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Skid Resistance of Egyptian Asphalt Roads

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يهدف هذا البحث إلى اختيار أفضل المعادلات لحساب معامل احتكاك سطح الرصف عن طريق قياس مقاومة التزلج للخلطات الأسفلتية الساخنة الشائعة الاستخدام في مصر، بالإضافة إلى إعطاء قيم عملية لمقاومة التزلج للرصف تحت مختلف الظروف وذلك لتمكين المصمم من اختيار الطبقة الأسفلتية السطحية طبقا لقيمة مقاومة التزلج المطلوبة. ومن خلال ذلك يمكن حساب مسافة التوقف الآمنة(Stopping Sight Distance) بالنسبة للخلطات المستخدمة بالمواد المحلية والمناسبة لبيئة التشغيل المصرية وبالأسلوب المقترح.

Abstract

The present research paper aims to measure Skid resistance of commonly used hot mix asphalt in the Egyptian road network, in addition to give the values of Skid resistance for paving under various Egyptian condition in order to enable the designer to select the wearing asphalt coarse according to the required Skid resistance values. Selection of the accurate regression formula that suits the Egyptian road coefficient of friction situation (road asphalt mixture in Egypt) of two important regression formulas that had been mentioned in the introduction for reaching the optimal formula that can be used by the Egyptian engineers for designing the roads. Root mean square error RMSE and Main bias error MBE have been calculated in order to find the accurate formula to be used in calculating the coefficient of friction based on the British pendulum number.

Key words

Skid resistance, British pendulum number, MBE, RMSE, Regression formula

1. Introduction

Skid resistance is known as the force developed when a tire that is prevented from rotating slides along the pavement surface [3]. It is a property of the road surface which characterizes road pavement roughness and effect on friction forces when the pavement is exposed to the wheel load [4]. The Skid resistance of an asphalt pavement is an important parameter that affecting driving safety on a road. Especially, as it has been shown that there is a linear relationship between slipperiness of the pavement surfaceand accident crashes [5]. Moreover, several researches show a dramatic increase in accident when the friction numbers decrease below certain threshold values [6].

Skid resistance/friction has two components, namely, adhesionand hysteresis [7]. These components largely depend on two properties of the pavement surface, vis-à-vis, macrotexture and microtexture. The aforementioned terms are discussed subsequently.The Skid resistance of an asphalt pavement evolves overtime and is affected by environmental factors. High ambient and pavement surface temperature could significantly influence the reliability of Skid resistance measurements [8]. Thus, this paper seeks to provide a concise but critical review of the Skid resistance for Egyptian asphalt mixture composition and its related coefficient of friction (F_{wet}) through studying environmental factors, aggregate gradation for three asphalt mixture 4C, 4B and 3D, temperature effect and finally study two source of local bitumen.

Many researches was interested in the methods needed to provide safe, Skid-resistant surfaces, the most important researches regarding this comparative study can be summarized as follows:

[1] Indicated the different devices used to measure pavement surface friction, and the correlation between friction results measured using California Skid Tester (CST), the British Pendulum Tester (BPT), and other devices. They also reviewed the methods used to calibrate friction results measured at different pavement temperature.

[2] conducted an investigation consisting mainly of a literature review and a review of current research had been conducted to determine the methods needed to provide safe, Skid-resistant surfaces on Navy and Marine Corps pavements. More information has been reported in this report for serving to update the information about friction-measuring methods, correlation of the measuring methods, factors affecting friction coefficients, minimum requirements for Skid resistance, and methods of improving the Skid resistance of slippery pavements. However, some new topics which are of recent interest are also discussed in detail. These topics include hydroplaning, the mechanism of rubber friction, the friction associated with various operating modes of vehicle tires, the relationship of friction coefficients to pavement surface texture and to surface drainage of water, and the effects of pavement grooving on hydroplaning and on friction coefficients. All the information from the investigation had been summarized, and recommendations had been given for research and development efforts needed to provide safe, Skid-resistant pavement.

