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A Comprehensive Evaluation of Polymer Additives in Modified Bitumen for Enhanced Pavement Performance

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Polymer Additives
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ABSTRACT

In Libya, as in many other countries, highway pavements primarily consist of bituminous mixtures, where the bituminous binder, despite its low proportion (5-7% by weight), significantly influences pavement performance. Standard bitumen often fails to meet desired performance levels under repeated traffic loads and adverse weather conditions. Over the last 20-30 years, the necessity to enhance pavement durability and minimize economic and environmental losses has led to the modification of bituminous binders with various additives, notably polymers. Successful bitumen modification requires understanding the characteristics of both the bitumen and the polymer used, as well as optimal production conditions for polymer-modified bitumen. This study compares 2 popular types of polymers (SBS & RUBBER) used in Libya. The results showed that the asphalt mixture with SBS & RUBBER improved the rutting % and Stabilty compared to the asphalt mixture without additives .

تقييم شامل لإضافات البوليمرات في البيتومين المعدل لتحسين أداء الرصف

حسن عويدات سالم

قسم الهندسة المدنية، كلية الهندسة، جامعة وادي الشاطئ، براك، ليبيا

الكلمات المفتاحية
تعديل البيتومين
إضافات البوليمر
البيتومين المعدل بالبوليمر
SBS
أداء الرصف

الملخص

في ليبيا، كما هو الحال في العديد من البلدان الأخرى، تتكون أرصفة الطرق في المقام الأول من الخلطات البيتومينية حيث يكون الرابط البيتوميني رغم قلة نسبته بالوزن . يؤثر بشكل كبير على أداء الرصيف البيتوميني القياسي في كثير من الأحيان ، (5-7%) يفشل في تلبية مستويات الأداء المطلوبة في ظل الأحمال المرورية المتكررة الظروف الجوية السيئة. على مدى 20-30 سنة الماضية، ظهرت ضرورة تعزيز مثانة الرصف وتقليل الخسائر الاقتصادية والبيئية إلى تعديل المواد الرابطة البيتومينية بمختلف الإضافات، خاصة البوليمرات. يتطلب التعديل الناجح البيتومين فهم خصائص كليهما البيتومين والبوليمر المستخدم، بالإضافة إلى ظروف الإنتاج المثالية البيتومين المعدل بالبوليمر. تهدف هذه الدراسة إلى زيادة الوعي لدى الباحثين وممثلي الصناعة حول إضافات البوليمر التي تعمل على تحسين خصائص البيتومين.

1. INTRODUCTİON

With increasing traffic volumes and vehicle loads, hot mix asphalt experiences permanent deformations and thermal cracking, necessitating improved properties for better resistance. Polymer additives are frequently used in bitumen and hot mix asphalt to enhance these properties, with styrene-butadiene-styrene (SBS) being the most common. This study, conducted in the comprehensive laboratory, tested three polymer additives: ITERCHIMICA - GIPAVE® (a polymeric super modifier enriched with graphene), TecRoad (a rubber-modified additive), and Pr Flex 20 W (SBS). In 2017 LIU, L., XIAO, F., ZHANG, H., AMIRKHANIAN, S. explained the Rheological characteristics of alternative modified binders," Construction and Building Materials [1].

During laboratory trials, it was found that GIPAVE did not melt effectively with bitumen due to its hard plastic properties, resulting in unsuccessful modification. The tecRoad additive dissolved in bitumen but did not enhance its properties. Conversely, Pr Flex 20 W fully dissolved and positively modified the bitumen, as evidenced by penetration, softening point, elastic recovery, specific gravity, flash point, indirect tensile strength, and HAMBURG (HWT) rutting tests. The Marshall briquette stability results further evaluated the effects of TecRoad on asphalt.

