The Effect of Using Dust of Crushed Boulders on Hma Properties

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Abstract

It is well recognized that mineral fillers play an important role in the properties of mastics and hot-mix asphalt (HMA) mixtures. Better understanding of the effects of fillers on the properties of mastics and HMA mixtures is crucial to good mix design and high performance of HMA mixtures. This paper presents a laboratory investigation into the effects of crushed boulders dust compared to reference (control) filler(limestone dust)on some properties of asphalt HMA mixtures.. The effects of filler on the characteristics of HMA mixtures were also investigated. The properties of HMA mixtures evaluated include optimum asphalt cement (AC) content, MarshallStability and flow, the indirect tensile strength (I.T.S) to evaluate the temperature susceptibility, Index of Retained strength to measure the moisture damage resistance. The research concluded that the use of crushed boulders dust as mineral filler with same texture of crushed aggregates(same source) into asphaltic mixtures an economic objective positive effect administratively(Full control and maneuvering of the production and quality control) in addition to improving the performance of the HMA like (marshall stiffness value more than 160%, less temperature susceptible to low temperature cracking,and increase the resistanceof moisture damage more than 135%) in comparison to reference (conventional)lime stone dust. This tendency of the mix nature used in the Erbil- Perda highway project is observed in the pavement and in spite of the truck axles loading exceeding levels specified in the specifications under the temperature exceeded 65 C^o for two Consecutive seasons and then the depth of accumulative rutting remained within the limits allowed on the right truck lane.

Keywords: Dust of Crushed Boulders, Hma Properties, limestone dust, HMA mixtures.

تأثير استخدام غبار مسحوق الجلمود على خواص الخلطة الاسفلتية

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الخلاصة

للغبار المعدني دور هام وحاسم في تحسين خواص الخلطات الاسفلتية بشكل عام .في هذا البحث تم استخدام غبار الجلمود المكسر ودراسة مدى تأثير ذلك على اداء الخلطة الاسفلتية مقارنة بغبار مسحوق حجر الكلس الجيري . تم استخدام هذا الغبار الناتج من تكسير الجلمود في معامل شركة ماكيول –جنكيز التركية (المقاول المنفذ للسايد الثاني لطريق اربيل- التون كوبري)في انتاج الخلطات الاسفلتية ولكونها من نفس نسيج الحصى المكسر الخشن والناعم وامتلاكها لخواص اسمنتية اضافة الى كونها ذات تركيب خشن، لها متانة وصلادة عالية ادت كل ذلك الى زيادة متانة مارشال (اكثر من 160%)، وتحسس اقل للحرارة (ذات مقاومة شد اعلى في الاجواء الباردة) اضافة الى زيادة المقاومة للاضرار الناتجة من الرطوبة(اكثر من 135%) مقارنة بالخلطات بغبار مسحوق الحجر الكلسي وعلى التوالي. وادت هذه الخواص الى مقاومة التبليط /الطبقة الرابطة لانواع التخدد (التشوه الدائمي) للطريق طوال موسميين متتاليين رغم تجاوز الحرارة لاكثر من 65 درجة مئوية اضافة الى سوء الاستخدام نتيجة للاحمال الثقيلة في المركبات المستخدمة للطريق جاعلة الطريق ضمن مواصفات الحدود المسموحة.ان استخدام هذا النوع من الغبار حقق مردود اقتصادي كبير بعد توفيرها، وهذا لم يكن تحقيقه سهلا" الا بعد تجهيز هذا النوع من المعامل (معمل الاسفلت الالماني المنشأ المجهز بوحدة تجميع الغبار الابتدائي والثانوي) بهذا النوع من التقنية ،اضافة الى تسهيلات ادارية حققت سيطرة كاملة على النوعية والانتاج والنقل.

