The Use of Sulaimania Marble Waste to Improve The Properties of Hot Mix Asphalt Concrete

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ABSTRACT.

Thousands of tons of marble waste can be reused every year in Iraq. Few investigations are made to study the effect of marble as a filler on hot mix asphalt concrete.. This big amount of waste has a bad effect on the environment and needs a lot of money and effort for recycling or disposal. Lime stone dust was used as a control filler. The laboratory tests have been conducted in order to evaluate the properties of each type of filler, which consist of the grain size distribution, the specific gravity (Gs), specific surface area (SA), pore volume(PV), mineral composition, pH and chemical composition.To study the effect of SM on the performance of HMA mixture, several tests were made consist of Marshall stiffness, Indirect tensile strength, Moisture susceptibility and Creep tests. Many conclusions were achieved referring the importance of using Sulaimania Marble waste (SM) in the enhancing most of the properties of HMA concrete.

Keywords: Marble, Filler, Waste, asphalt, mixture.

1. INTRODUCTION.

Leaving the waste material to the environment directly can cause environmental problems. Therefore many countries have still been working on how to reuse the waste material so that they give fewer hazards to the environment.

The Marble waste is one of these materials which can be reused. Marble blocks are cut into smaller blocks in order to give the required smooth shape. During the cutting process about 25% marble is resulted in dust [1].

In Iraq the marble production is not developed and still need more progressing. The marble waste is come from the production of marble tiles and the marble powder used in mosaic tiles as a mortar.

The most important quarries of marbles in Iraq are in Sulaimania (north of Iraq).

Thousands of tons of marble waste can be reused every year in Iraq.

In Iraq, few investigations are made to study the effect of marble as a filler on hot mix asphalt concrete.

Otherwise, in the developed countries, many researches have been made to investigate the effect of using marble waste as filler in hot mix asphalt concrete.

Most of these researches refer to the ability of using marble waste (or powder) as a filler due to its enhancing for the hot mix asphalt concrete properties [2,3].

2. MATERIALS.

2.1. Asphalt Cement.

One grade of (40-50) asphalt cement was tested, it is from Nasiria Refinery. The physical properties of this type are illustrated in **table(1).**

2.2. Aggregate.

Two types of aggregate were used in this study:

1- Nibaay course aggregate (passing sieve 3/4 inch and retained sieve No. 4) with 100% crushed particles, brownish in colour, quartzite mineral composition and angular faces.

2- Thmail fine aggregate (passing sieve No.4 and retained sieve No. 200) with rounded faces particles, orange in colour, quartzite mineral composition.

Fig.(1) shows the midline gradation of the aggregate used in the mix design. The aggregate gradation confirms to the Iraqi Standard specifications for Road and Bridge for 19 mm (3/4 inch) maximum size for surface course type III/A.

2.3. Fillers.

Two different types of filler are used from two local sources in Iraq which are:

1- Limestone dust (Li), from Karbala lime factory, about 180 Km to the west south of Baghdad. It was used as a control filler.

2- Sulaimania Marble waste (SM), it is from Sulaimania quarries for marble and tile mortar production about 300 Km to the north east of Baghdad..

The laboratory tests have been conducted in order to evaluate the properties of each type of filler, which consist of the grain size distribution, the specific gravity (Gs), specific surface area(SA), pore volume (PV), mineral composition, pH and chemical composition.

Hydrometer analysis was conducted on each type of filler according to ASTM D-422 to obtain the grain size distribution for each type of filler as shown in **fig.(2)**. All types of filler are passing the sieve No. 200 (0.075 mm).

A specific gravity test was conducted according to ASTM D-854 using Water Pycnometer method.

A Surface Area Analyzer instrument as shown in **fig.(3)** was used to determine the surface area (SA) and pore volume (PV), (i.e. volume of voids within the surface area of filler particle). The test was conducted in the Petroleum Research& Development centre/Ministry of Oil. Test procedure is based on Brunauer, Emmet and Teller (B.E.T) Theory.

The chemical composition test was carried out in the Control Department of Kubaisa Cement Factory.

Table(2), illustrate the chemical composition of fillers, while the physical properties of each type of filler are shown in **table(3)**.

The mineralogical composition of each type of filler which was conducted using X-Ray diffraction method is tabulated in **table(4)**.

3. HOT ASPHALT CONCRETE MIXTURE TESTS AND RESULTS.

To study the effect of SM on the performance of HMA mixture, several tests were carried out.

