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Investigation of Emulsion Bitumen Adhesion to Aggregates in Chipseal at Various Temperatures for Low-Cost Pavement Management

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Abstract: Preventive maintenance is recommended by economic models in pavement management. One of the issues that the Chipseal mix is currently dealing with is the degree of separation of the material from the mixture's surface due to a lack of proper adhesion between the emulsion(green) bitumen, and the aggregate. Have and cause an accident. In this study, it was attempted to reduce material separation by increasing the percentage of bitumen in the mixture as well as the percentage of sand as a filler. The results of this study showed that with increasing the percentage of emulsion bitumen in the chipseal mixture and with it increases the percentage of filler in the mixture, the separation rate of aggregates to less than 10% in the temperature range of -15 to +45 ° C, and a Created a more cohesive mixture.

Keywords: Green bitumen, billowing sands, chipseal, pavement management, cost reduction

1. Introduction

From the moment asphalt is laid on the road surface, various factors such as rain, snow, earthquake, etc. always cause new joints and cracks to appear on the asphalt surface. As governments today face a shortage of financial resources and raw materials, they always tend to provide the best protection and maintenance of old pavements, so the use of methods such as asphalt chip seal leads to the creation of new joints and cracks. Prevents the pavement surface and in addition causes the PCI performance index of the road to be kept in the usable range. Today, in addition to maintaining the pavement performance index, chip seal are used to seal the pavement surface and fill its joints and cracks[1].

The cost of construction and maintenance is one of the most important factors to consider in road construction projects. To achieve an economical and cost-effective plan, it appears necessary to conduct an economic analysis of various pavement maintenance options. Cost reduction should be requested in pavement management; economic analytical models show that preventive maintenance has the lowest costs. Road maintenance consists of a variety of activities such as paving maintenance, as well as other components and other technical infrastructure, to ensure that the road remains in its original condition. Engineering economics is a major branch of economics that deals with the analytical methods used to calculate the cost and value of engineering systems, products, and services. Engineering economics analysis can be used as a guide to determine the best option in terms of maintenance management. However, due to limited financial resources and technology, we should strive to maintain and improve the condition of existing roads at a low cost. Another factor to consider is that, safety is important in urban transport, especially on public

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transport routes. Therefore, chip seal for bus routes and reduce downtime can also be used. According to a 2008 study of chips, it was found that the use of chips also protects the pavement from adverse weather conditions [2, 3]. On rainy days, the surface texture of the chipseal reasons water on the pavement to drain faster and prevents water from penetrating the roadway body; Aggregates, in general, influence the behavior of asphalt mixtures, including warm asphalt and chipseal [4]. Chipseal are not suited for use on roads that demand significant slip resistance since aggregates have a low resistance to vehicle braking force [5]. The aggregates used in the chipseal mixture should be uniformly composed of coarse and fine grains and in general, the aggregates should be immersed up to 70% of their volume in the emulsion bitumen mixture [6]. The aggregates utilized should have a rough surface, but their size should not exceed a particular range, as larger particles in the chipseal mixture raise the sound of car tires on the existing pavement [7].

In general, the adhesion of the gypsum mixture to the aged asphalt surface is a function of various factors, the most important of which is the temperature; therefore, when applying the chips, the asphalt surface temperature should be more than 0 ° C [8]. Usually, in any asphalt mixture that uses emulsion bitumen, if the ambient temperature during spreading and compaction of asphalt are more than 0 ° C, the performance and durability of the asphalt mixture is better [9]. Studies in the field of chips have shown that the rate of application of emulsion bitumen in the chips mixture depends on the depth of placement of aggregates [10]. The implementation of the chipseal is based on experimental methods and there is a special program for its implementation in each country [11].

Climatic conditions are one of the most important factors in the implementation of Chipseal, which in addition to the methods of its implementation, are also economically different [12].

