and 7.5% of PR FLEX 20® led to a PG 70-16 and a PG 76-16, respectively.

Table 3: Classical approach for binder characterisation

Test	50/70	50/70 + 5.0% FLEX 20	50/70 + 7.5% FLEX 20
Penetration @ 25°C, 1/10 mm	65	55	51
Softening Point (SP), °C	48.2	55.4	70,6
Elastic recovery (ER), %	NA	40%	95%
Viscosity (Brookfield) @ 135°C	NA	1120	1350
Flash point, °C	> 230°C	> 230°C	> 230°C
Post RTFOT mass loss, m%	NA	0.11%	0.18%
Post RTFOT penetration, 1/10 mm	NA	39	36
Post RTFOT SP, °C	NA	62.2	76.8

Table 4: PG determination with a 50/70 + 5% PR FLEX 20®

	Original	RTFOT		RTFOT + PAV (20 h @ 100°C)			
		DSR 10 rad/s				BBR @ 60s	
Grade	**G*/sind (kPa) > 1 kPa**	**G*/sind (kPa) > 2.2 kPa**	**Temp °C**	**G*sind (MPa) < 5 MPa**	**Temp °C**	**Stiffness, S < 300 MPa**	**Slope, m > 0.30**
PG 70			34		0		
	1.405 Pass	3.231 Pass	31	1.28	-6	101.8 Pass	0.312 Pass
			28	1.63	-12	259.3 Pass	0.289 Fail
			25		-18		
PG 76			37		0		
	0.740 Fail	1.705 Fail	34		-6		
			31		-12		
			28		-18		
Test result : PG 70 – 16							

The influence of increased PR FLEX 20® concentration was visible in traditional testing (Table 3) and the Superpave PG system (Tables 4 and 5).

These binders are used in mixtures with 5% binder content, representing 1/20 of the total AC weight. Therefore, the loading to be added at the mixing plant is divided by a factor of 20, as shown in Table 6. It was previously established that the regions of Awjilah and Ghadamis require a PG 70-10, whereas the region of Ghat needs a PG 76-10. Table 6 indicates the required PR FLEX 20® loadings in each case. However, it is essential to note that this is only an indication, and the addition rate depends heavily on the compatibility of the SBS/bitumen pair. In the presence of an unknown bitumen type, laboratory tests must be performed to determine the appropriate loading.

Asphalt concrete results

Asphalt concrete testing has been conducted in laboratories on three continents with and without PR FLEX 20® additive. The formulation has been optimized in each case to accommodate the traffic level and local climatic conditions.

Project in Central Asia

In this area, the winters can get extremely cold, and a callous type of asphalt, PG64-34, is used in a small portion of the country. The low-temperature side of this classification poses a significant challenge for road engineers. A type B 0/20 mm asphalt concrete was tested locally for a project with heavy traffic. The asphalt was tested with and without 0.5% PR FLEX 20® modification. The 90/130 bitumen used had a penetration of 101 1/10 mm and a softening point of 47°C. A soft base bitumen was chosen as the asphalt concrete needed to withstand thermal stresses even at very low temperatures. This ability was tested in uniaxial tensile mode in the Restrained Cooling Tester, with temperatures as low as -36°C. The results of Table 7 indicate that adding 0.5% PR FLEX 20 significantly improves the water sensitivity of the asphalt. Additionally, the rutting tendency is reduced by a factor of 2 and the uniaxial strength at low temperatures is significantly improved.

