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Adhesion Characteristics Dolomite and Basalt Asphalt Mixes

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الملخص العربي:

هناك حالة من التطور في مجال هندسة الطرق في مصر وذلك بسبب السعي لإنشاء أفضل شبكة طرق تغطي الجمهورية من طرق داخلية وطرق سريعة. الرصف الاسفلتي المرن هو الاكثر انتشار في طرق الرصف المختلفة. لذلك هناك سعي دائم من الباحثين لتحسين خواص الخلطات الاسفلتية للوصول الى أفضل اداء ممكن لها من تحمل الاحجام المرورية العالية والتغيرات المناخية المختلفة من ارتفاع درجات حرارة. أحد هذه الطرق هي تحسن التصاق البيتومين بحبيبات الركام وتغطيتها بالشكل الأمثل. لذلك تمت دراسة التصاق البيتومين بنوعين من الركام هما البازلت والدولوميت بدون إضافات، وبثلاث إضافات منفصلة وهي غبار الأسمنت وغبار الجير وعامل مانع للتقشير. تم إجراء ثلاث اختبارات هي اختبار الاستخلاص، واختبار الثبات والتدفق من مارشال، والركام المغطى بالبيتومين باستخدام الماء المغلي. وذلك لدراسة كل ما يتعلق بخليط الإسفلت وكفاءته ومدى إمكانية تطبيقه عمليا في مختلف المشاريع لكل من طبقات الرابطة والسطحية. مع المقارنة بين العينات المرجعية والعينات المضاف اليها المحسنات اثبتت النتائج تحسن واضح في التصاق البيتومين وحبيبات الركام وتحسن في الخواص الميكانيكية المختلفة للمخلوط الاسفلتي.

الكلمات الافتتاحية: الرصف الاسفلتي المرن، غبار الأسمنت، غبار الجير، وعامل مانع للتقشير التصاق البيتومين، اختبار الاستخلاص، اختبار مارشال.

Abstract

There is a state of development in the field of road engineering in Egypt, due to the quest to establish the best road network covering the country from internal roads and highways. Flexible asphalt pavement is the most popular in different paving methods. Therefore, there is a constant quest by researchers to improve the properties of asphalt mixtures to reach the best possible performance for them to withstand high traffic volumes and various climatic changes from rising temperatures.

One of these methods is to improve the adhesion of bitumen to the aggregate particles and to cover them optimally. Therefore, the adhesion of bitumen to two types of aggregates, namely

basalt and dolomite without additives, and with three separate additives, namely cement dust, lime dust and an anti-stripping agent, was studied. Three tests were the extraction test, the stability and flow test of Marshall, and the aggregate covered with bitumen using boiling water. In order to study everything related to the asphalt mixture, its efficiency and the extent to which it can be applied in practice in various projects for both the binding and surface layers.

With the comparison between the reference samples and the samples with additives added, the results showed a clear improvement in the adhesion of bitumen and aggregate granules and an improvement in the different mechanical properties of the asphalt mixture.

Keywords: flexible asphalt pavement, cement dust, lime dust, bitumen adhesion anti-stripping agent, extraction test, Marshall test.

1. INTRODUCTION

Countries of the world are always striving to raise the value of their economy. One of the indicators that help it reach the best economy are roads. As connecting cities together or linking countries together is not only important for internal and external trade or the provision of services and its ease of transportation to citizens across the country, but for momentum. To facilitate the opening of new tourist, religious, recreational, and social horizons. This became clear with the race of the world's countries to build the longest and widest roads, passing through the collapse and passing between the rocks of the mountains. Therefore, researchers are always striving to develop and update one of the most important sciences of civil engineering is the science of roads.

Since the Egyptian government is seeking to use the highest standards of quality in all stages of road implementation. With regard to asphalt paving, the dolomite rocks that have been used for years and years in asphalt mixtures have become unavailable, especially in the southern region. Therefore, other rocks are used, but they are more complex, such as basalt and granite. It was necessary to study the different rocks and seek to improve the performance of the bituminous paving in order to obtain a highly efficient and effective mixture that has the ability to withstand frequent loads, climatic changes, and high temperatures. Therefore, it was necessary to study the properties of the asphalt mixture, especially the adhesion and cohesion of the aggregate and bitumen granules and seek to increase it.

2. MATERIAL

Asphalt concrete mixes investigated in this study consisted of coarse aggregate, fine aggregate, bitumen, and additives. The materials used for preparing the asphalt mixture specimens were aggregate from basalt and dolomite. The crushed sand got from crushing the

aggregate from the same type. It was used Suez bitumen 60/70.Also, it was used Cement dust, Anti-Stripping agent and Lime dust.

2.1. Aggregates

It was used aggregate which locally available with measure size between 25 - 10 mm as first group, measure size between 10 - 5 mm as second group and sand crushed as Filler in third group. The overall shape was circular and sub-angular, with a perfectly smooth, uniform surface texture free of any unwanted impurities.