Chipseal design methods for high-traffic roads should be much more precise, and also the desired chipseal surface should be more uniform [13]. According to experiments, the smoother the surface of the chips and the greater the depth of aggregate placing in the emulsion bitumen, the higher the level of product quality [14]. Studies in the field of chips have shown that one of the weaknesses of chips after loading by road traffic is the reduction of adhesion of aggregates in the mixture, especially on roads with heavy traffic and areas with cold weather [15]. Numerous studies have been performed on the separation of materials from the surface of the chips, for example in several studies it has been shown that if added to the emulsion bitumen used in latex chips, the material removal rate is reduced and the chips mixture performs better under conditions. bad weather and heavy traffic load [16, 17, 18]. Asphalt mixture and bitumen are mixed with a variety of additives and wastes. The chipseal mixture can contain a variety of polymeric materials. The polypropylene is used in the chipseal mixture to improve the bonding between the bitumen and the aggregate, raise the cohesion of the mixture, and increase its elastic modulus. [19, 20, 21].

In this study, for more cohesion and adhesion of rock materials to bitumen emulsion, aerated sand in a certain amount compared to the percentage of bitumen emulsion used in the mixture has been used. And the experimental results showed that in general, with increasing sandblasting as a filler in a certain percentage in the chipseal mixture, the rate of separation of rock materials from the mixture decreases, and its resistance to weather conditions and heavy traffic load increases. The vial test was performed in the temperature range of -15 ° C to + 45 ° C to assess the adhesion of the aggregate to the micro-surfacing mixture.

2. Materials

2.1 Aggregates

The aggregates used in this study are calcareous and completely broken, and their physical properties are shown in Table 1.

Table 1 - Physical properties of aggregates

Aggregates	Apparent weight in terms of grams	True weight in grams	Percentage of water absorption	Los Angeles wear
Coarse grain	2.734	2.689	0.6	20
Filler	2.754	2.626	1.2	

2.2 Filler

In this research, wind sand has been used as a filler in the chipseal mixture. Table 2 shows the physical and mechanical properties of the filler used. Billowing sands are found in desert regions around the world, particularly in hot deserts. This sand is used to repair pavement layers, but it has not been used as a fine-grained or filler component in a chip seal. The subject of blown sand can be studied and important from a variety of perspectives, so extensive research has been conducted in this field in areas such as physical sciences, earth sciences, life sciences, and development studies.

Table 2 - The filler specifications used in this study

factor	content	unit	Standard used
Sand classification	A-3	-	AASHTO
Gs	2.7	-	ASTM D-854
CBR	28.5	(%)	ASTM D-1883
C	0.1	(Kpa)	ASTM D-3080
Ø	46	(degree)	ASTM D-3080
ω_{opt}	16	(%)	ASTM D-698
γ_{max}	1.845	(gr/cm^3)	ASTM D-698

2.3 Bitumen Emulsion

In general, two types of cationic emulsion bitumen CRS-1 and CRS-2 are used for bitumen mixed emulsion bitumen. In this study, CRS-1 cationic emulsion bitumen was used, and its characteristics are shown in Table 3.

Table 3 - Specifications of emulsion bitumen used in research

test		result	regulations
Kinematic sluggishness at 50 ° C		430	400-1000
Percentage of bitumen remaining		65	Minimum 65
24-hour stability		1%	1%
Sieve test		0.01 %	1%
Tests on the remaining asphalt	Degree of penetration	115	Minimum 100
	Angiic properties	40	Minimum 40
	Percent solubility	99.7	Minimum 97.5

3.Scope of Research and Test Method

To evaluate the adhesion of aggregate to Chipseal protective asphalt mixture using vialit test in this study, different levels of emulsion bitumen including 40, 80, and 120 g of bitumen and in three different levels of sandblasting according to the percentage of bitumen used including 10, 20 and 30% has been used. Also, to complete this research and evaluate the mixture in unstable climatic conditions, the adhesion of materials to the chipseal mixture in the range of -15 ° C to +45 ° C has been evaluated.

The Vialit test is used on the first time in the United States to analyze the adherence of materials to the chipseal mixtures. [22]. In this experiment, a steel plate with specified dimensions and about 20cm * 20cm and a steel ball is used, as seen in Figure (1). The amount of aggregates separated from the mixture is weighed and expressed as a percentage of the initial weight of the mixture. In general, using the following formula, the separation rate of stone materials is calculated in terms of percentage.

$$\text{Aggregate loss } \% = \frac{(\text{WB, aggregate} - \text{WA, aggregate})}{(\text{WB, aggregate})}$$

WB, aggregate = weight of the chipseal before a test

Fig. 1 - Vialit test apparatus and Samples prepared for vialit test

4.Test Result and Analysis

The results of the vialit test have been evaluated in three different levels of bitumen, which are shown in the following table in the form of tables and graphs. Results of Vialit test for 40 g of bitumen emulsion used in chipseal mixture,showed in fig2.,3. and 4.