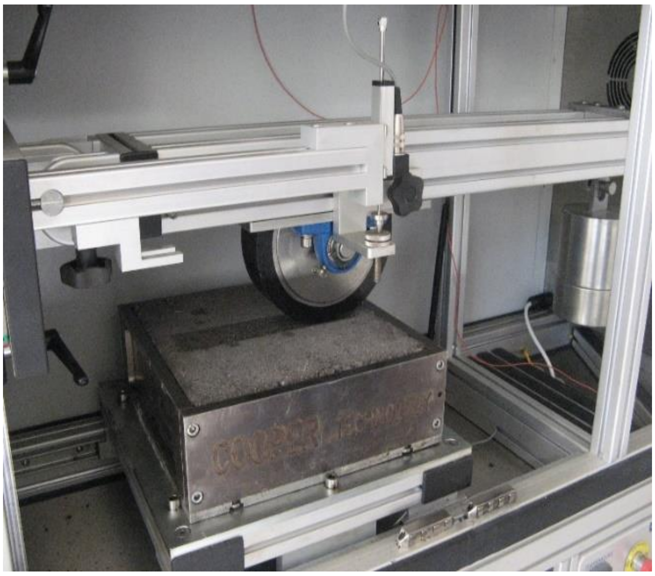

Figure 3: Hamburg Wheel Rut Tester

Project in South America

The Type CAC D19 CA30 formulations were tested on a road with heavy traffic. CA30 is a type of bitumen with a viscosity of 60°C ranging between 2400 and 3600 Poise, equivalent to a 35/50 pen grade. The mixtures were prepared using a fixed bitumen content of 4.1% of the total mass. Stiffness modulus and resistance to rutting were studied by adding 0%, 0.2%, or 0.4% of PR FLEX 20® to the total AC mixture. The results of the study are summarized in Table 8.

The study results (Table 8 and Fig. 3) show that adding 0.4% PR FLEX 20® reduces the rut depth by two when compared to the reference without the additive. As for the stiffness modulus data, there was no clear trend observed. It can be concluded that the additive had no significant influence on the stiffness modulus values.

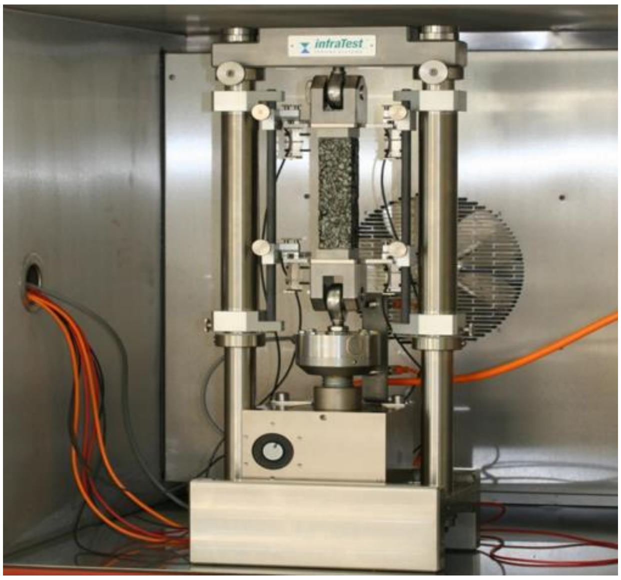

Figure 4: Restrained Cooling Tester

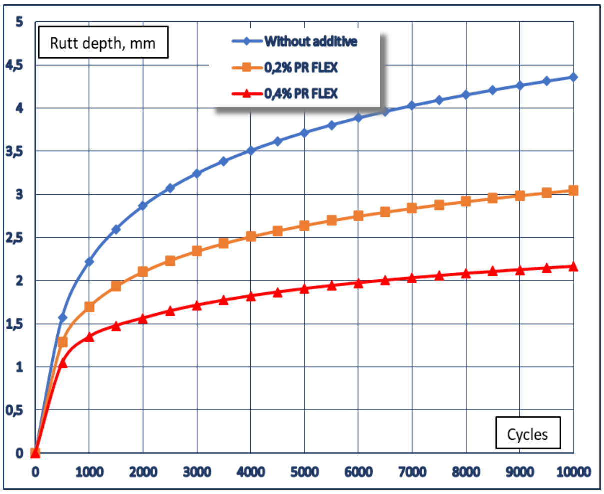

Figure 5: Results of the Hamburg Wheel Rut Tester

Project in Africa

This region has a tropical and humid climate. Two formulations of BBME (Béton Bitumineux à Module Elevé) 0/14 Class 1 were tested for the project. The reference mixture included 50/70 bitumen (4.8% of the total mixture). The modified asphalt concrete had 0.3% of PR FLEX 20® additive, reducing the bitumen content to 4.5%. Table 9 provides a summary of the results. The results indicate that rut depth can be reduced by a factor of 2, even with just 0.3% of PR FLEX 20®. It should be noted that the text above was not generated by an AI-powered assistant.