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2. OBJECTIVES

The aim of this study is to comprehensively analyze the current literature on the modification of asphalt binders using polymers. In 2024 Yao, X., et al.) made Advancements in the modification of asphalt binders with functionalized polymers[6]. The specific objectives are:

- To investigate the chemical properties of polymer-modified asphalt binders.
- To examine the factors influencing the compatibility between asphalt binders and various polymers.
- To assess the methodologies used to evaluate the compatibility of polymer-modified asphalt binders.
- To review contemporary practices aimed at enhancing the compatibility between polymers and asphalt binders.
- To identify the most effective polymers for modifying asphalt binders in high desert climates, such as those found in Libya.

By addressing these objectives, the study seeks to provide valuable insights into the use of polymer additives in asphalt binder modification, contributing to the development of more durable and efficient pavement materials.

3. BITUMEN AND ITS PROPERTIES

Bitumen, a non-volatile, sticky, and water-resistant material, is obtained from natural asphalt or crude oil distillation. Despite its complex and variable chemical composition, bitumen is primarily composed of saturates, asphaltenes, resins, and aromatics. The chemical ratios depend on the crude oil source and refining process. In 2011 MCNALLY, T introduced polymer modified bitumen (PmB)[10].Tests on Italian 60/70 bitumen, used in this study, are shown in Table 1.

Table 1. 60/70 Bitumen Properties and Test Result

Sr No.	Bıtumen Concensus Properties	Units
Test Results		
1	Penetration@25°C, 100gr/	0.01mm
62		
2	Softening Point	°C
50,8		
3	Density @25C	Kg/L
1,038		
4	Duktility@25C	Cm
120+		
5	Flash point – Fire Point	°C
320 - 345		

4. BITUMEN MODIFICATION AND ITS OBJECTIVES

Depending on the natural structure of crude oil, the properties of pure bitumen often cannot provide the pavement performance at the desired level under increasing traffic loads and adverse climatic conditions. In 2013 YILMAZ, M., KÖK,B. V., KULOĞLU, N. ALATAŞ, T conducted research on the Storage stability and rheological properties of bituminous binders modified with elastomer type polymers[8]. For this reason, it has become a necessity for asphalt producers to provide a bituminous binder with the desired structural quality/durability for flexible pavements. Bitumen is a viscoelastic substance. These materials show elastic behavior and high durability at high loading speeds (fast vehicles). However, if the loading speed is low (slow and stationary vehicles), its durability is also low. Bitumen is also a thermoplastic material, Its consistency changes when heated. Due to this feature, its durability is low at high temperatures and high at low temperatures. In 2024 Li, Z., et al modified the impact of advanced polymer modifications on the performance of asphalt binders and pavements[7]. The purpose of adding polymer to bitumen is to improve the positive properties of bitumen without changing it. Thus, bitumen's sensitivity to temperature decreases, its softening point increases, and its brittleness point decreases.Some of the general purposes of modifying bitumen are:

1- Reducing high deformations (preventing rutting and deformation)
2- Improving performance at low temperatures (Flexibility and prevention of thermal cracks)
3- To reduce viscosity during construction, maintenance and repair, and to improve the workability and compaction of mixtures
4- Increasing the strength and stability of mixture
5- Increasing the wear resistance of mixtures, reducing aggregate losses by providing better adhesion between bitumen and aggregate in coatings
6- Reducing low temperature cracks in coatings
7- Increasing the fatigue resistance of the mixture
8- Accelerating the hardening of mixtures with high/sufficient fluidity
9- To improve the quality of low-performance bituminous binders, thus enabling the use of low-performance bituminous binders
10- To increase resistance to aging and oxidation, to renew/rejuvenate aged bituminous binders
11- Creating a thicker film layer on the aggregates, thus reducing peeling between them
12- To demonstrate usability as an additive in bituminous binder
13- To reduce sweating and vomiting
14- Reducing the layer thickness of coatings
15- To reduce the life cycle cost of coatings.