The material validity test was conducted for the different types of aggregates used (basalt - dolomite) in terms of gradation and knowing the proportion of natural, specific weight, ability of absorption flat and elongation based on ASTM D-4791, and the Los Angeles AASHTO - T 96 test was conducted. The results of these tests were as shown in tables (1), (2), (3), (4), (5) and (6)

Table 1 Aggregate Gradation for Basalt

Sieve No.	Opening (mm)	Percentage Passing % (24-19)	Percentage Passing % (19-14)	Percentage Passing % (14-10)	Percentage Passing % (10-5)	Percentage Passing % (5-0)	Percentage Passing %Back Filler
1 in	25	100	100	100	100	100	100
3/4 in	19	68.5	100	100	100	100	100
3/8 in	12.5	0.2	0.2	18.8	99.2	100	100
NO. 4	4.75	0.1	0.1	0.2	5.5	99.2	100
NO. 8	2.36	0	0	0.1	0.4	75.4	100
NO. 30	0.6	0	0	0	0.1	34.2	100
NO. 50	0.3	0	0	0	0	21.3	95.6
NO. 100	0.015	0	0	0	0	9.8	91.2
NO. 200	0.075	0	0	0	0	3.8	69.4

Table 2 Ratio of normal, flattened and elongation for basalt: ASTM D- 4791

Test	(24-19)	(19-14)	(14-10)	(10-5)	Specifications
Total Sample Weight (g)	1000	1000	1000	1000	
Weight of natural material in the sample (g)	2	1	5	1	no more than 10%
Percentage of natural materials (%)	0.20	0.10	0.50	0.10	
Weight of the slatted material in the sample (g)	40	26	34	30	no more than 10%
Flat percentage (%)	4	2.6	3.4	3	
Weight of the elongated material in the sample (g)	42	28	35	31	no more than 10%
Elongation (%)	4.2	2.8	3.5	3.1	

Table 3

Los Angeles Test for basalt: AASHTO - T 96

Test	(24-19)	(19-14)	(14-10)	(10-5)	Specifications
Total Sample Weight (g)	5000	5000	5000	5000	
Sample weight after testing (g)	4144	4159	4185	4121	
wastage ratio	17.12	16.82	16.3	17.58	**no more than 32%**

Table 4 Aggregate Gradation for Dolomite

Sieve No.	Opening (mm)	Percentage Passing % (24-12)	Percentage Passing % (12-5)	Percentage Passing % (5-0)	Percentage Passing %Back Filler
1 in	25	100	100	100	100
3/4 in	19	84.2	100	100	100
3/8 in	12.5	1.5	58.2	100	100
NO. 4	4.75	0	3.8	96.5	100
NO. 8	2.36	0	0	78.5	100
NO. 30	0.6	0	0	31.6	100
NO. 50	0.3	0	0	18.4	100
NO. 100	0.015	0	0	10.6	90
NO. 200	0.075	0	0	4.6	73

Table 5 Ratio of normal, flattened and elongation for Dolomite: ASTM D- 4791

Test	**(24-12)**	**(12-5)**	**Specifications**
Total Sample Weight (g)	1000	1000	
Weight of natural material in the sample (g)	90	88	no more than 10%
Percentage of natural materials (%)	9.00	8.80	
Weight of the slatted material in the sample (g)	35	39	no more than 10%
Flat percentage (%)	3.5	3.9	
Weight of the elongated material in the sample (g)	25.2	20	no more than 10%
Elongation (%)	2.5	2	

Test	(24-12)	(12-5)	Specifications
Total Sample Weight (g)	5000	5000	
Sample weight after testing (g)	3340	3360	
wastage ratio	33.2	32.8	**no more than 32%**

Table 6 Los Angeles Test for Dolomite: AASHTO - T 96

2.2. Bitumen 60/70

It was used Bitumen by grade 60/70 which was described the most suitable grade for paving roads. Bitumen 60/70 has many properties that are suitable for different paving processes and stages. It is not only used as a binder for aggregates with each other but is also used in the synthesis of emulsions and cut-back of volatile medium MC and adhesive RC. It is characterized by boiling at higher temperatures than the rest of the other grades. The degree of penetration is large, from 60 to 70 mm, with high viscosity and high purity. Many tests were conducted on samples mixed with bitumen in order to reach the best percentage added to the asphalt mixture.