DISCUSSION

Data on rutting have been generated for three different projects. The Reduction of Deformation Risk (RDR) due to

polymer modification was calculated for each project.
The RDR values were then plotted against the PR FLEX 20® additive loading to see the effect. The resulting graph shows the increase in high PG temperature due to higher PR FLEX 20® loading and the single and double PG bump (an increase of 6°C) obtained with 0.25% and 0.375% of PR FLEX 20®, respectively. Notably, there is an excellent correlation between the results of the three different projects. The graph reveals that the increase in high PG temperature due to higher PR FLEX 20® loading aligns with the Reduction of Deformation Risk.

Table 6: Equivalence of the PR FLEX 20® loadings in the binder and in the mixture

	For a PG 70-16	For a PG 76-16
Loading of the PR FLEX 20® in the binder	5,0%	7,5%
Loading of the PR FLEX 20® in the Asphalt Concrete assuming a binder content of 5% in the mixture.	0,25% 2,5 kg/ton	0,375% 3,75 kg/ton

Table 7: Summary of the results

Test description	Test standard	90/130	same with 0.5% PR FLEX 20	Specification ST RK 1223 type B
Water sensitivity Strength water / dry	EN 12697-12	76%	90%	>= 80%
Hamburg wheel tracking Rut @ 60°C 10k cycles	EN 12697-22	6.62 mm	2.67 mm (2.47)*	
Restrained Cooling Tester Uniaxial tensile strength	EN 12697-46	3,23 MPa	5,24 MPa	-

* Reduction of the Deformation Risk compared to the reference without additive

Table 8: Summary of the results

Test	Test standard	CA30	same with 0.2% PR FLEX 20®	same with 0.4% PR FLEX 20®
Hamburg Wheel Tracking 60°C 10k cycles				
Proportional Rut Depth %	EN12697-22	7.1	5.1 (1.39)*	3.4 (2.09)*
Wheel Tracking Slope mm/kcycle		0.18	0.10	0.04
Stiffness Modulus, MPa				
10°C	EN12697-26	10.269	13.195	11.636
20°		4.890	5.257	4.881
40°		1.083	1.015	0.952

* Reduction of the Deformation Risk compared to the reference without additive.

Table 9: Summary of the results

Test	Test standard	50/70	same with 0.3% PR FLEX 20®
Binder content (% of the total mixture) 50/70		4.8%	4.5%
Additive (soluble matter)		0.0%	0.3%
Total binder (sum)		4.8%	4.8%
French Laboratory Rutting Tester Rut at 60°C after 30k cycles	EN12697-22	5.2%	2.8% (1.85)*

* Reduction of the Deformation Risk compared to the reference without additive

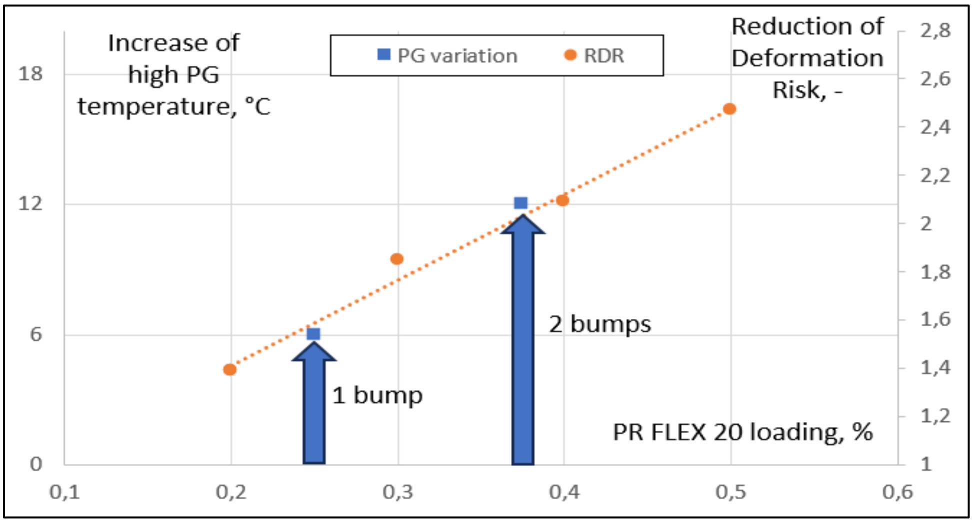

Figure 7: Increase of high PG temperature and RDR as a function of PR FLEX 20® loading