2. Study Objective

Following a comprehensive study of past research carried out in the field of Skid resistance, with particular emphasis on the area of surface course mixture composition, the following were determined to be the primary objectives of the study:-

- Review of the nature of Skid resistance carried out in the field of Skid resistance with particular reference to the fundamentals of the type pavement friction mechanism and the pavement behavior.
- Review of presently accepted and widely used principles and facts on highway and pavement design in this field.
- To investigate and provide experimental results for the relation between mixture composition, bitumen source, weathering condition and pavement temperature and the Skid resistance.
- Through the previous mentioned, investigate the friction coefficient of local Hot mix asphalt mixture through British pendulum (BPN) laboratory measurement converting it to pavement coefficient friction (F_{wet}) from the field using two regression formula and comparing friction coefficient of AASHTO with friction coefficient of Egyptian hot mix Asphalt composition on 40 mph.

3. Methodology

To study the effect on the widely used mix design type course 4C, 4B wearing course and 3C binder course, a mold of rectangular shape used to form asphalt slab and compacting with using (concrete compression machine C039 1500KN motorized two gauges) to compact the slab specimen.

Skid resistance of thirty-six different Asphalt mixtures was evaluated using group of three graduation 4C, 4B and 3D. In addition, two types of local bitumen Alexandria, and Suez with three bitumen content of each asphalt slab Optimum Asphalt content, Optimum Asphalt content + 0.5%, Optimum Asphalt content + 1% with accordance to ASTM E303 – 93(2013) " Standard Test Method for Measuring Surface Frictional Properties Using the British Pendulum Tester".

Figure (1): Portable Skid Resistance Tester

Figure (2): Portable Skid Resistance Tester contact-area specimen adjustment

As shown in Figure (1) adjustment of Asphalt slab on the lab table for horizontal position and pendulum swinging arm verticality, then in Figure (2) is to check the sliding length adjustment of the rubber slider.

The samples examined in previous mentioned conditions.

4. Results

The following Figures illustrates the BPN with each Hot mix asphalt design in this paper with Dry/Wet and temp of 25C° and 50C° with two local source of bitumen Alexandria and SUEZ.