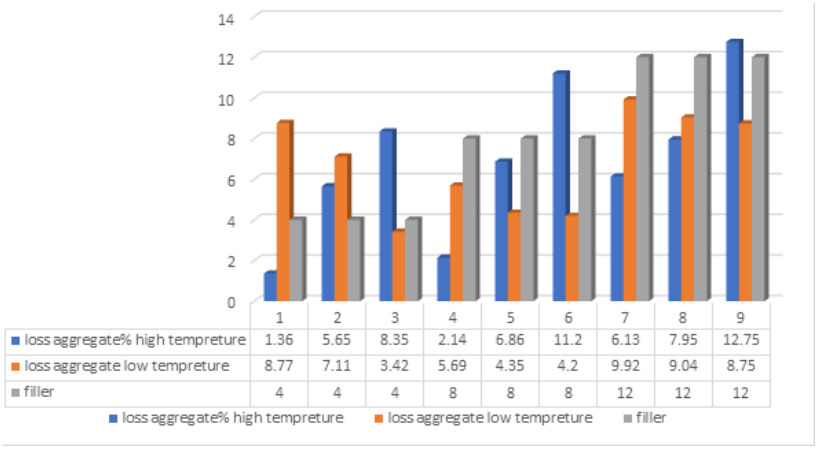


Fig. 2 - The result of testing the viality of chipseal mixture per 40 g of bitumen emulsion used

Fig. 3 - The result of the SEM is a mixture of chipseal containing 40 grams of bitumen emulsion

According to the results of vialit test per 40 g of bitumen emulsion used in the chipseal mixture, It was found that increasing the percentage of filler in the mixture resulted in, the separation of materials has increased in both high and low temperatures in general, but to Partial form At high temperatures, the rate of material separation decreases with increasing temperature and the cohesion of the mixture increases. However, at lower temperatures, as the temperature decreases, the separation rate of the aggregate material from the mixture increases, which means that the strength of the mixture decreases. Also, the results of SEM analysis test for a mixture of chips containing 40 grams of bitumen showed that this amount of bitumen in the mixture is very low and does not cover all aggregates.

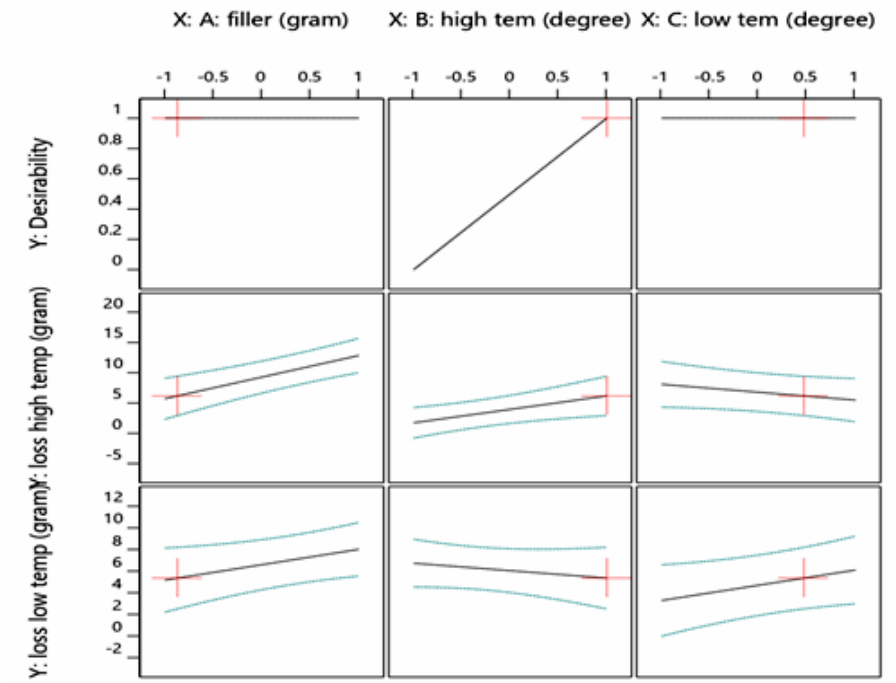


Fig. 4 - Results from analysis of variance of a two-factor chipseal containing 40 g of emulsion bitumen

The results of two-factor analysis of variance performed by Design-Expert software showed that for 40 grams of bitumen emulsion used in the chip-seal mixture, at high and low temperatures, the average separation of materials is around 5%, and this indicates that It is said that bitumen has a good performance in different weather conditions and traffic loading.