Conclusions

Asphalt concrete pavement often fails due to permanent deformation in Libya, particularly in the hot desert regions of Awjilah, Ghadamis, and Ghat. In order to tackle this matter, a study was conducted to enhance the pavement's rut resistance using PR FLEX 20®, an SBS-based modifier. The study utilized two wheel-track testers, the Hamburg Wheel Rut Tester (HWRT) and the French Laboratory Rut Tester (FLRT), both provided reasonable results and good correlation with field performance. The tests revealed that an asphalt concrete modified with 0.3 to 0.5% PR FLEX 20® offers the following benefits compared to an unmodified reference:

- Achieving a single or double grade bump (PG70-16 and PG76-16).
- Reducing Water Sensitivity by 10 to 20%.
- Reducing the Deformation Risk (RDR) by a factor of 2.
- Maintaining a relatively unchanged Stiffness Modulus (at 10 – 40°C).
- Modified asphalt concrete can be produced directly at the mixing plant to construct more durable pavements in Libya.

Recommendations and future work

The PR FLEX 20® additive has shown success in various parts of the world, and it can be efficiently utilized in Libya through the "Dry Process" for manufacturing. This process does not require PMB plants. However, additional laboratory testing is needed to confirm the added value of PR FLEX 20® modification using available aggregates and bitumen grades in Libya. The shape of the sieve grading curve and other characteristics of asphalt concrete, such as binder content and volume filled with bitumen, need to be considered in optimizing the asphalt concrete formulation. Further work will be done to validate this.

Wheel Tracking Tests (HWRT and FLRT) are typically conducted at 60°C, but the map established using the Superpave approach (Table 1) shows that pavement temperatures can reach between 64 and 76°C. Future studies will consider the possibility of conducting WTT at 70°C.

Author Contribution: “Conceptualization, methodology, writing, review and editing, Salem.”
Funding: “This research received no external funding.”
Data Availability Statement: “The data are available at request.”
Acknowledgments: "The author would like to express his appreciation to the Wadi Alshatti University."
Conflicts of Interest: “The authors declare no conflict of interest."

References

[1] J. Šrámek, “Evaluation of Bitumen Modification using a Fast-Reacting SBS polymer at a Low Modifier Percentage,” *Materials*, 16: 2942, 2023.
[2] M. Lecomte, “Advantages of polymer additives ready to be used at the asphalt mixing plant.” *Eurasphalt & Eurobitume Congress 2020*.
[3] Fabrizia Lapecorella et al. “Climate-resilient infrastructure” OECD Environment policy paper, no.14, 2018, ISSN 2309-7841.
[4] Didier Colin et al. “Choice and implementation surface layers in areas subject to conditions harsh weather,” IDRRIM no.43, Dec. 2020.
[5] W. Zeiada, et al. “Review of the Superpave performance grading system and recent developments in the performance-based test methods for asphalt binder characterization.” *Construction & Building Materials*, 220: 196-205, 2019.
[6] H. Salem, D. Uzelac, and Z. Lozanov-Crvenković. "Development of a model to predict pavement temperatures for Alkufrah region in Libya," *Journal of Society for Transportation and Traffic Studies (JSTS)*, 5(4), 2014.
[7] R. Hajj, A. Filonzi, A. Bhasin, “Improving the Performance-Graded Asphalt Binder Specification,” University of Texas, May 2019.
[8] Abed, A., Thom, N., Lo Presti, D., and Airey, G. “Thermo-rheological analysis of WMA-additive modified binders,” *Materials and Structures*, 53(3), 2020.
[9] G. Airey. “Dynamic shear rheometry, fluorescent microscopy, physical and chemical evaluation of polymer modified bitumens,” *7th conference on asphalt pavements*, 1999.
[10] Federal Highway Administration (FHWA). Federal Highway Administration Administrators. *Materials*, vol. 319, 2022, 126063