2.3. Anti-stripping agent

anti-stripping agent is a chemical material which used in improving the adhesion between the bitumen and aggregate. It consists of mixture of phosphoric acids derivatives. This chemical material is stored in containers and drums. The following table shows the physical properties:

Properties of Material	
Aspect	Liquid
Color	Red - Dark Brown
Density at 25 C (gm/cm3)	0.9 - 1.0
Viscosity at 25 C (cP)	150 - 250
Flash Point	≥ 150 C
Pour Point	≤ -5 C

Table 7 Properties of Anti-Stripping Agent

2.4. Lime dust

Lime dust is a white limestone natural powder with fine spherical particles resulting from the crushing and grinding of limestone aggregates in quarries, as its properties and qualities are the same as those of limestone. However, its quality is tested by making sure that the percentage of pass-through from sieve 30 is 100%, and the percentage of pass-through from sieve 100 is no less than 85%, and the percentage of pass-through from sieve 200 is not less than 65%

Table 8 Lime Dust gradation

Sieve No.	Opening (mm)	Percentage Passing % Lime Dust	Project specifications
1 in	25	100	
3/4 in	19	100	
3/8 in	12.5	100	
NO. 4	4.75	100	
NO. 8	2.36	100	
NO. 30	0.6	100	min.100
NO. 50	0.3	96.5	min.100
NO. 100	0.015	85.5	min.85
NO. 200	0.075	79.5	min. 65

2.5. Cement dust

Cement dust is a grey, volatilized cement powder that is collected from the cement industry. Its properties are the same as those of cement and it was used as a catalyst for lime dust in order to improve the asphalt concrete in the surface layer and it is also added with the base layer in order to raise the efficiency of the layer and increase its homogeneity and fill its void.

Table 9 Cement dust gradation

Sieve No.	Opening (mm)	Percentage Passing % Cement Dust	Project Specification
1 in	25	100	
3/4 in	19	100	
3/8 in	12.5	100	
NO. 4	4.75	100	
NO. 8	2.36	100	
NO. 30	0.6	100	
NO. 50	0.3	100	min.100
NO. 100	0.015	97.4	min.85
NO. 200	0.075	94.5	min. 65

3. EXPERIMENTAL PROGRAM

By percent of 0.2%, 0.4%, 0.5% and 0.6% of the bitumen weight, Anti-Striping Agent was added by preparing four mixtures for the asphalt binder layer. Adding Cement dust at percentages of 1%, 2%, 3% and 4% of the weight of the aggregate. Four mixers were also equipped with the same proportions and type of aggregate and the percentage of bitumen, with the addition of Lime dust at rates of 1%, 2%, 5% & 6% of the weight of the aggregate.

The same samples and the same number were prepared in the same proportions with the asphalt surface layer. So that the total samples are 26 samples between 12 for the asphalt bond layer, 12 for the asphalt surface layer and 1 samples reference for each layer.

The reference samples were called present design, as they were designed without any additions. The twelfth samples were named by the type of layer, whether it was a bond or

superficial, and the type of additive used, whether it was Cement dust, Anti-Stripping agent and Lime dust, and the percentage of addition, as mentioned previously.

3.1. Extraction Test – AASHTO T 164

In this test, the bitumen in the asphalt mixture is extracted to know the percentage of the bituminous content. As a sample is taken from the asphalt mixture of known weight. Then it is placed in the extraction device and gasoline is added while the device is running until the bitumen is released and then weighed again and the difference between the two weights is the weight of the bitumen used. The resulting aggregate enters the sieve analysis experiment.

As shown in the figure, the extraction device is a solution above a device for the movement of this drum in a circular motion at different speeds of up to 3500 rpm. With this device, a container is collected from the experiment product after adding gasoline through a drain (hose).

Figure 1 Bitumen extraction device

3.2. Marshall Stability and flow Test AASHTO T 245 – 97

This test aims to measure the stability of the asphalt mixture by Marshall method and to measure the strains resulting from the loading. As shown in the figure, the Marshall device consists of a load transfer rod connected from above to the Hydraulic Jack and from below with two jaws are load cells inside which the sample is placed. It is pressed until collapse and there are two gauges, one of them records the strain of the mixture and the other records the value of the load. There is also a water bath in which the sample is placed before the test for about half an hour.