4. PREPARATION OF MARSHALL MIXTURE.

The preparation of Marshall mixtures was made in accordance to ASTM D-1559 specification. Marshall specimens were made to determine the resistance to plastic flow and indirect tensile strength.

The properties of HMA concrete for each type of filler according to series of tests for Marshall stability, flexibility (flow) and durability (density-voids analysis) was carried out on each type of filler in different mixtures to select the optimum asphalt content OAC and to determine Marshall test parameters as shown in **figs.(4 and 5). Fig.(6)** shows the parameters of

Marshall test for each type of filler according to predicted Optimum Asphalt Content (OAC) of 4 % for each type of filler.

It can be seen that most of Marshall parameters for each of SM and Li mixes are within the Iraqi specifications. The SM mixes has high stability if compared to hat of Li mixes. Almost this property is associated with Gs of filler, where the low value of Gs means high volume of filler. This increment in volume may be responsible for the ability of mix to resist the applied load, it looks like increasing in aggregate volume which is responsible for increasing the friction angle between particles as in SM mixes [8]. Also the SM decrease the density of mix due to its lower Gs with respect to Li and that reflect inversely on the results of air voids (%AV).

5. INDIRECT TENSILE STRENGTH (ITS) TEST.

The method covers the procedure of preparing specimens in the same method described for Marshall method and tested for ITS according to ASTM D-4123. The triple specimens of each test temperature were left to cool for 24 hours at room temperature, then were immersed in water bath at two different test temperatures (25 oC and 60 oC) for 30 minutes, and were tested for ITS at rate of 50.8 mm/min. (2 in./min) in Marshall compression machine until recording the ultimate load resistance. **Fig.(7)** shows the results of tests, it is also consists of the results of temperature susceptibility (TS) which can be obtained as follows:

$$TS = \frac{ITS\ @\ 25 - ITS\ @\ 60}{t1 - t2} \quad (1)\ [8]$$

Where:

$t1$= 60 oC (Test temperature)

$t2$= 25 oC (Test temperature)

6. INDIRECT RETAINED STRENGTH (IRS) (MOISTURE SUSCEPTIBILITY) TEST.

This method determines the stripping potential of asphalt cement from aggregate in asphalt concrete mixtures which is a function of the affinity between aggregate and the bitumen and its consequent ability the displacing effect of water [5]. The test was conducted according to ASTM D-4867 through which two subsets of triple specimens were prepared in the same method described for Marshall method to determine the Indirect Tensile Strength (ITS) values. The results of test are shown in **fig.(8)**. The figure is also shows the results of ITS for conditioned sub set after immersing in water bath of 60 oC for 24 hours (ITS after 24 hr). The Indirect Retained Strength (IRS) is then calculated as follows:

$$\%IRS = \frac{\text{ITS (conditioned subset)}}{\text{ITS (unconditioned subset)}} \times 100 \quad (2)\ [8]$$

The results show that SM provides more adhesion between the aggregate particles and asphalt as compare to Li, so that the use of SM will increase the cohesion of whole mix, and that clear in the results of ITS at different test temperatures.

Also the use of SM will increase the resistance of mix to the effect of moisture, that was very clear in high value of IRS when using SM as compare to Li which has a value lower than the limitations Iraqi specifications. This property of SM is belong to the basic property of SM with high value of pH compared to Li. The acidity has an adverse effect on the retained strength (IRS) of HMA mixture due to Hydrophilic nature to water [6]. The high surface area of SM can be responsible for the ITS tests results by increasing contact area. The mix with Li has less effectiveness to the change in test temperature as compare to the SM, and that was obvious in TS results.

7. RESISTANCE TO PERMANENT DEFORMATION (CREEP) TEST.

Diametrical indirect tensile creep test has been used to evaluate the effect of using Ki as a filler on the permanent deformation tendency of HMA mixtures at two test temperatures 25 oC and 40 oC . The results are shown in **figs.(9 and 10)**. **Table** shows the results of test consisting of the values of initial stiffness (μo) at instant of loading and the permanent deformation (εp) at the end of unloading case after 120 minutes of test. The Creep stiffness (μo) is important to shed valuable insight into asses rutting [7].

It can be noticed that the results of Creep test for each of Li and SM are almost similar in terms of the effect on the stiffness and permanent deformation (the potential of rutting) of the mix.