Results of Vialit test for 80 g of bitumen emulsion used in chipseal mixture, showed in fig5.,6. and 7. In this case, the bitumen used covers most of the aggregates.

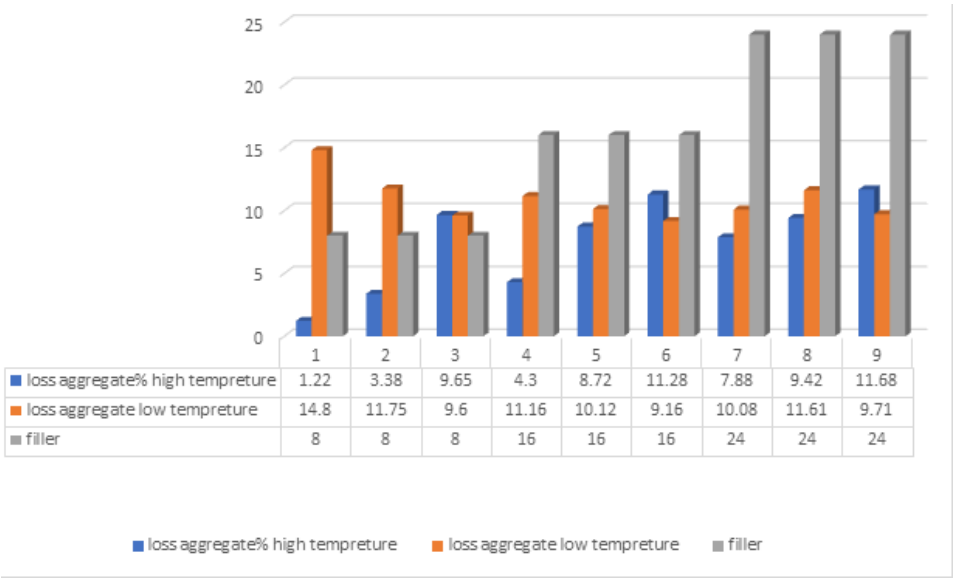


Fig. 5 - The result of testing the viality of chipseal mixture per 80 g of bitumen emulsion used

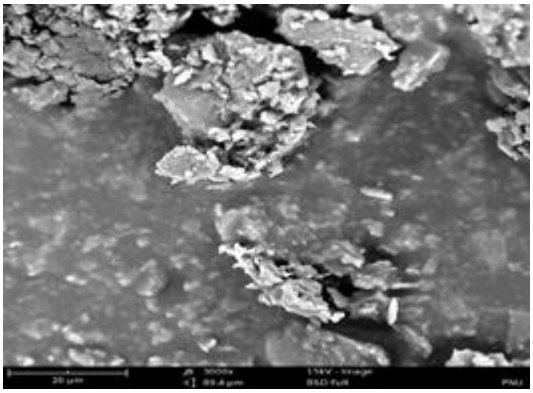


Fig. 6 - The test result of FTIR chipseal mixture containing 80 g of emulsion bitumen

The results of the test of vialit of chipseal mixture containing 80 g of used emulsion bitumen showed that in general, chipseal mixture containing 80 g of used emulsion bitumen, with increasing filler, the separation of its materials at both low and high temperature has decreased. This means that the adhesion of bitumen to the aggregates has increased and also the results of SEM show that the emulsion bitumen has created a suitable coating around the aggregates.