Figure 2 Marshall device

3.3. Bituminous-Coated Aggregate Using Boiling Water

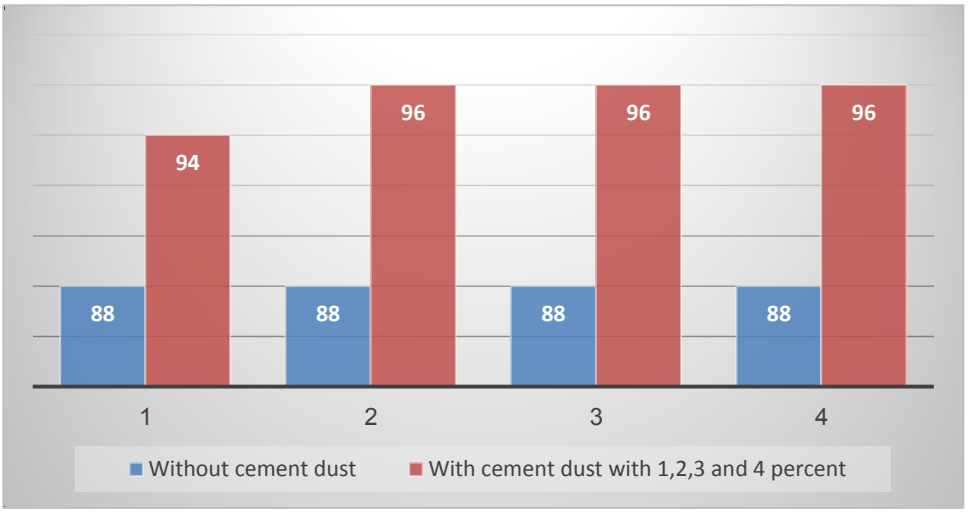
This test is based on preparing the asphalt samples and placing them in a pot with distilled water and boiling it for a period of 10 to 15 minutes. After this time, the container containing the asphalt sample and distilled water is removed from the heat source and left to cool. Then the water is poured, and the mixture is placed after the test on a white towel. The fine and coarse aggregates are visually observed to know the degree of bitumen coating for aggregate granules. The paint quality and its quality are measured by the Coefficient of Paint Index CI.

4. RESULT AND ANALYSIS

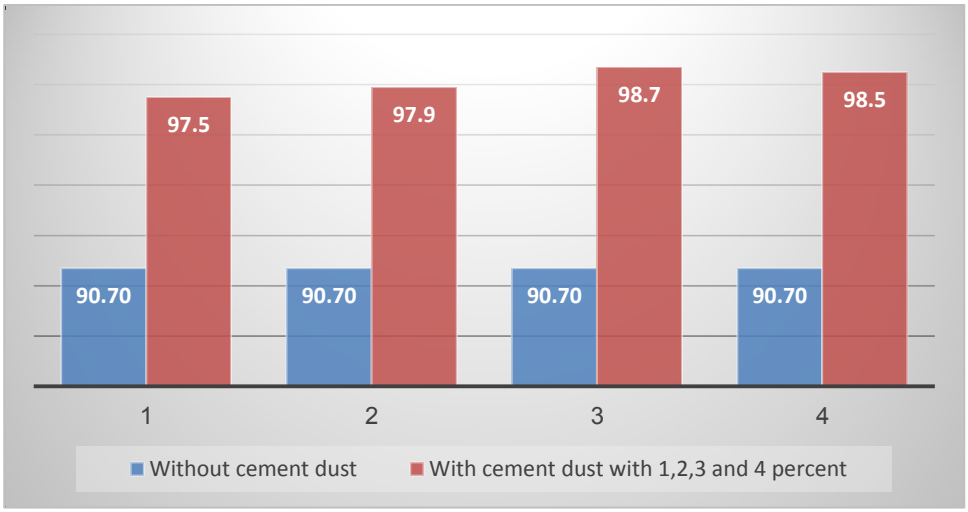
The components of the asphalt mixture, its homogeneity and the bitumen covering of aggregate granules are the main axes in obtaining high-efficiency roads and have a great ability to resist loads and obtain high performance. Therefore, the adhesion of bitumen to two types of aggregates, basalt, and dolomite without additives, and with three additives separately, namely cement dust, lime dust and anti-stripping agent, was studied. Three tests were performed, they are extraction test, Marshall stability and flow test, and Bituminous-Coated Aggregate Using Boiling Water. This is in order to study everything related to the asphalt mixture, its efficiency, and the extent to which it can be applied in practice in various projects for both layers binder and surface. 52 samples were prepared, and the aforementioned tests were conducted, and their results recorded accurately in order to be able to clearly compare the matching samples and cancel the results of non-conforming samples

Laboratory experiments and test results and analysis prove the following:

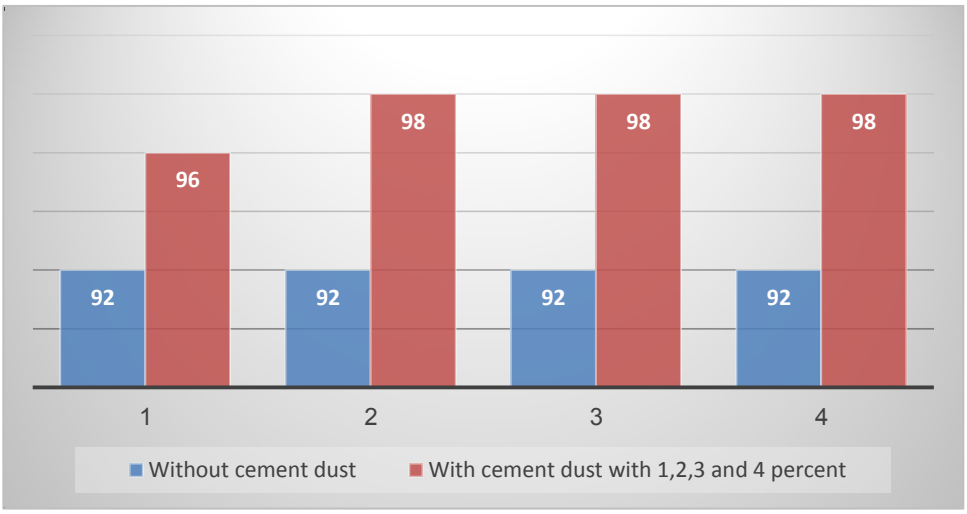
1- **Cement dust** with percentages of 1% and 2% achieved distinguished results in the binder layer using basalt as aggregate, while percentages of 2%, 3% and 4% achieved distinguished results in the surface layer of the same type of aggregate. On the other hand, with its four ratios, it achieved great results in the binder and surface layers by using dolomite as aggregate.



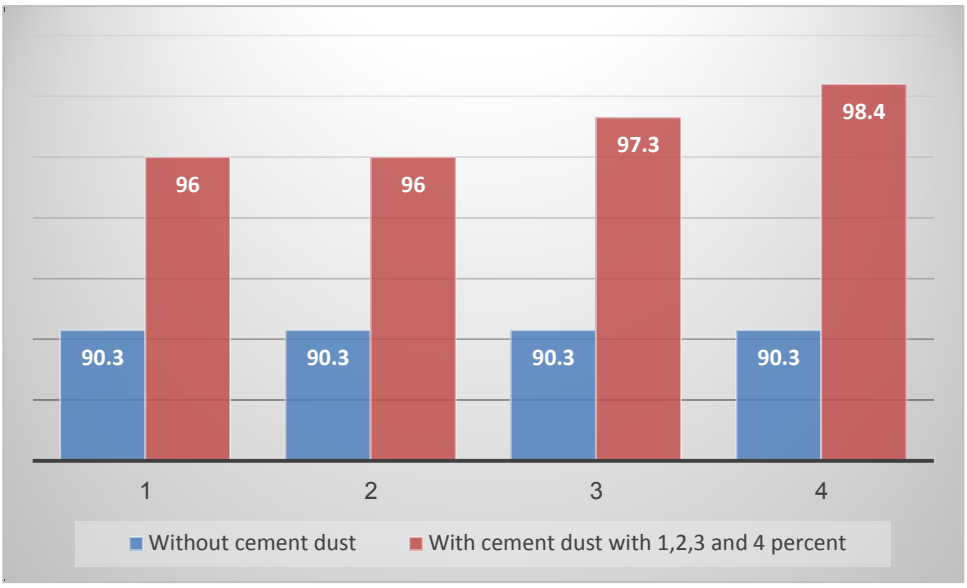
Curve 1 Adhesion between aggregate and bitumen Cement Dust binder basalt layer