8. CONCLUSIONS.

Based on the results of the study the following conclusions are made:

1- The use of Sulaimania Marble waste as a filler in HMA concrete will increase Marshall stability of mix. It also increases the air voids and flow, and decreases the density of mix, this effect almost matching with the Iraqi specifications.Adding Sulaimania Marble waste to the mix reflects a good effect on the cohesion of mix due to high values of Indirect Tensile Strength While showing high effectiveness to change in temperature with high value of Temperature Susceptibility.
2- The abundant effect of Sulaimania Marble waste on Indirect Retained Strength value refers to its importance to reduce the moisture attack.

9. RECOMMENDATIONS.

All the above conclusions refer to the importance of Sulaimania Marble waste to be use as a filler in hot mix asphalt concrete moreover the following reasons:

1- Since it is a byproduct (waste) of cement productions, it is very cheap and has an economical advantage.
2- Its usage will decrease the side effect of pollution caused by the accumulations of tons of waste in situ.

10. FURTHER WORKS.

1- More investigations should be made using Sulaimania Marble as a filler with different percentages according to lower and upper limits of Iraqi specifications.
2- These investigations need to be associated with durability tests in situ to guarantee the performance of mixture of Sulaimania Marble filler under the actual conditions of loads and environment.

12. REFERENCES.

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11. LIST OF ABBREVIATIONS.

I- εp: Permanent Strain in Creep test.

II- μo: The Stiffness Modulus immediately at Creep test.

Table (1): physical properties of Nasiria asphalt cement.

Property	Symbol	ASTM Designation No.	Test condition and units	Results
Penetration	Pe	D-5	25oC,100g, 0.1 mm	46
Softening point	SP	D-36	Ring & ball, oC	51
Ductility	D	D-113	25oC, 5cm/min,cm	+100
Specific gravity	Gs	D-70	25oC	1.028
Flash point	FP	D-92	Cleveland open cup, oC	+246
Solubility	S	D-2042	Trichloroethylene Solvent, %	99

Table (2): The chemical composition of each type of filler.

		Oxides Percentage (%)						
Filler type		Sio2	Al2O3	Fe2O3	CaO	MgO	SO3	L.O.I
	Li	2.36	0.17	0.27	52.56	0.92	1.22	42.19
	SM	36.44	2.07	6.73	5.17	20.15	0.16	16.44

Table (3): Physical properties of each type of filler.

		Physical property			
Filler type		Gs	SA m2/kg	PV cm3/gm	Ph
	Li	2.763	2.21	0.00530	7.56
	SM	2.657	29.32	0.04456	8.14

Table(4): Mineral and chemical composition of each type of filler.

		Properties	
Filler type		Mineral type	Chemical composition
	Li	Calcite	$CaCO_3$
	SM	Birnessite	$Na_{0.55}Mn_2O_4.1.5H_2O$

Table(5): The results of Creep test parameters.

Filler type	**μo @ 25 oC Kpa**	**μo @ 40 oC Kpa**	**εp @ 25 oC mm/mm**	**εp @ 40 oC mm/mm**
Li	7.95	7.83	2.65	2.87
SM	6.30	5.00	2.19	3.09