5. PREVIOUS STUDIES ABOUT SAME SUBJECT

Several studies have tested modified additives to improve bitumen properties and asphalt performance. Notable references include:

- **Citation:** Emtiaz, M.; Imtiyaz, M.N.; Majumder, M.; Idris, I.I.; Mazumder, R.; Rahaman, M.M. A Comprehensive Literature Review on PolymerModified Asphalt Binder. CivilEng 2023, 4, 901–932. https://doi.org/ 10.3390/civileng4030049[4].
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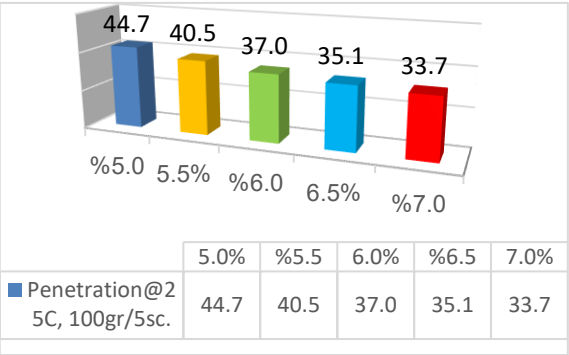
6. APPLIED EXPERIMENTS AND RESULTS

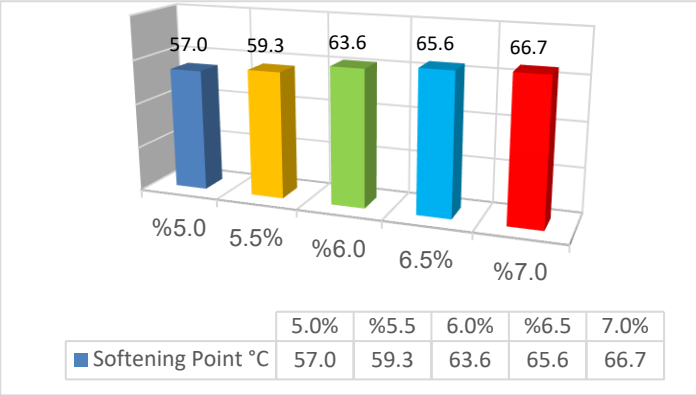
6.1. Penetration test and results

This test was performed according to ASTM D5 standard. A needle of the specified dimensions was allowed to sink into the bitumen under a constant load (100g) at 25°C for 5 seconds. Needle penetration distance (0.1 mm) is considered as penetration. The results of the penetration test are given in Table 2. It was observed that mixtures made with Pr Flex 20 W caused a regular decrease in penetration values. It was observed that mixtures made with Tecroad at 6%, 7% and 8% in bitumen did not affect the penetration value. Due to the hard plastic properties of the mixtures made with the Gipave additive material, homogeneous mixtures could not be obtained in the laboratory environment, but mixtures made with the modified plant will give positive results.

Table 2. Penetration Test Results – Pr Flex 20 W

Sr No.	Bitumen Concensus Properties	5,0%	%5.5	6,0%	%6.5	7,0%
1	Penetration@25C, 100gr/5sc.	44,7	40,5	37,0	35,1	33,7





6.2. Softening Point Test and Results

Testing was performed according to ASTM D36 standard. As a result of the tests, the Pr Flex 20 W additive has a great effect on the softening point. Test results are given in table 3. As I mentioned before, mixtures made with Tecroad did not affect the modification of bitumen and naturally there was no increase in the softening point.

Table 3. Softening Point Test Results – Pr Flex 20 W

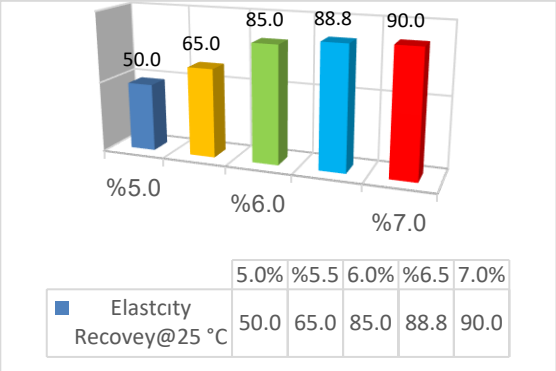
Sr No	Bitumen Concensus Properties	5,0%	%5.5	6,0%	%6.5	7,0%
2	Softening Point °C	57.0	59.3	63.6	65.5	66.7

6.3. Elasticity Recovery Test Results

Testing was performed according to ASTM D6084 standard**.** Considering the high air temperatures and increasing traffic load in Libya, the elasticity of bitumen becomes of great importance. As a result of the tests, the elastic recovery effect of Pr Flex 20 W additive was great. TecRoad additive material had no effect on elasticity. Test results are given in table 4.