Curve 2 Adhesion between aggregate and bitumen Cement Dust surface basalt layer

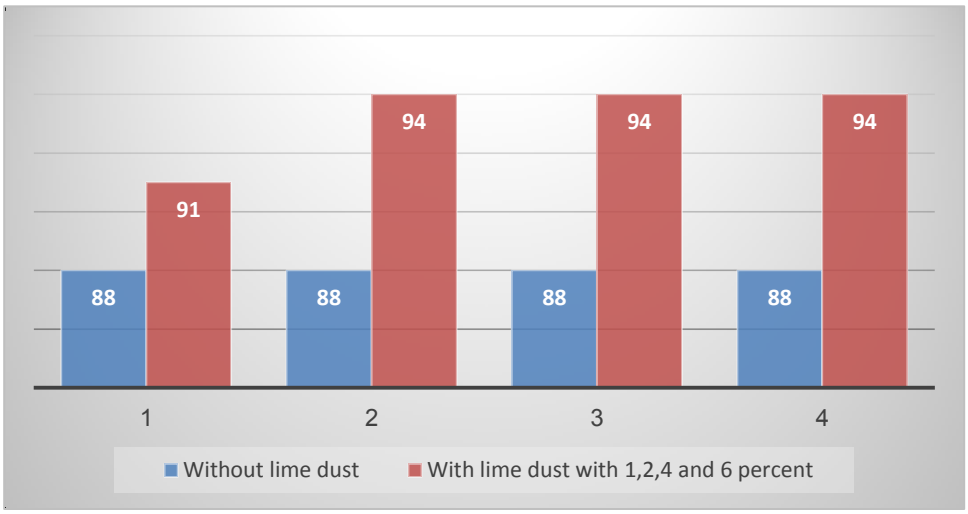


Curve 3 Adhesion between aggregate and bitumen Cement Dust binder dolomite layer

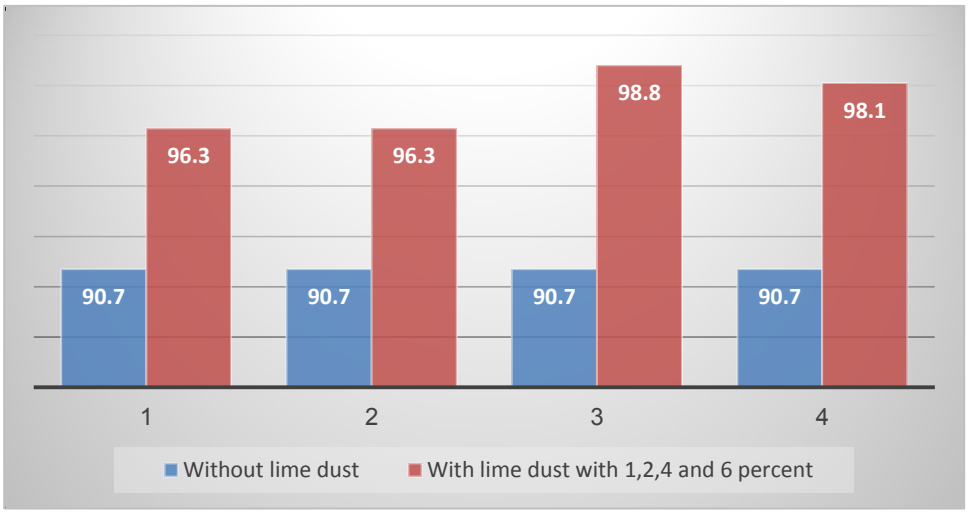


Curve 4 Adhesion between aggregate and bitumen Cement Dust surface dolomite layer

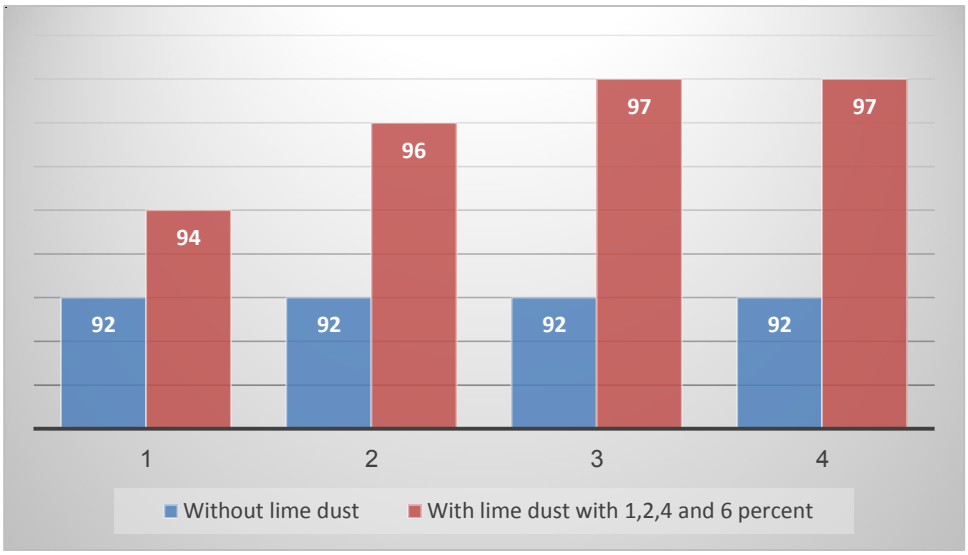
2- **Lime dust** with percentages of 1% and 2% achieved distinguished results in the binder layer using basalt as aggregate, while ratios of 4% and 6% achieved distinguished results in the surface layer of the same type of aggregate. On the other hand, the percentage of four achieved great results in the binder layer using dolomite as aggregate, and the lime dust was at 1% rate, which did not succeed in the surface layer using dolomite.