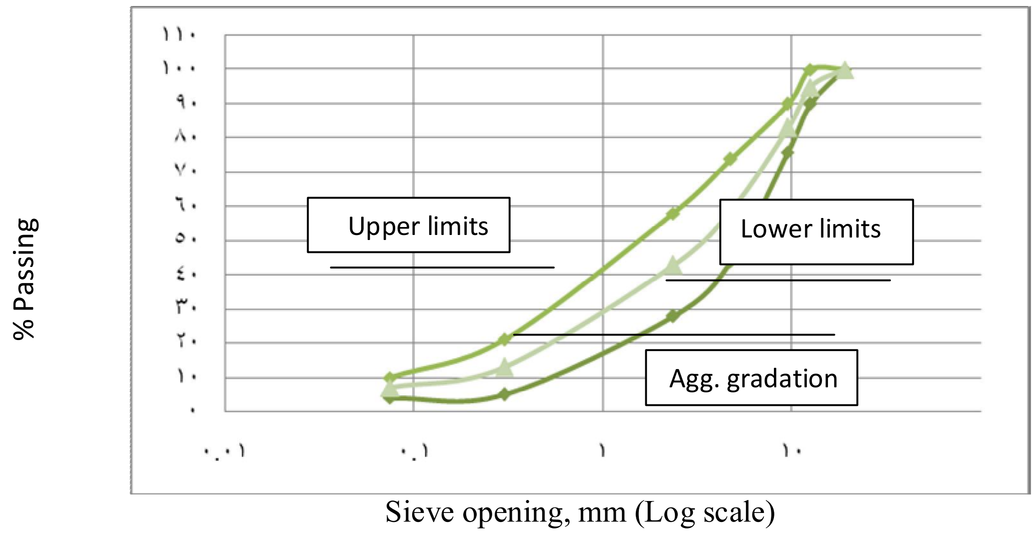
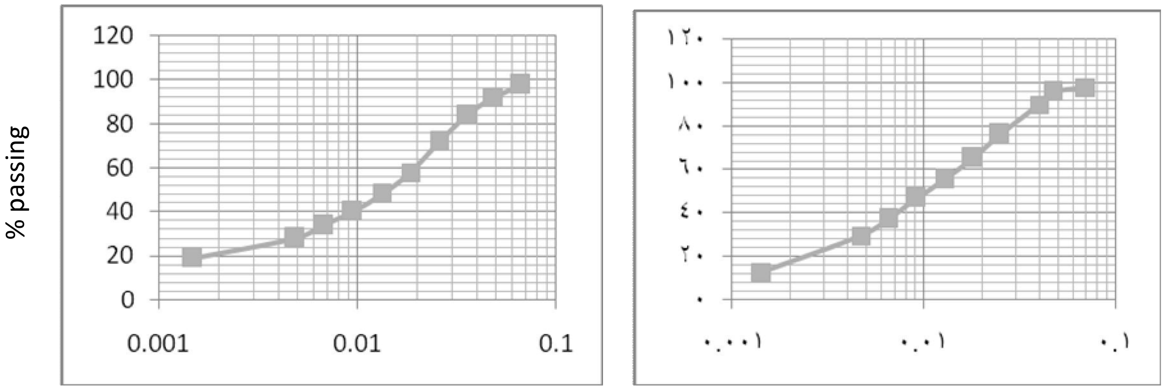


Figure (1): Specification limits and selected gradation of aggregate maximum size (19mm).

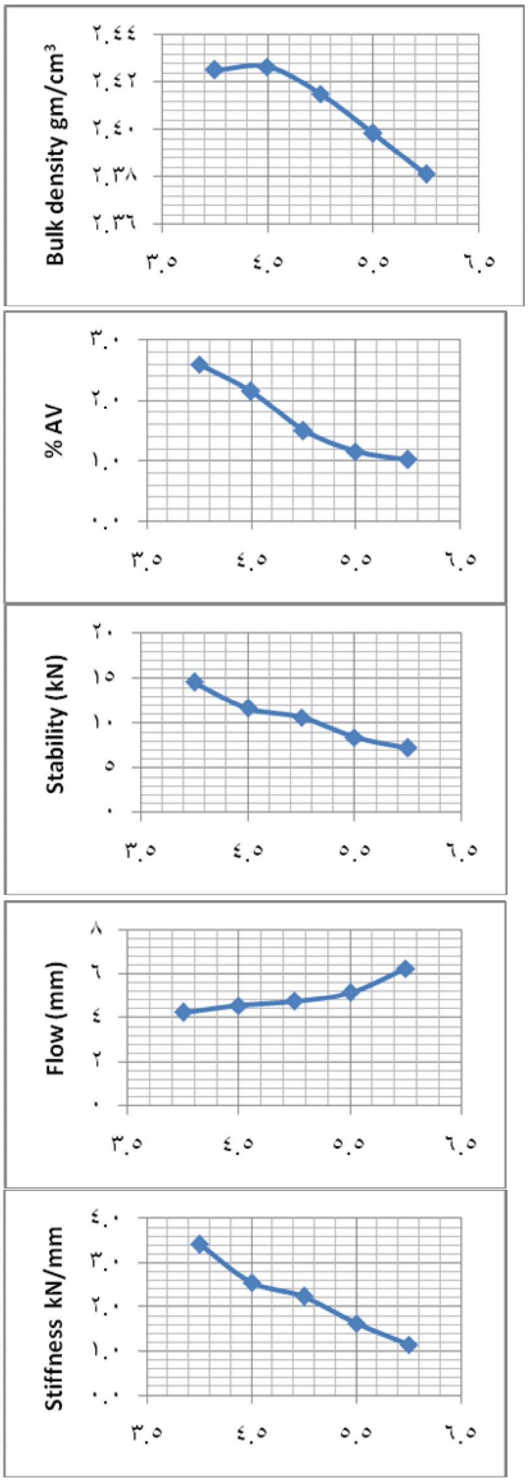


(SM) (Li)