Table 4. Elastcıty Recovey Test Results – Pr Flex 20 W

Sr No	Bitumen Concensus Properties	5,0%	%5.5	6,0%	%6.5	7,0%
3	Elastcıty Recovey@25 °C	50.0	65.0	85.0	88.8	90.0

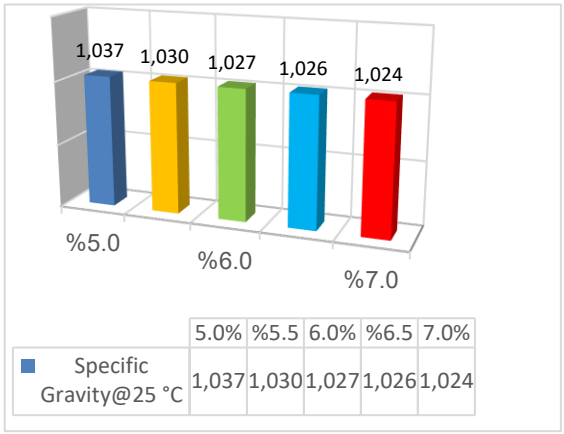


6.4. Specific Gravity Test Results

Testing was performed according to ASTM D 70-18-13 standard**.** As a result of the tests, certain decreases were observed in the bitumen specific gravity of the Pr Flex 20W additive and this is normal. Test results are given in table 5.

Table 5. Specific Gravity Test Results – Pr Flex 20 W

Sr No	Bitumen Concensus Properties	5,0%	%5.5	6,0%	%6.5	7,0%
4	Specific Gravity@25 °C	1.037	1.030	1.027	1.026	1.024



7. EFFECT ON MODIFIED BITUM ASPHALT PERFORMANCE

Its processability, especially thanks to polymer modification additives, can contribute to performance. In this study, the effects of the additives we tried on asphalt performance were examined. Peeling rate between modified bitumen and aggregate, respectively, Stability and flow values in asphalt mixtures, Determination of the indirect tensile strength of bituminous specimens and wheel rutting performance was evaluated. In 2022 Gao, X., et al showed the Performance and durability of polymer-modified asphalt binders[9].

7.1. Peeling Rate Between Modified Bitumen and Aggregate

The peeling rate was high in mixtures made with pure bitumen. In mixtures made with TecRoad additive material, the results obtained with pure bitumen are the same Picture 1. The results obtained with the Fr flex 20 w additive, especially in the 6% mixture, were very good Picture 2.

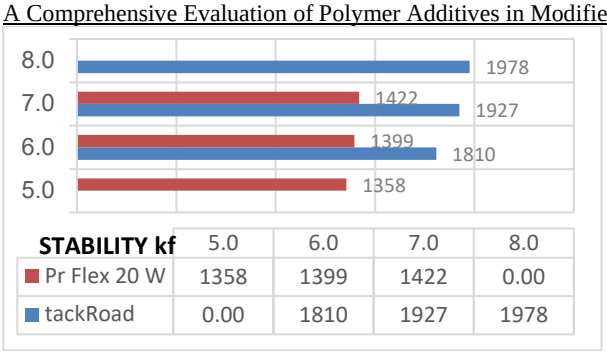
Picture 1 – TecRoad %7 Picture 2 – Pr Flex 20 W %6