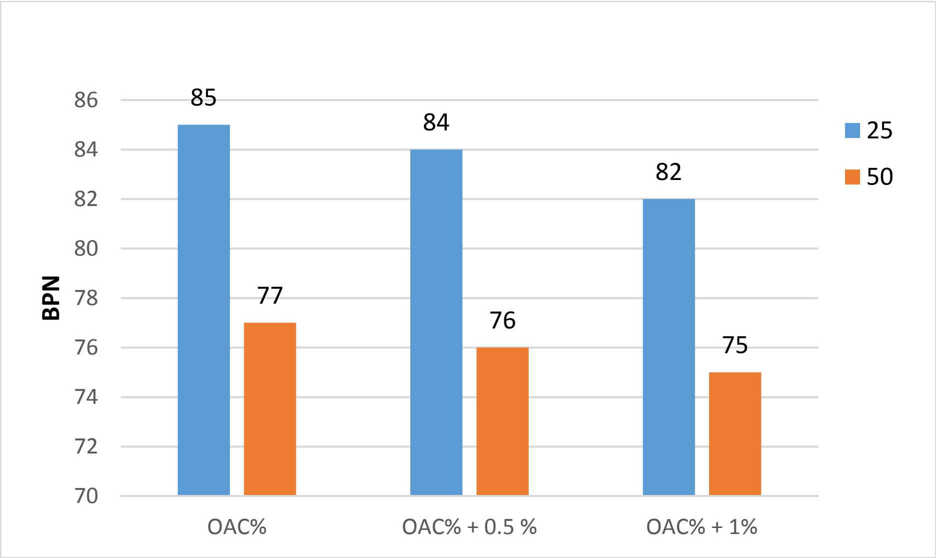

Figure (3):Wearing 4C "SUEZ BITUMEN" – DRY

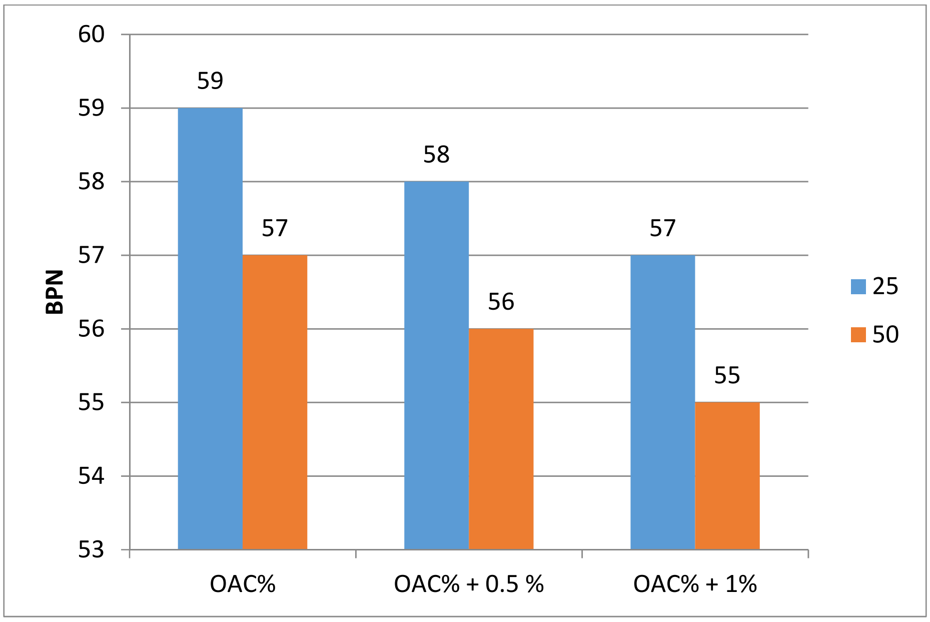

Figure (4):Wearing 4C "SUEZ BITUMEN" - WET

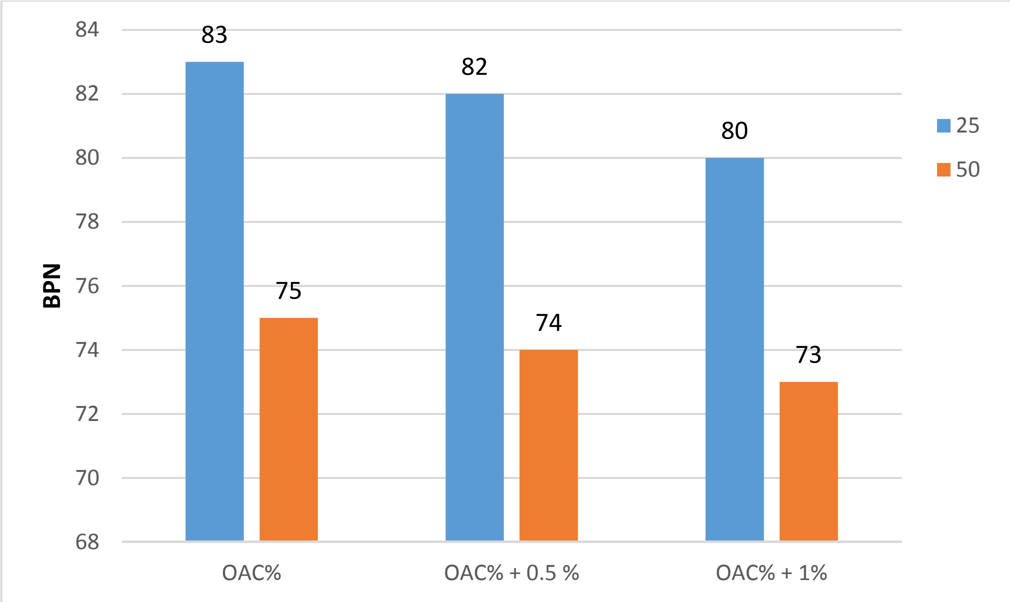

Figure (5):Wearing 4C "ALEX BITUMEN" –DRY

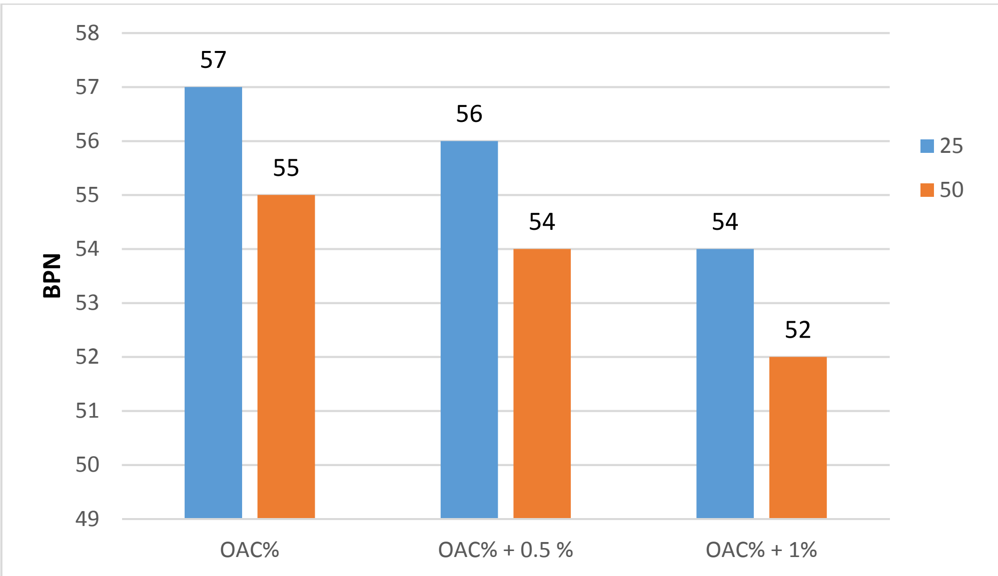