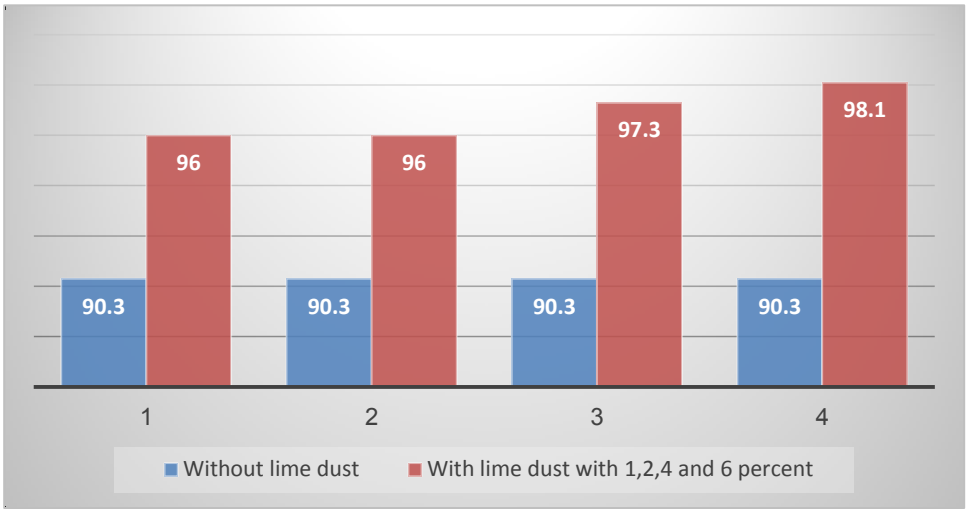
Curve 5 Adhesion between aggregate and bitumen Lime Dust binder basalt layer



Curve 6 Adhesion between aggregate and bitumen Lime Dust surface basalt layer

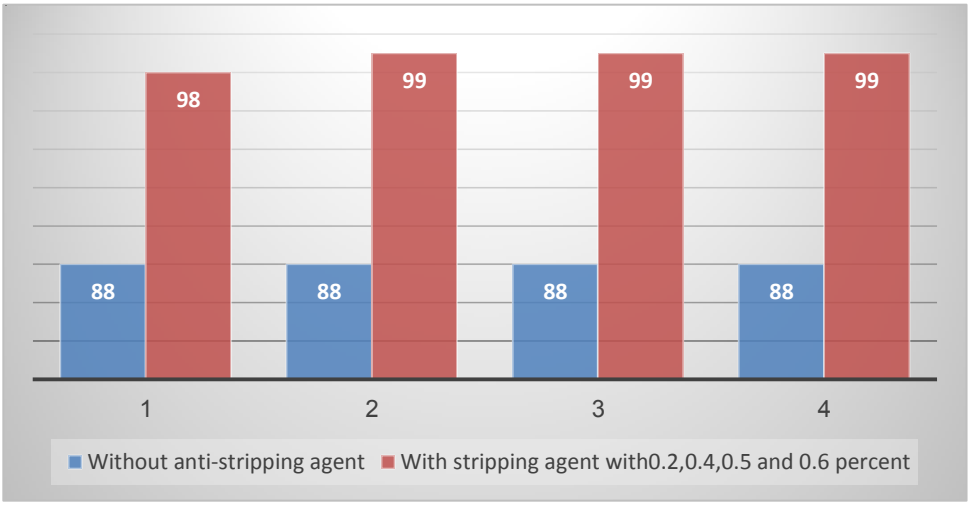


Curve 7 Adhesion between aggregate and bitumen Lime Dust binder dolomite layer



Curve 8 Adhesion between aggregate and bitumen Lime Dust surface dolomite layer

3- **Anti-stripping agent** with ratios of 0.2% and 0.4% achieved distinguished results in the binder layer and surface using basalt as aggregate. On the other hand, with its four ratios, it achieved great



Curve 9 Adhesion between aggregate and bitumen anti-stripping agent binder basalt layer

Curve 10 Adhesion between aggregate and bitumen anti-stripping agent surface basalt layer

Curve 11 Adhesion between aggregate and bitumen anti-stripping agent binder dolomite layer

Curve 12 Adhesion between aggregate and bitumen anti-stripping agent surface dolomite layer

5. CONCLUSION

Each sample of the bonding and surface samples of both basalt and dolomite was subjected to the necessary tests to ensure its laboratory safety and compliance with standard specifications, whether it was adhesion, stability, flow, sieve analysis or design bitumen ratio according to the American Code of Roads (AASHTO). The following results were obtained:

1- Cement dust by 1%, lime dust by 2%, and anti-stripping agent by 0.2% are the optimal ratios for the four ratios in the binder layer using basalt, as it is the most economical in

terms of materials, cost and sieve analysis, and the best in TSR and adhesion. Also, it is in the range of the special specifications.

2- Cement dust by 2%, lime dust by 4%, and anti-stripping agent by 0.2% are the optimal ratios for the four ratios in the surface layer using basalt, as it is the most economical in terms of materials, cost and sieve analysis, and the best in stability and adhesion. Also, it is in the range of the special specifications.
3- Cement dust by 1%, lime dust by 2%, and anti-stripping agent by 0.4% are the optimal ratios for the four ratios in the binder layer using dolomite, as it is the most economical in terms of materials, cost and sieve analysis, and the best in cohesion, adhesion, stability, and flow. Also, it is in the range of the special specifications.
4- Cement dust by 2%, lime dust by 2%, and anti-stripping agent by 0.4% are the optimal ratios for the four ratios in the surface layer using dolomite, as it is the most economical in terms of materials, cost and sieve analysis, and the best in cohesion, adhesion, stability, and flow. Also, it is in the range of the special specifications.