الكلمات الدالة: غبار مسحوق الجلمود ،الخلطة الاسفلتية، حجر الكلس الجيري، خلطةHMA

Introduction

It has long been recognized that the filler plays a major role in behavior of the asphalt mixtures Fillers fill voids between coarse aggregates in the mixture and alter properties of the binder, because the filler acts as an integral part of the mastic (combination of bitumen, filler, and entrapped air). The quality of mastic influences the overall mechanical performance of asphaltmixtures **[**1**].** In this study, Marshall Mixes will be designed for Binder course one of the advantages of theMarshall Mix Design method is that the performance of the mixes can be expected for local materials and environmental impact. The experimental work in this study provides a comparison among twofiller types. We used dust of crushed boulders, and Limestone as fillers. The work was limited to one type of gradation as crushed aggregate of boulders, (its nominal maximum size aggregate19 mm for binder coarse layer –R9/3) which used in Erbil-Perda highway project as 60 mm thickness. One source of asphalt cement (40-50 penetration grades) was used in these mixes.

Research Objective

The overall objective of this study is to investigate the characteristics of HMA mix using two types of mineral fillers. The specific objective is to investigate the effect of mineralfillers (crushed boulders dust, and limestone dust) on the Marshall Properties and moisture resistance of HMA concrete and give recommendation.

Review of Literature

Numerous studies have shown that the properties of mineral filler (especially the materialpassing No. 200 sieve) have a significant effect on the properties of the HMA mixtures. Theintroduction of environmental regulations and the subsequent adoption of dust collection system (baghouse) have encouraged the return of most of the fines to the HMA mixture. A maximumfiller/asphalt ratio of 1@2 to 1@5, based on weight, is used by many agencies to limit the amount ofthe minus 200 material. However, the fines vary in gradation, particle shape, surface area, voidcontent, mineral composition, and physico-chemical properties and, therefore, their influence onthe properties of HMA mixtures also varies. Therefore, the maximum allowable amount should be different for different fines. Fines can influence the performance of HMA mixtures as follows [2]

1. Depending on the particle size, fines can act as filler or as an extender of asphalt cement binder. In the latter case an over-rich HMA mix can result leading to flushingand / or rutting.

In many cases, the amount of asphalt cement used must be reduced toprevent a loss of stability or a bleeding pavement.

2. Some fines have a considerable effect on the asphalt cement making it act as a much stiffer grade of asphalt cement compared to the neat asphalt cement grade, and thereby affect the HMA pavement performance including its fracture behavior.

3. Some fines make the HMA mixtures susceptible to moisture-induced damage (1). Watersensitivityof one source of slag baghouse fines has been reported in the United States, and the water-sensitivity of other stone dusts has been reported in Germany. Stripping of HMA mixtures as related to the properties of filler/asphalt combinations (fillers were obtained from operating HMA plants) has been reported in Japan.

It is very important to characterize the fines so that the performance parameters of HMA pavements (resistance to permanent deformation, stripping, and fatigue cracking) are not compromised.

Role of mineral filler in HMA

Before accepting a definition for the "fines" or mineral filler in HMA, it is appropriate to is examine the role of the mineral filler in HMA. The strength and load carrying capacity of HMA is largely the result of the aggregate framework created through particle-particle contact and interlock. Ideally graded, a dense HMA contains successively smaller particles such that the framework created by the larger particles is just filled by the smaller particles. Thus the coarse aggregate framework is filled by the sand-sized material and finally by the mineral filler. However, at some point the smallest particles no longer make contact and, instead, lose contact and become suspended in asphalt binder. These suspended particles do not have the particle-particle contact that is created by the larger particles [3] he hypothesized that for dense-graded mixes this loss of particle-particle contact occurred with sizes somewhat less than 75 tm, most likely between 50 and 75 p.m depending on the filler and mixture. He further concluded that mineral filler should be defined as the fraction of the aggregate with particles sufficiently small such that the particles are suspended in the asphalt binder and no longer maintain particle-to-particle contact. Unfortunately this size isdifficult to define. For practical purposes mineral filler is best thought of as the minus No.200 fraction in the mix. In this paper mineral filler will be considered as that portion of the aggregate that is finer than 75 p.m, with the understanding that the actual division is somewhat nebulous and probably lies between 50 and 75 p.m.

General Description

In accordance to Standard Specification Designation[D 242 – 95 -Reapproved 2000-ASTM]for Mineral filler shall consist of finely divided mineral matter such as rock dust, slag dust, hydrated lime, hydraulic cement, fly ash, loess, or other suitable mineral matter. At the time of use, it shall be sufficiently dry to flow freely and essentially free from agglomerations.