Figure (6):Wearing 4C "ALEX BITUMEN" - WET

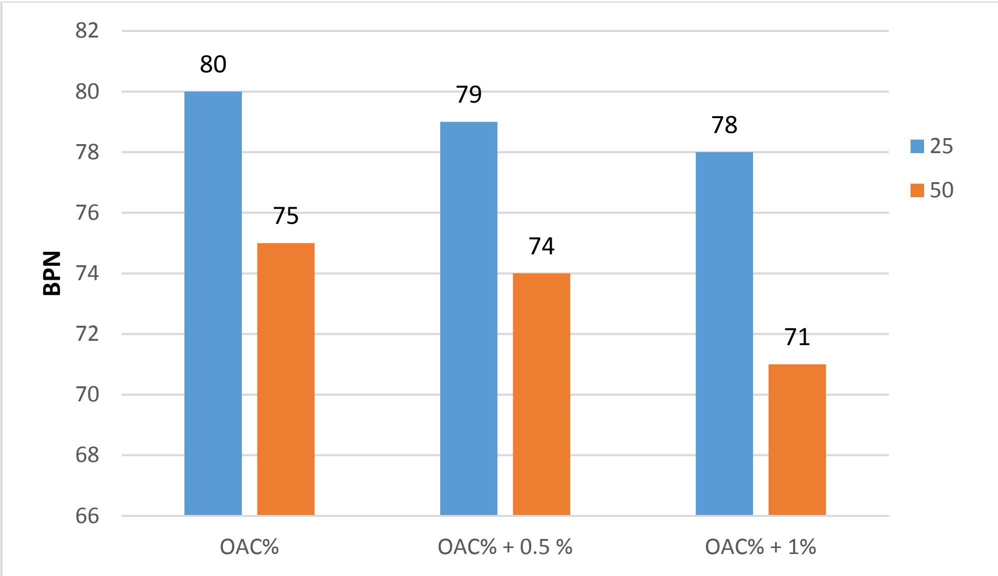

Figure (7):Wearing 4B "SUEZ BITUMEN" –DRY

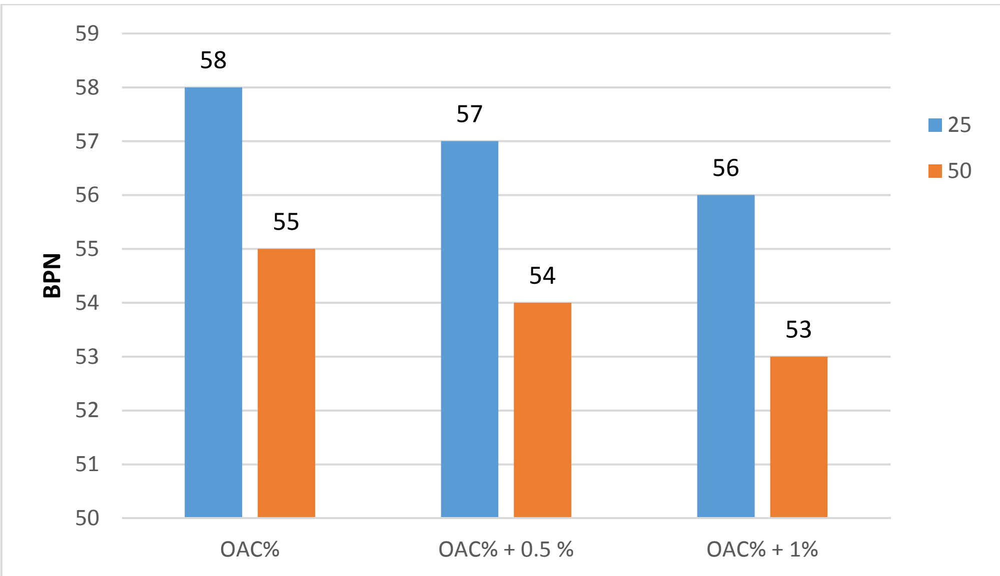

Figure (8):Wearing 4B "SUEZ BITUMEN" - WET

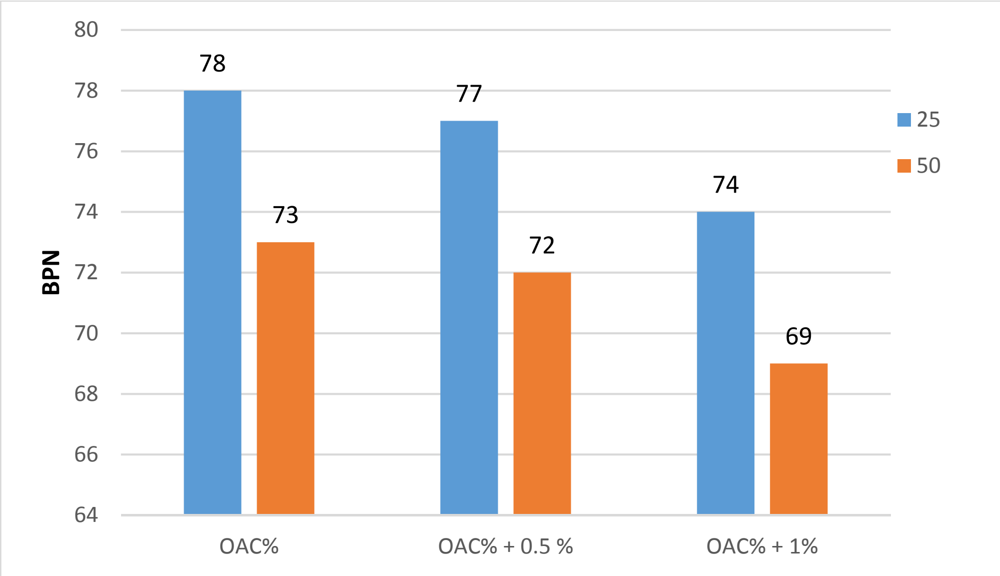

Figure (9):Wearing 4B "ALEX BITUMEN" –DRY