Diameter (mm) Diameter (mm)

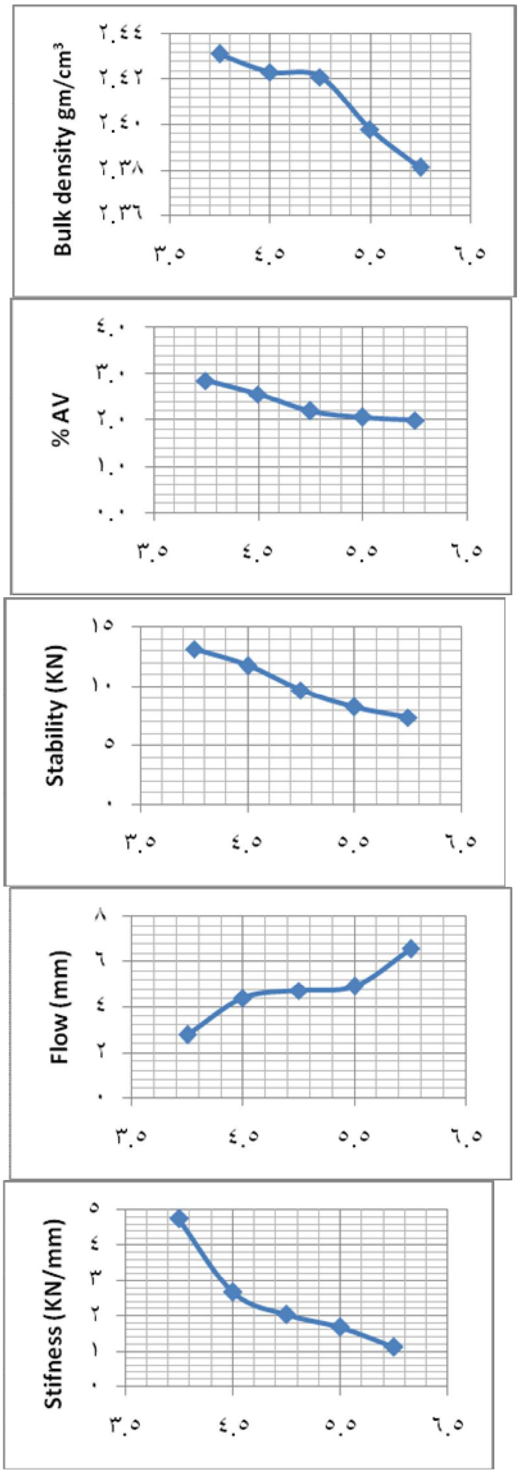
Figure (2): Grain size distribution for each type of filler.

Figure (3): Surface Area Analyzer instrument.