Physical Requirements

Mineral filler shall be graded within the following limits

600-µm (No. 30) 100, 300-µm (No. 50) 95 to 100, and 75-µm (No. 200) 70 to 100.

Mineral Filler prepared from rock dust, slag dust, loess, and similar materials shall be essentially free from organic impurities and have a plasticity index not greater than 4.

The mechanism of dust production (mineral filler)

The asphalt plant(German origin) belongs to the makyul –genkez company(joint venture) was the main contractor of Erbil-perda project highway that asphalt plant has been worked supplied with dust collector unit(baghouse unit) [4]

Crushed gravel dust stuck after a crushing processes of boulders (larger than 50.8 mm) due to heat and circulation into drier unit and the assembly is due to the continuing drag from the unit before the first assembly, and secondly by cyclone ,and filters processed and where it is to keep the fine dust transit No. 200 and re-balance to the elevator unit again as fine crushed aggregate as shown in figures (I), and(2) respectively.

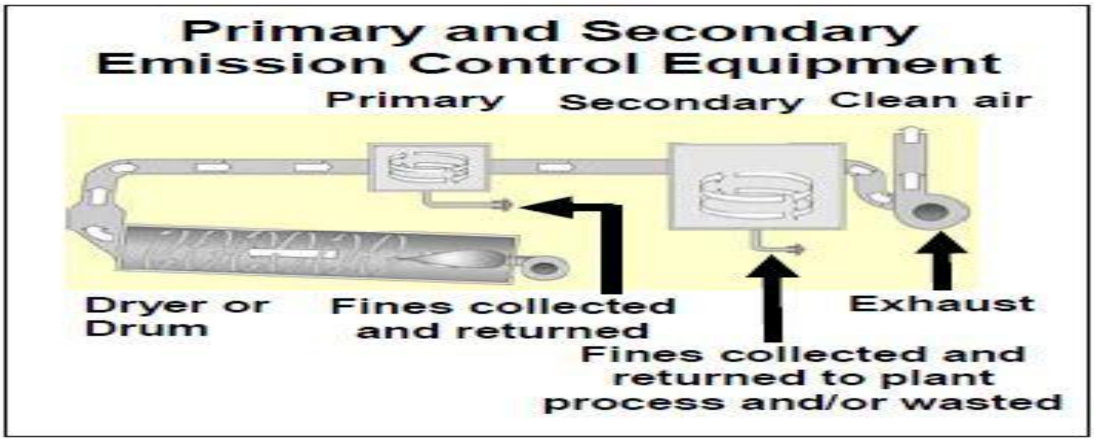

Figure (1): Mechanism Schematic of Dust Collector(baghouse) Unit in Asphalt Plant. [2]

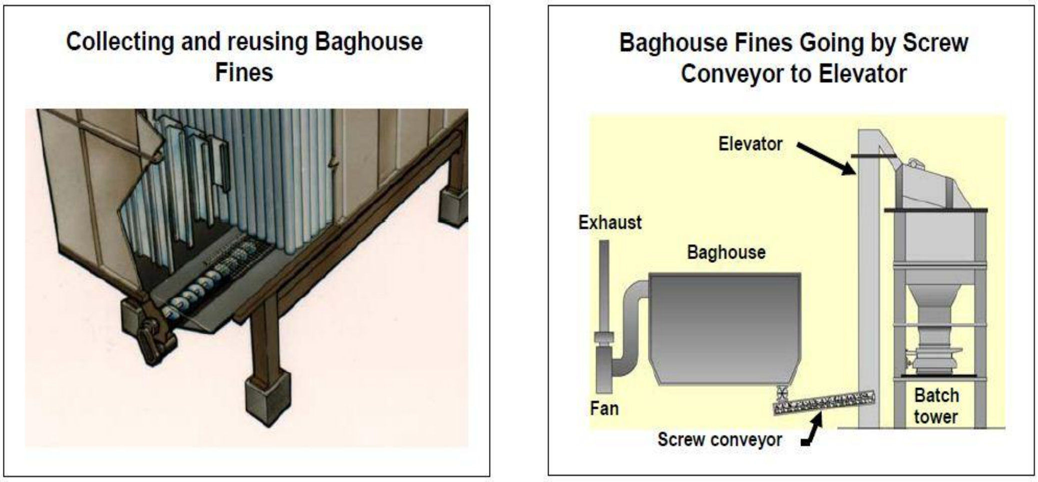

Figure :(2) Baghouse Unit(collecting and reusing by screw to elevator) in Asphalt Plant [2]