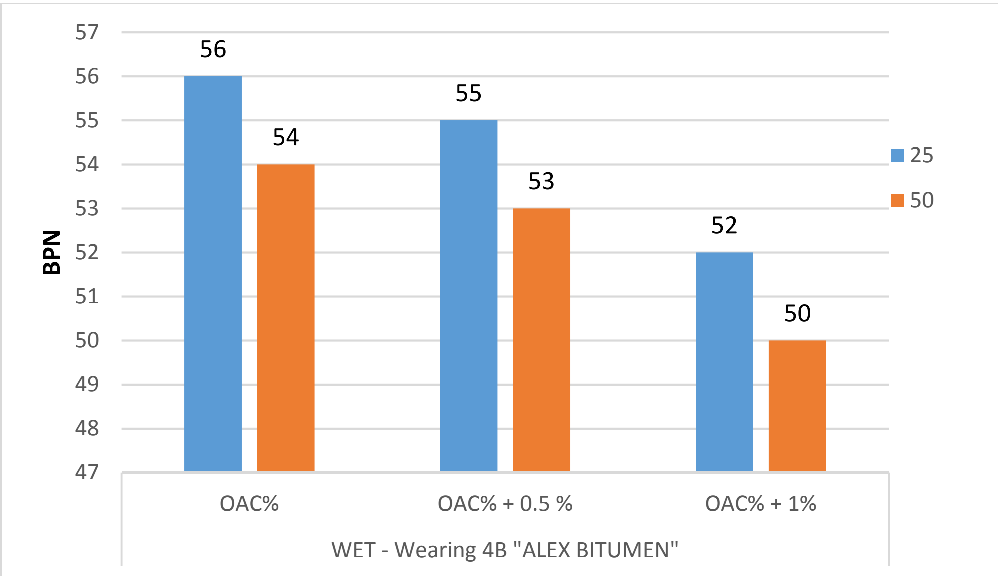

Figure (10):Wearing 4B "ALEX BITUMEN" - WET

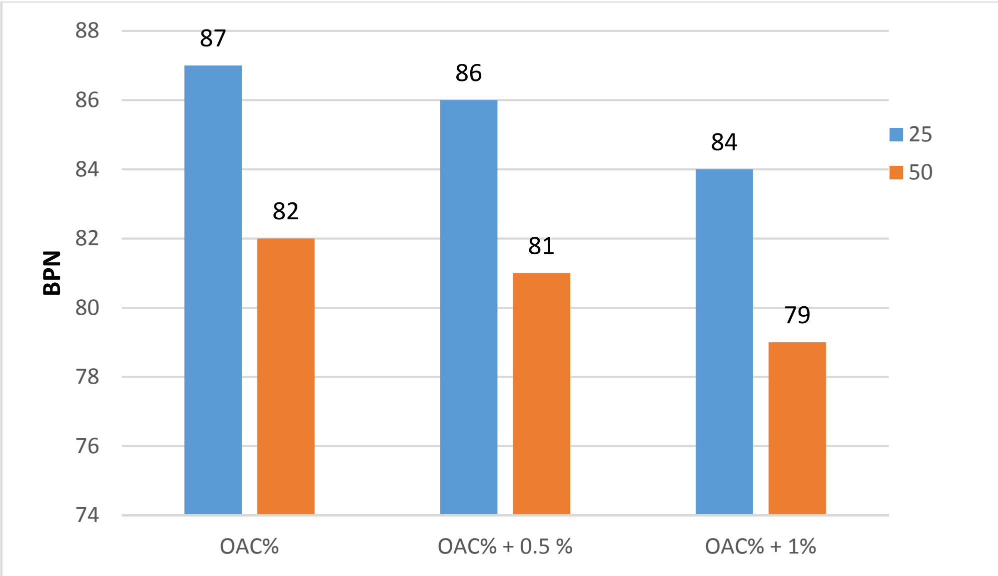

Figure (11):Binder 3D "SUEZ BITUMEN" –DRY

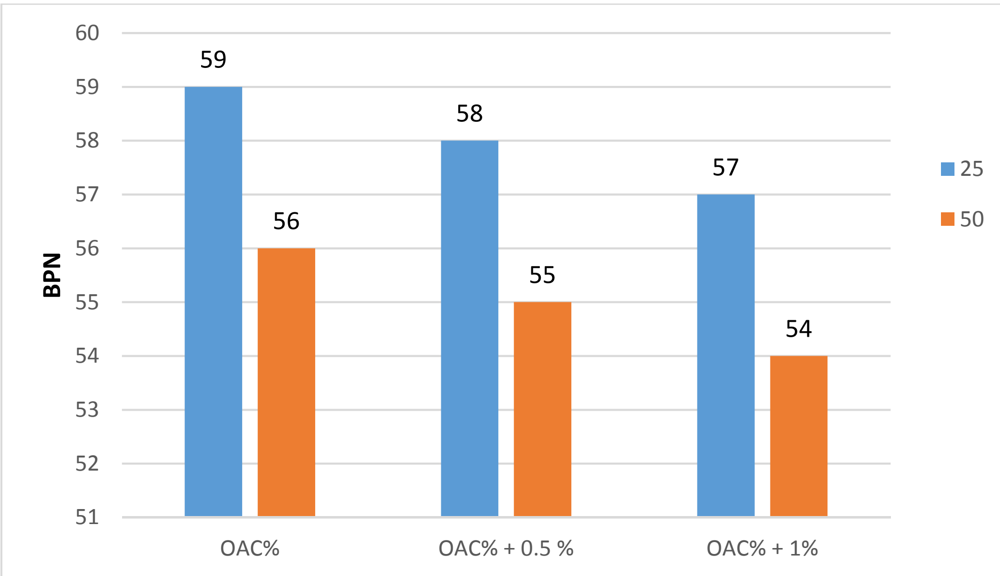

Figure (12):Binder 3D "SUEZ BITUMEN" - WET

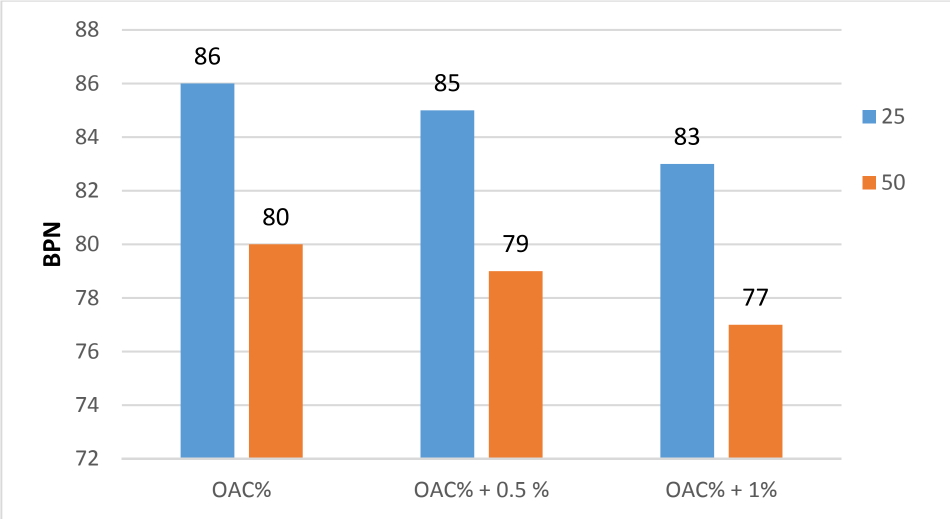