7.2. Effect On Stability and Flow in Asphalt Mixture

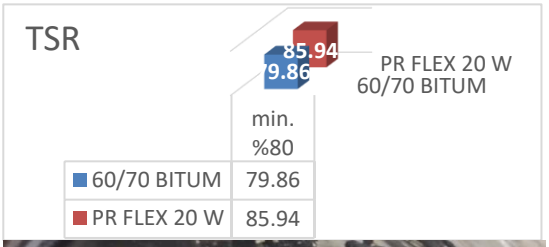
Stability, it is the ability to resist traffic loads without shifting or rutting. A stable pavement maintains its shape and smoothness under repeated traffic loads. That's why stability and flow values are very important in asphalt pavements. As a result of the tests, very high increases in stability values were observed in the mixtures made with TecRoad. Very high stability values are not a desired feature in asphalt pavements because they affect the pavement's breakage under traffic. The stability and flow values of the mixtures made with Pr Flex 20 w gave very good result Table 6.

Table 6 – Stability and Flow Test Results

ITEM	Description	UNIT	60/70 Bıtum	TecRoad %6	TecRoad %7	TecRoad %8	Pr Flex 20 W %5	Pr Flex 20 W %6	Pr Flex 20 W %7
1	Stability	kg	1310	1810	1927	1978	1358	1399	1422
2	Flow	mm	3.05	3.12	3.16	3.07	2.96	3.08	3.02



STABILITY kf	5.0	6.0	7.0	8.0
Pr Flex 20 W	1358	1399	1422	0.00
tackRoad	0.00	1810	1927	1978

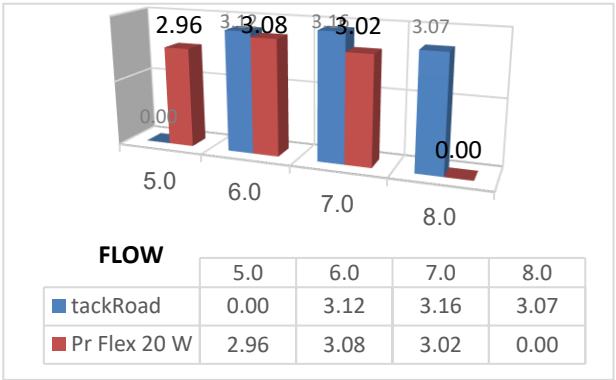


7.3. Determination Of the Indirect Tensile Strength of Bituminous Specimens

The sensitivity of asphalt pavements to water is determined according to the AASHTO T283 standard. into the water sensitivity to water, which may occur due to water in the coating's structure after it comes into contact with water It indicates its resistance to damage. Water in the pavement breaks the bond between aggregate and asphalt weakens and causes deterioration. Therefore, this test is of great importance. In this experiment, only modified asphalt mixture with PR Flex 20 W additive was tried. Since TecRoad gave high stability values, it was not deemed suitable for these tests. As a result of the tests, it was determined that pr flex 20 w 6% was quite good and studies were carried out at this rate. Test results are given in table 7.

Table 7 – Determination Of the Indirect Tensile Strength of Bituminous Specimens Test Results

Description	Test Results %	SPECİFİCATİON
60/70 bıtum	79,86	
%6 Pr Flex 20 w	85,94	80 min.



7.4. Evaluation Of Wheel Rutting Formation

Rutting is a prevalent early issue in asphalt pavements that not only drastically reduces the road's service quality and lifespan but also presents a significant hazard to vehicle safety. The structural capability of hot mix asphalt concrete layers is affected by various factors, with temperature being a key contributor to multiple types of pavement distress. Therefore, temperature is a critical factor influencing the performance and durability of pavement.

This study assessed the tire tread performance of asphalt mixtures incorporating Pr Flex 20 W. Prior tests on 60/70 bitumen indicated a softening point of 50.8°C. By incorporating the Pr Flex 20 W additive, the softening characteristics improved, and the asphalt mixture's resistance to temperature increases was enhanced. The findings are presented in Tables 8 and 9.