Experimental work and results

Materials: The virgin materials used in this study are widely available and currently used in road paving in Iraq. All materials are obtained from commercial sources.

i. Asphalt Cement

ii. The (40-50) penetration grade asphalt cement from Iran source(Asfahan refinery) was used. The physical properties and tests of this asphalt cement are presented in Table (1).

Table (1): Physical properties of asphalt cement Penetration Grade (40- 50)used

Test	Unit	Test Results
Penetration (25^{o}C, 100g, 5 sec)ASTM D5	0.1mm	46
Absolute viscosity @ 60^{o}C ASTM D-2170	Poise	2162
Kinematic viscosity @ 135 ^{o}C ASTM D-2170	cts	410
Ductility (25^{o}C, 5cm/min) ASTM D-113	cm	> 100
Softening point (Ring & Ball) ASTM D-36	^{o}C	52
Specific gravity @ 25^{o}CASTýM D-70		1.030
Flash point ASTM D-92	^{o}C	>240
After thin-film oven test ASTM D-1754		
Penetration of residue (25^{o}C, 100g, 5 sec)	0.1mm	32(>55%)
Ductility of residue (25^{o}C, 5 cm/ min)	Cm	>100
Loss in weight (163 ^{o}C, 50g, 5hrs)	%	0.150

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iii. Aggregate

The source of aggregate is Perda(Alton copry)quarry as boulders its size is larger than 2" (50.8 mm). By using the central crusher in next to the asphalt plant (khoushtabbadistrict) has been used to break down(crushing) two times and produce four fractions of crushed boulders possesses more than one face fracture, as shown below:

First fraction size (25.4-19 mm), Second fraction size (19-9.5 mm), Third fraction size (9.5 -5 mm), and Fourth fraction size (less than 5.0 mm) All that four fractions, in case of sticking todust (mineral filler) formed by repeated crushing gas same texture (this nature cause's strong bond among them).The physical properties of aggregate are shown in Table (3).

Table (3)Physical Properties Of crushed boulders *.

Property	Coarse crushed boulders	Fine crushed boulders
Bulk specific gravity (ASTM C-127 & C-128)	2.678	2.673
Apparent specific gravity (ASTM C-127 & C-128)	2.785	2.757
Percent water absorption (ASTM C 127 & C-128)	0.233	0.256
Percent wear (Los-Angeles abrasion) ASTM C-131	12.5	-----

*Makyol – GenkezCompany (Turkish) Field Laboratory /Erbil-Khoshtabba

iv. Mineral Filler

The mineral filler (Crushed gravel dust) from same crushed boulders to introduce of crushed gravel that used in HMA was used and it was brought from the plant of hot asphalt concrete mix of Makyol – GenkezCompany (Turkish), % passing sieve No.200 was equal to 98% with a specific gravity of 2.85 .The second type of mineral filler (reference or control type) was lime stone dust (as familiar type) possesses % passing sieve No.200 was equal to 97% with a specific gravity of 2.727.

Testing procedure

1. Preparation of Specimens :(Marshall design method.)

Marshall Specimens are used to determine the Index of retained strength, compressivestrength, stability, plastic flow, and indirect tensile strength. These specimens are prepared in accordance with the requirements of ASTM D-1559(Specimen dimensions, D=100.16, H=63.5 mm). The Hot Mixes Asphalt (HMA) has been prepared with equivalent design criteria.

I. Preparation of mixtures

The aggregate has been dried to constant weight at 110 ^{o}C, separated into the desired size and recombined with the mineral filler in order to meet the desired gradation. The aggregate is then heated to a temperature of 155^{o}C before mixing with asphalt cement The asphalt cement is heated to a temperature of 160^{o}C producing a kinematic viscosity of (170 $\pm$ 20) centistokes. Then, the asphalt cements are weighted to the desired amount, added to the heated aggregate ,which its gradation as job mix formula(jmf) was selected and shown in tables (5, and 6) in addition to figure (3) and mixed thoroughly until all aggregate particles are coated with asphalt at optimum asphalt content (=4.85% ±0.30) of total mix.