Figure (13):Binder 3D "ALEX BITUMEN" –DRY

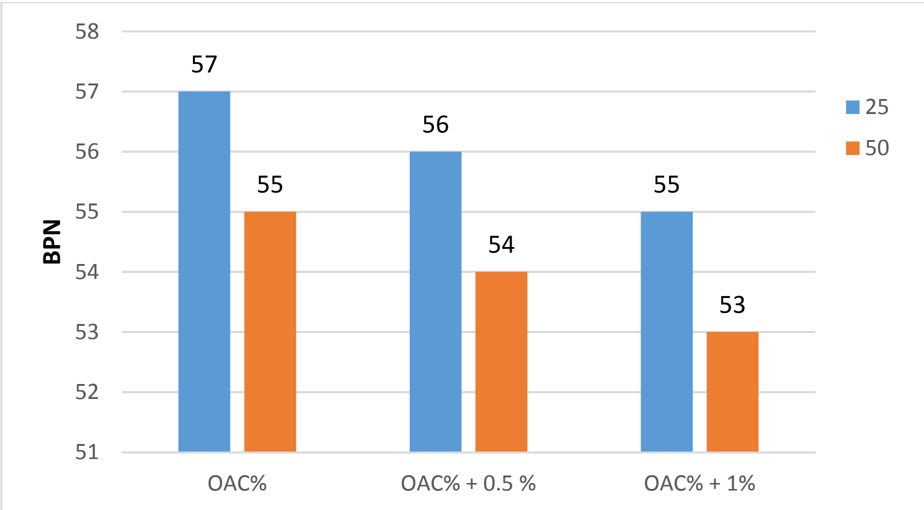

Figure (14):Binder 3D "ALEX BITUMEN" - WET

From previous Figures, it is clear that 4C mix design asphalt gives higher number in (Friction/BPN) in wet / low temperature 25C°. However, 3D mix design asphalt to gives higher number in (Friction/BPN) in higher temperature 50C°. 4B Mix design asphalt is not recommended in dangerous area (critical) due to (Friction/BPN).

On the other hand, the current work aimed to differentiate between the coefficient of friction at 40 mile/hr in the AASHTO mixtures and Egyptian mixtures.