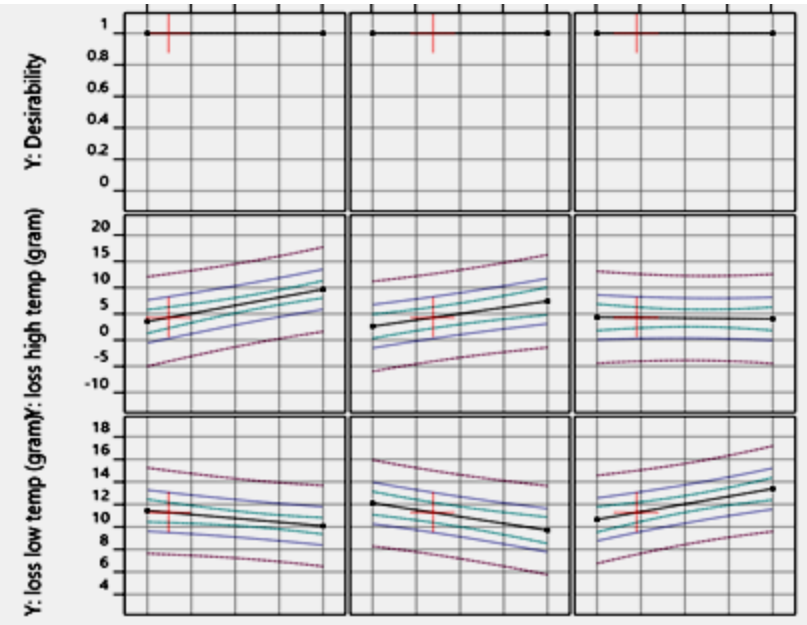
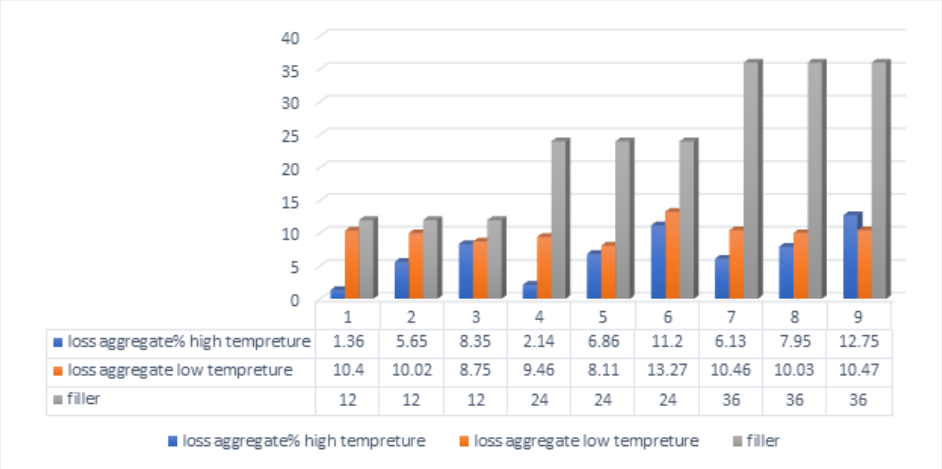


Fig. 7 - Results from analysis of variance of a two-factor chipseal containing 80 g of emulsion bitumen

The results of two-factor analysis of variance performed by Design Expert software showed that for 80 grams of bitumen emulsion used in the chip-seal mixture, the average separation of materials at high temperature is less than the separation of materials at low temperature. In general, the rate of separation of materials from the surface of the mixture at low temperatures is twice the rate of separation of the mixture at high temperatures.

Results of Vialit test for 120 g of bitumen emulsion used in chipseal mixture,showed in fig8.,9. and 10. In this case, the bitumen used completely covers the aggregates.



	1	2	3	4	5	6	7	8	9
loss aggregate% high tempreture	1.36	5.65	8.35	2.14	6.86	11.2	6.13	7.95	12.75
loss aggregate low tempreture	10.4	10.02	8.75	9.46	8.11	13.27	10.46	10.03	10.47
filler	12	12	12	24	24	24	36	36	36

Fig. 8 - The result of testing the vialit of chipseal mixture per 120 g of bitumen emulsion used

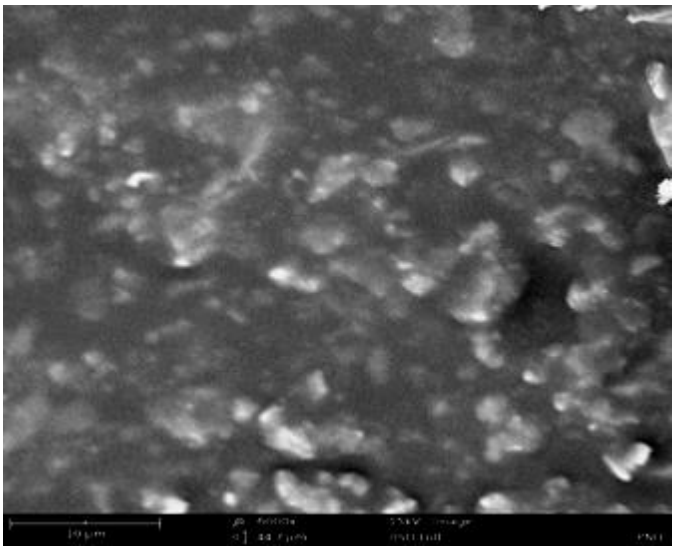


Fig. 9 - The result of the SEM is a mixture of chipseal containing 120 g of emulsion bitumen