II. Preparation of Compressive Strength Specimens

The test specimens, 101.6mm (4in) diameter and 101.6 mm (4in) height are prepared after compressing initially by static stress of 1 MPa (150 psi) to set mixture against the sides of the mold, then applying a molding load of 20.3 MPa (3000 psi) for 2 mins. The specimens are ejected and oven-cured at 60^{o}C for 24 hours. The preparation is done in accordance with ASTM D 1074 specification.

Testing of samples

I. Stability and plastic flow of asphalt mixtures (Marshall Method)

This method covers the measurement of stability and plastic flow of Marshall cylindrical specimens of bituminous paving mixtures loaded on the lateral surface by means of the Marshall apparatus according to ASTM D 1559. The test specimens are compacted using 75 blows on each face.

The bulk specific gravity and density (ASTM D2726), theoretical (maximum) specific gravity (ASTM D2041) and percent air voids (ASTM D3203) are determined for each specimen. The maximum load resistance and the corresponding flow values have been recorded. Three specimens for each combination are prepared and the average results are reported. Table (7) provides a summary of the volumetric properties and Marshall tests results for each of the selected mixtures.

Table(5): JMF Determination:Gradation Analysis Of Bitumen Binder Coarse [5]

Dia. mm	Filler	0-3 mm	3-10 mm	10-20 mm	20-25 mm	Mix	BINDER	
							Min	Max
25.4	100.0	100.0	100.0	100.0	100.0	100.0	100	100
19.1	100.0	100.0	100.0	100.0	39.3	92.1	90	100
12.5	100.0	100.0	100.0	50.3	4.4	78.1	70	90
9.5	100.0	100.0	100.0	18.2	1.4	71.6	56	80
4.75	100.0	100.0	50.1	0.3	0.3	55.6	35	65
2.36	100.0	83.4	3.5	0.3	0.3	37.5	23	49
0.300	100.0	18.4	1.0	0.3	0.2	11.5	5	19
0.075	91.3	5.2	0.3	0.2	0.1	5.8	3	9
Mix Ratio	4	39	25	19	13			

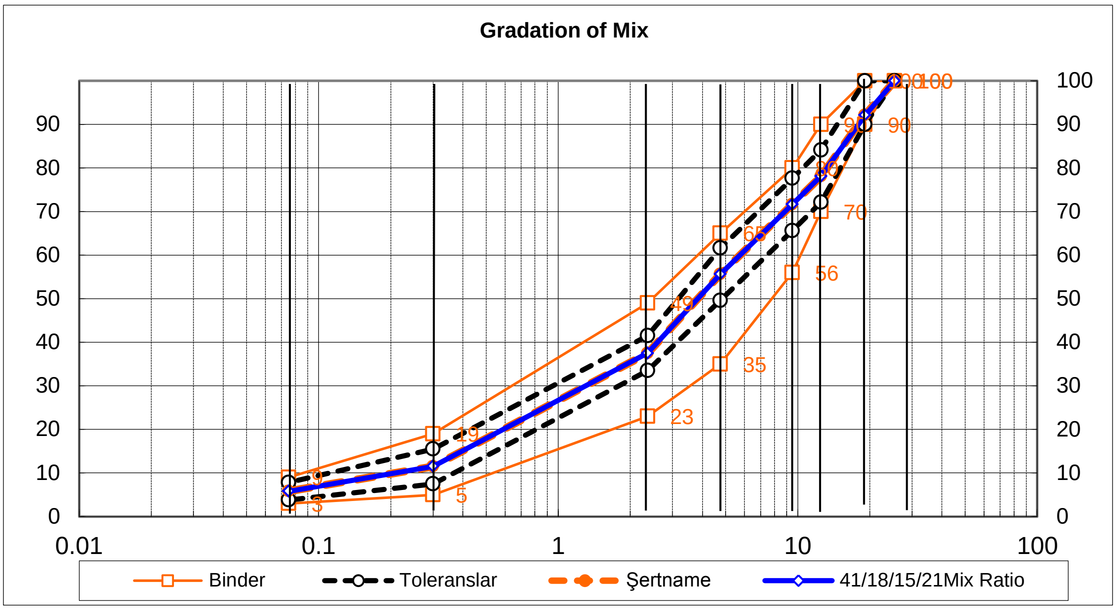

Figure (3): SORB Specifications And Prepared JMF Limits For BBC Layer

Table (6): Results of JMF,binder coarse R9/3 [5]