Comparison have been conducted between the coefficient of frictions of the Egyptian mixtures and the AASHTO mixture for evaluating the Egyptian Asphalt mixture. For calculating the coefficient of friction of the Egyptian mixtures, two empirical equations from different reviews have been applied[1], [2]

$$SN = -5.6 + 1.22\ BPN \qquad [1]$$
$$SDN = -66 + 1.82\ BPN \qquad [2]$$

For determination the amount of error between the two empirical formulas two measures have been used namely mean bias error (MBE) and Root mean square error (RMSE)

$$MBE = \frac{1}{n}\sum_{i=1}^{n}\frac{X_i - X_{true}}{X_{true}} \qquad (3)$$

Where MBE is the main bias error

X_i is the results obtained from the regression model

X_{true} is the AASHTO actual results which illustrated in Table (1)

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\frac{X_i - X_{true}}{X_{true}}\right)^2} \quad (4)$$

Where RMSE is the root mean square error

Table (1) 1990 and 1994 Design coefficients of friction for stopping sight distance [9]

Design Speed		Running Speed		1990 and 1994 AASHTO Coeff. of Friction for f_{WET}	AASHTO Coeff. of Friction for trucks, f_{TR}	Acceptable Deceleration for Trucks, a_{TR} ft/sec^2
(20 mph)	30 kph	(20 mph)	32 kph	0.40	0.25	8.1
(30 mph)	50 kph	(28 mph)	45 kph	0.35	0.21	6.8
(40 mph)	65 kph	(36 mph)	58 kph	0.32	0.19	6.1
(50 mph)	80 kph	(44 mph)	71 kph	0.30	0.18	5.8
(60 mph)	100 kph	(52 mph)	84 kph	0.29	0.17	5.5
(70 mph)	115 kph	(58 mph)	93 kph	0.28	0.16	5.1

Figure (15) indicates the differences in calculation using the previously mentioned equations for calculating the friction number by substituting the values British Pendulum Number (BPN).

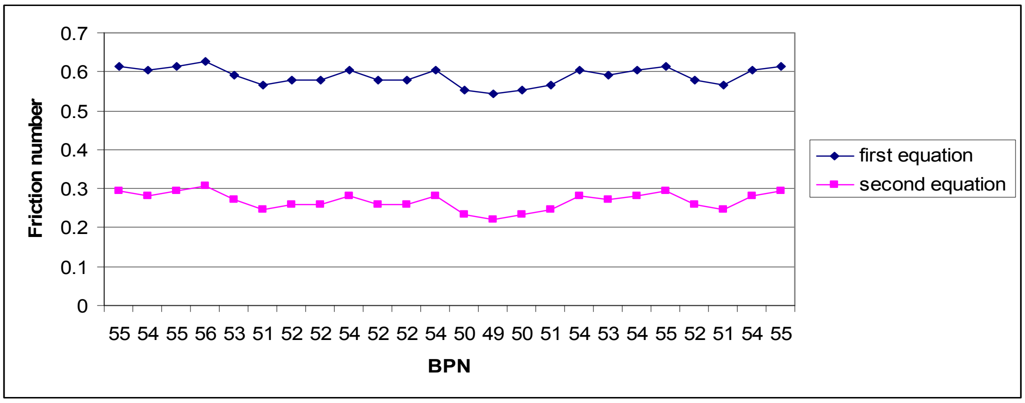

Figure (15) the friction number against the BPN using two different empirical equations

Then the calculations of the MBE and RMSE have been conducted and the results of both measures are illustrated in Table (2)

Table (2) error measurements using both MBE and RMSE

Error measures	Friction (First equation)	Friction (second equation)
MBE	26.8	3
RMSE	84.2	14.6

It is clear from Table (2) that the values of MBE and RMSE in the first equation had reached to 26.8 and 84.2 respectively, while the values of MBE and RMSE in the second equation had reached to 84.2 and 14.6 respectively, the matter that means that the error in the second equation is relative very small. This means that the second equation is recommended for the use in the Egyptian case as its results are relatively near to the Egyptian case compared to the AASHTO recommended values at speed of 40 miles /hr. the current results are accorded will with the results obtained by [1]

5. Conclusion

This paper aimed at differentiating between the coefficient of friction at 40 mile/hr in the AASHTO mixtures and Egyptian mixtures. BNP Results have been obtained from field study.

This investigation was undertaken with the primary objective to compare the Skid resistance of different mixtures based on the findings of the experiment results, the following main conclusions have been concluded:-

- 4C mix design asphalt is recommended in wet / low temperature (25C°) areas in Egypt.
- 3D mix design asphalt is recommended in higher temperature (50C°) areas in Egypt.

6. Recommendations

- Skid resistance of the asphalt road should be checked during the service life of the roads.
- British pendulum Skid resistance tester is recommended for computing road coefficient of friction and through coefficient of friction (F_{wet}) we can calculate stopping sight distance according to Egyptian standard.

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