According to the results, it was found that both increasing the amount of emulsion bitumen in the chipseal mixture and increasing the filler causes the separation of the material from the surface of the chipseal mixture to decrease and the strength of the mixture has also increased. Also, the result of SEM showed that by increasing the amount of bitumen used in the mixture by 120 grams, the amount of bitumen coating around the aggregates increased and the aggregates with emulsion bitumen formed a cohesive and stable mixture.

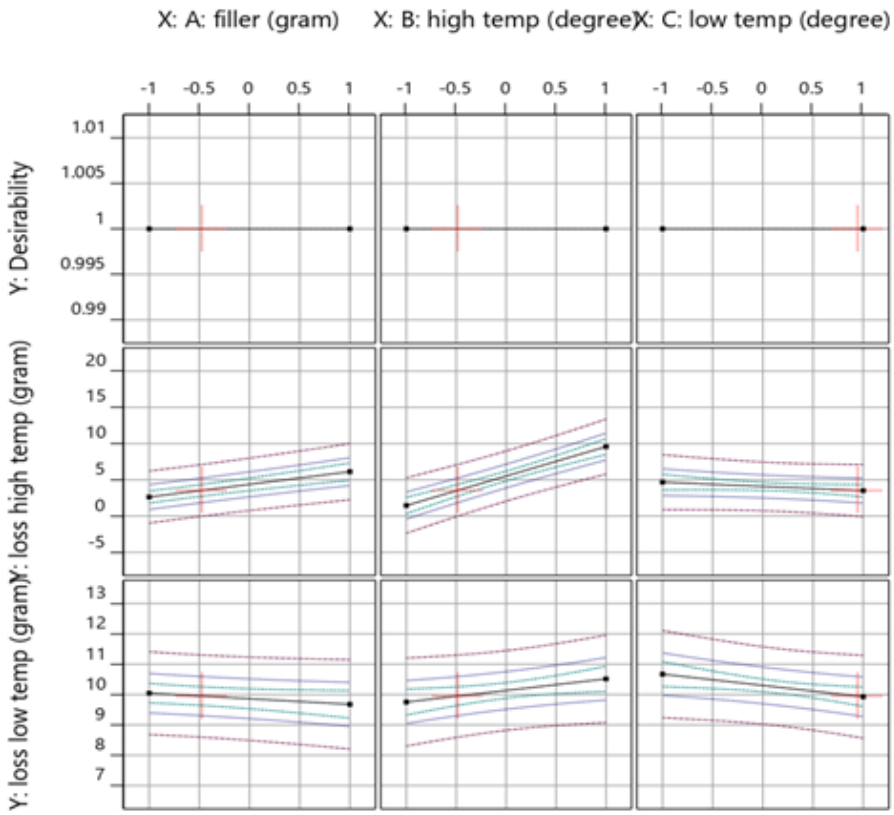


Fig. 10 - Results from analysis of variance of a two-factor chipseal containing 120 g of emulsion bitumen

5.Conclusion

The effect of using aerated sand as a filler in the chipseal mixture showed that with increasing the percentage of filler in the chipseal mixture containing 40 g of bitumen emulsion, the separation rate of the materials increases due to the lack of sufficient bitumen in the mixture and its smaller volume ratio. It is to the aggregates, but with the increase of emulsion bitumen in the chip cell mixture, the separation rate of the materials is reduced and the increase of filler in the mixture by a percentage of the bitumen weight causes the mixture to be more cohesive and integrated so that the separation rate is less than 10 Percentage and also compared to mixtures containing 40 and 80 grams of used emulsion bitumen, chipseal mixture containing 120 grams of bitumen emulsion has a better performance in bad weather conditions as well as traffic loading.

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