		Opt. Bitümen Fixing		Optimum	Specifitaion
		Base Worth	%Bitümen	Results	Binder
Volume Specific Weight		Max	5.00	2.418	
Air Blank		4.0%	4.80	3.80	*3~5*
Bitümen Full Blank		70%	4.60	74	*60~80*
Stability		Max	5.00	1650	*Min 700 Kg*
Flow				3.50	*2~4 mm*
		Optimum Bitümen (Wa)	4.85%		

Table(7): Volumetric Properties and Marshall test result of Asphalt Mixtures

Mix Property (% Of Filler type Added	Bulk, G_{mm} g/cm3	G_{mm}g/cm3	Air void %	V.M.A. %	Stability kN	Flow mm	Marshall Stiffness kN/mm
Limestone dust 100 %	2.350	2.422	4.01	12.45	9.95	2.98	3.339
Lime stone dust 50 % + Crushed boulders dust 50 %	2.360	2.433	3.9	14.34	13.34	3.03	4.403
Crushed boulders dust 100 %	2.371	2.441	4.08	16.76	16.90	3.12	5.417

The results in table(7) show that crushed boulders dust mix possess VMA values more thanLime stone dust mix(>134%) and consequently indicate sufficient spaces with more ability to absorb access compaction under field pavement conditions. Also the results state clearly crushed boulders dust mix has marshall stiffness value more than 160%,compared to Lime stone dust mix and this reality give us how the use of crushed aggregate facilitate mix to prevent rutting(permanent deformation) due to nature of crushed boulders dust which has rough touch texture to make more interlock and bonds with crushed aggregates in cooperation with asphalt molecules.This tendency of the mix nature used in the Erbil- Perda highway project is observed in the pavement and in spite of the truck axles loading exceeding levels specified in the specifications under the temperature exceeded 65 C^{o} for two Consecutive seasons and then the depth of accumulative rutting remained within the limits allowed on the right truck lane.

II. Indirect Tensile Strength

The specimens prepared in the same method and described for Marshall Method are tested for indirect tensile strength according to ASTM D 4123. The prepared specimens are cooled at room temperature for 24 hrs, immersed in a water bath at one of two different test temperatures (10 ^{o}C, and 40^{o}C) for 30 min., then tested for indirect tensile strength at a loading rate of 50.8 mm/min (2 in/min) in a compression machine until reaching the ultimate load resistance Three specimens for each mix combination are tested and the average results are reported in Table (6). The indirect tensile strength (I.T.S) is calculated, as follows:

$$[I.T.S=2P/\pi tD] \qquad (1)$$

Where: P = Ultimate applied load to fail the specimen, N.

t = Thickness of specimen, mm.D = Diameter of specimen, mm.The change in (I.T.S) with temperature is expressed as Temperature Susceptibility of asphalt mixture. Temperature Susceptibility for various mixes can be determined by subtracting (I.T.S) at 40°C from (I.T.S) at10°C divided by the difference between two testing temperatures as reported in Table (8).

Table (8) Temperature Susceptibility & (I.T.S) for mixes

Mix Property (% Of Filler type Added)	I.T.S at testing Temperature 10°C kPa	I.T.S at testing Temperature 40°C kPa	Temperature Susceptibility kPa / °c
Lime stone dust 100 %	2510	240	75.670
Lime stone dust 50 % +Crushed boulders dust 50 %	2610	370	74.334
Crushed boulders dust 100 %	2670	490	72.667

It is observed from table.(8) ,that temperature susceptibility values decline gradually increase the proportion of added Crushed boulders dust ,this property is due to more affinity between the crushed dust as mastic portion(nature cementite of dust) with crushed aggregates under low temperature ,making it less susceptible to low temperature cracking .