Table 8 - Technical Date

Standart Test Mode	300x300x50 mm
Wheel Load Contact Pressure	0.7 Mpa
Test Temprature	60°C
Wheel Rotation Speed	42±1dk

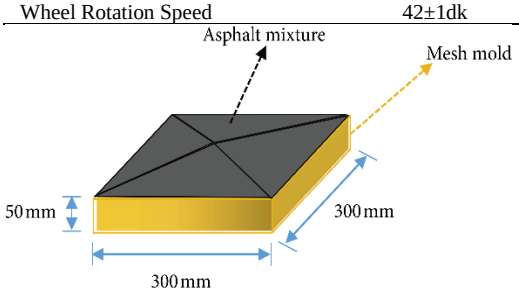


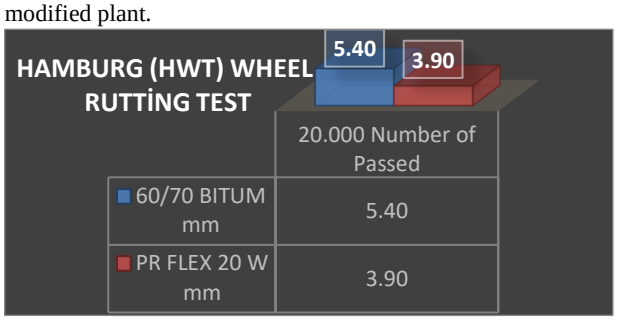
Table 9 - Wheel Rutting Test Results

MATERIAL	Hamburg (HWT) Wheel Rutting Test
60/70 Bıtum – 20.000 Number of Passed	5.4 mm
%6 SBS + 60/70 Bıtum 20.000 Number of Passed	3.9 mm

8. RESULTS AND EVALUATİONS

The purpose of these Experiments is to evaluate what might be the best solutions to rehabilitation the roads of the Libya. With this work, a methodology is proposed regarding characterization and formulation of asphalt mixture for flexible pavement structures. From a literature study, it became obvious that only asphalt concrete reinforced by polymers could resist the temperature fluctuations observed in the desert. The different tests conducted in this work demonstrate that polymer modification by the dry process (polymer addition during the mixing process) has a beneficial effect. Based on the results obtained in this study, it is anticipated that the use of appropriate modified binder type and HMA mixture in the construction of new and rehabilitation of existing roads in Libya can significantly extend their useful life.

When the test results of 3 different additive materials used in the experiments are examined, the Pr Flex 20 W material with SBS additive gave positive results in all test results. SBS with its elastic nature conveys some flexibility and UV cracking resistance to flexible pavements. It is an ideal modifier for the Wearing Courses of Libya. It has been observed that when TecRoad additive is mixed with bitumen, it does not change the properties of bitumen. It has been observed that adding TecRoad material to the plant aggregate in the asphalt mixture increases the stability of asphalt, but when the high temperatures and overloaded tonnages in Libya are taken into account, very high stability values will produce negative results. Due to the hard plastic properties of Iterchımıca - Gipave additive, a homogeneous mixture could not be obtained in the laboratory environment. The additive material must be tested again through the modified plant.



Considering the results of all research, PR FLEX 20 W SBS additive was selected to be used in projects. The storage stability of the

additive material as a result of the modification is also very good. The studies were carried out in the spacious laboratory.

9. RECOMENDATIONS

Especially in regions where the desert climate is felt, such as Libya, due to high temperatures and drought, our recommendation for asphalt production is to modify bitumen. Given the rising costs, most companies are avoiding them. More cost-effective additives are preferred. As a result of the research and tests, it has been seen that rubber additives added to the aggregate only affect the stability of asphalt. In hot countries such as Libya, the durability and flexibility of asphalt against high temperatures under traffic loads is very important. For this reason, our recommendation is to add modified bitumen as well as asphalt plant and to produce and store the modified bitumen homogeneously. While doing this, there should be stock tanks with mixers. Considering these, the most suitable additive is the use of SBS. Among SBS additives we give priority to Pr Flex 20 W. It is easy to modify with bitumen and its storage stability is very good. Performance tests are positive.

10. REFERANCE

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