REFERANCES

1 Rosa E. Feick,"Imperial routes, national networks and regional projects in the Pan-American Highway", 1884–1977, Research Articlehttps://doi.org/10.1177/0022526616654699, Volume: 37 issues: 2, page(s): 129-154, December 2016.

2 Muhammad O.E, Muhammad Kh. A (2011). "Paving engineering". ISBN-10: 9959816249.

3 C.A. O'Flaherty, " Highways (Fourth Edition)", ScienceDirect, ISBN: 978-0-7506-5090-8, 2012.

4 Viktors Haritonovs, Janis Tihonovs and Juris Smirnovs, "High Modulus Asphalt Concrete with Dolomite Aggregates", OP Conference Series Materials Science and Engineering 96(1):012084,DOI:10.1088/1757-899X/96/1/012084, November 2015.

5 Viktors Haritonovs, Martins Zaumanis, Guntis Brencis, Juris Smirnovs, "Performance of Asphalt Concrete With Dolomite Sand Waste and Bof Steel Slag Aggregate", The Baltic Journal of Road and Bridge Engineering 8(2):91-97 DOI:10.3846/bjrbe.2013.12, June 2013.

6 Ovidijus Šernas ,Viktoras Vorobjovas , Lina Šneideraitienė ,Audrius Vaitkus, "Evaluation of Asphalt Mix with Dolomite Aggregates for Wearing Layer", ScienceDirect,https://doi.org/10.1016/j.trpro.2016.05.340, Volume 14, 2016, Pages 732-737, June 2016

7 Nicolae Ciont, "DIFFERENT AGGREGATES AND BITUMEN TYPES ON ASPHALT MIXTURES", Conference: 17th International Multidisciplinary Scientific GeoConference SGEM 2017, June 2017.
8 Watcharin - Witayakul, Somsak Chotichanatha Wewong, Weerakaset Suanpaga, " Asphalt Concrete Mixtures Properties by Using Basalt Aggregates “, DOI:10.3850/978-981-08-7920-4_M-35-0301 Conference: Research, Development and Practice in Structural Engineering and Construction, January 2012.
9 Amara Asif, Naveed Ahmad, Aneeqa Hayat, Sabahat Hussain " Study of adhesion characteristics of different bitumen aggregate combinations using bitumen bond strength test”, Journal of the Chinese Institute of Engineers, DOI:10.1080/02533839.2018.1490205, July 2018.
10 Jens Grönniger, Michael P. Wistuba, Peter Renken, " Adhesion in Bitumen-Aggregate-Systems", Road Materials and Pavement Design 11(4):881-898, DOI:10.1080/14680629.2010.9690311, January 2010.
11 Jan Trejbal, Tereza Valentová, Tereza Horová, " ASSESSMENT OF ADHESION BETWEEN BITUMINOUS BINDER AND MINERAL AGGREGATE USING DIGITAL IMAGE ANALYSIS", Acta Polytechnica CTU Proceedings 21:38-41 DOI:10.14311/APP.2019.21.0038, March 2019.
12 Cesare Oliviero, " Adhesion Promoters in Bituminous Road Materials: A Review", Applied Sciences 7(5):524, DOI:10.3390/app7050524, May 2017.
13 Matthieu Horgnies, Philippe Toubeau, Helmi Fezai, Evelyne Darque-Ceretti, " Adhesion between aggregates and bitumen characterized by peel tests and surface analyses", Conference: 4th World Congress on Adhesion and Related Phenomena At: Arcachon, France, September 2010.
14 Peng Ren, Xiao Jun Zhao, Yi Qing Ren, Bo Zhang, Qiang Du, " The Analysis of the Adhesion between Limestone, Basalt and Asphalt”, https://doi.org/10.4028/www.scientific.net/AMR.834-836.738, Advanced Materials Research (Volumes 834-836), Pages:738-744, October 2013.
15 Yueqin Hou, Xiaoping Ji, Jia Li, Xianghang Li, " Adhesion between Asphalt and Recycled Concrete Aggregate and Its Impact on the Properties of Asphalt Mixture", Materials 11(12):2528, DOI:10.3390/ma11122528, December 2018.
16 Hadeel Maiah, Ghazi Al-Khateeb, " Effect of basalt and limestone aggregate combinations on Superpave aggregate properties”, http://www.jeaconf.org/UploadedFiles/Document/f92b71d6-d4cb-4841-94a1-3d11770e90b2.pdf, January 2012.
17 Shuang Cui, Bamber R.K.Blackman, Anthony J.Kinloch, Ambrose C.Taylor, "Durability of asphalt mixtures: Effect of aggregate type and adhesion promoters", International Journal of Adhesion and Adhesives", Volume 54, Pages 100-111, October 2014.