Again ,it can be concluded from table (8) the mix of crushed dust shows higher indirect tensile stiffening values under low temperatures making them more strength (resistance) to low temperature cracking. Researcher through his duty as director of quality control in the company contracting for project implementation and follow-through and inspection of the surface pavement (binder coarse) has been no longitudinal or transverse cracks of the fact that the plan for the property owning little sensitivity to low temperature .

III. Water Damage Resistance

This method covers measurement of the loss in cohesion resulting from the action of water on compacted bituminous mixtures. Numerical index of reduced cohesion is obtained by comparing the compressive strength of freshly molded specimens, with the compressive strength of duplicate specimens that have been immersed in water for four days at 49 $\pm$ 1 ^{o}C . The specimens of the two groups are tested in axial compression at a uniform rate of vertical deformation of 5.8 mm/min. (0.2 in/min), as recommended by ASTM D 1074. The numerical index of resistance of bituminous mixtures to the detrimental effect of water as the original strength that is retained after the immersion period is calculated in accordance with ASTM D 1075, as follows:

Index of retained strength = S2/S1 * 100 ……………….(2)

Where : S1 = Compressive strength of dry specimens kPa and

S2 = Compressive strength of immersed specimens, kPa.

Three specimens for each mixture combination are tested and the average value is reported in Table (9):

Table (9): Index of Retained Strength of various mixes

Mix Property (Type Of Dust Used)	**Dry Compressive *Strength(kPa)***	**Conditioning Compressive *Strength(kPa)***	***Index of Retained Strength%***
Lime stone dust 100 %	*6300*	*4473*	*71*
Lime stone dust 50 % + Crushed boulders dust 50 %	*7490*	*6340*	*85*
Crushed boulders dust 100 %	*8123*	*7960*	*98*

It can be concluded from Table (9) that the percentages of crushed boulder dust mix affects resistance of mixtures to moisture damage resistance, which is defined by index of retained strength results indicate that exist of crushed boulders dust into the mix instead of lime stone dust type causes to increase more than 135% of index of retained strength(moisture damage resistance).

Therefore, lime stone dust mix has a less resistance to moisture damage, has 71% more than 70% {Iraqi standard value} , or in other words lime stone dust mix possesses a high value of moisture susceptibility, and vice versa whenever the increase of crushed boulders in the mixture leads to increase the resistance of moisture damage , this behavior return to hydrophobic property of aggregate type used in general firstly(Degranulation of crushed dust to asphalt adhesion strength of love with more than water) , secondly because of rough texture (toothed) of crushed boulder surfaces to build strong bond with asphalt molecules as mastic components [4].

Conclusions

From The work undertaken under the present study and described in the preceding articles, the following conclusions can be drawn:

1- Crushed boulders dust mixture has Marshall Stiffness value more than 130% (50% crushing) and 160% (100%) %) in comparison with lime stone dust mixture respectively.

2- Using of crushed dust instead of lime stone dust type causes to increase VMA more than 135%, this means mixtures possess more durable (sufficient VA% and ability to undertake excessive compaction under heavy traffics without of asphalt bleeding).

3- The increase of crushed boulders dust in the mixture leads to increase the resistance of moisture damage more than 135% of lime stone dust mix,

4- The mixes using of crushed dust instead of lime stone dust type show higher indirect tensile stiffening values(<95%) under low temperatures making them less temperature susceptible to low temperature cracking.

5- Using of crushed dust instead of lime stone dust type, it is more beneficial economically and easy in produce and handling.

Recommendations

This research tries to advice the responsible authorities related with this subject to revise the SORB /R9 as not allow to use the nature (rounded)sand in the mix completely in addition to advice the owners of asphalt plants to import the dust collector units according to international standards and high quality of the hand and ensure the preservation of the environment on the other hand.

Further researches

1. Other type of crushed aggregate like lime stone can be employed with modifier (polymer like SBS) to study the properties of asphalt mixtures.
2. Trial pavement sections are suggested to be prepared in the field to study the difference in performance of the various mixtures.

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