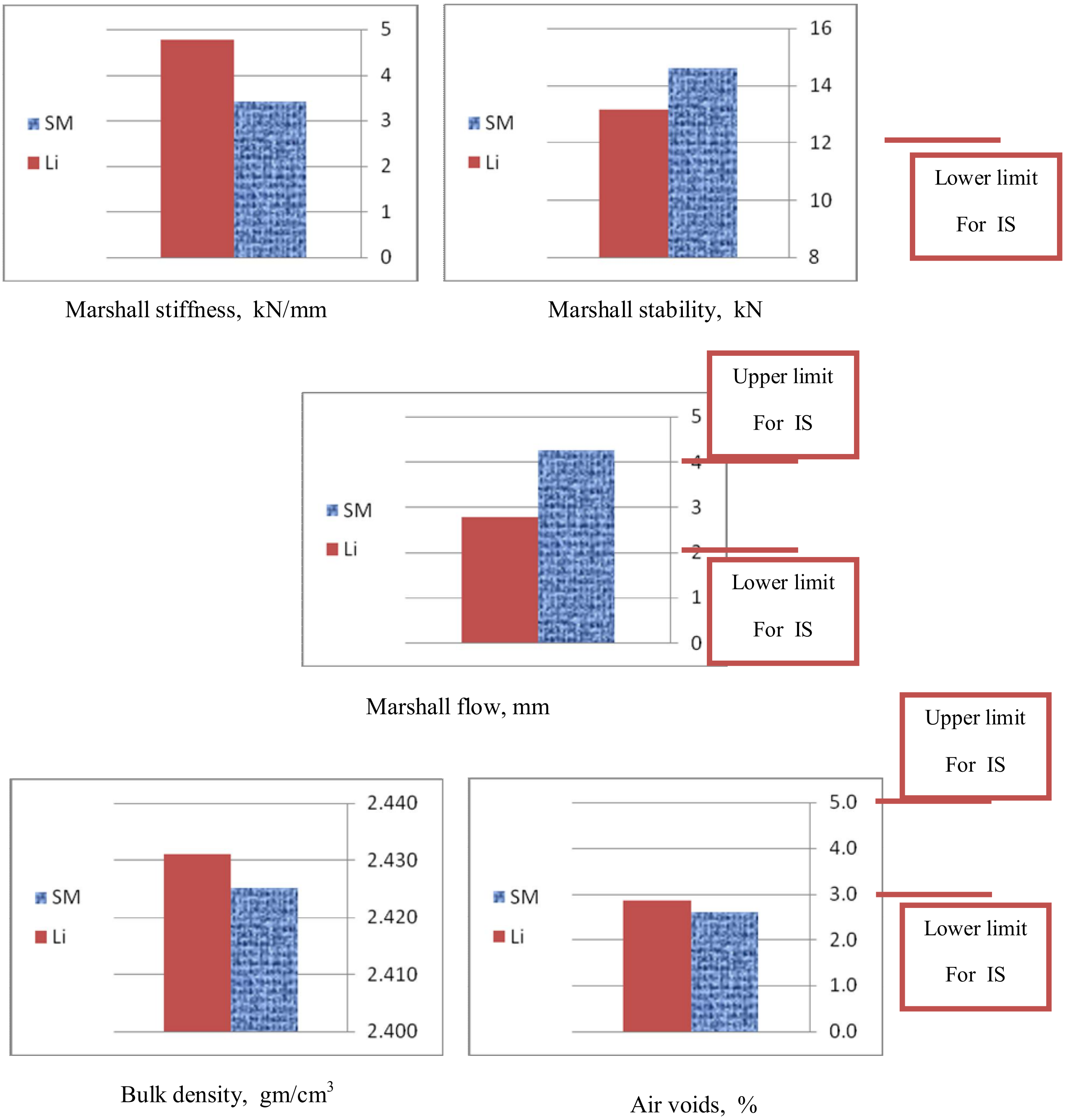
Asphalt content %

Figure (4): Marshall parameters for mixtures containing SM filler.

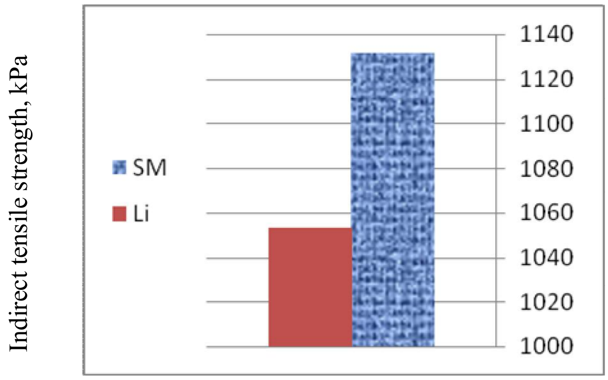


Asphalt content %

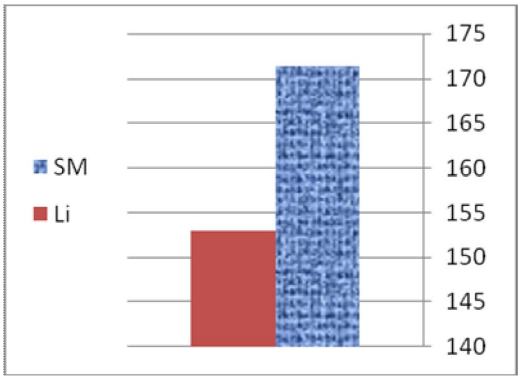
Figure (5): Marshall parameters for mixtures containing Li filler.



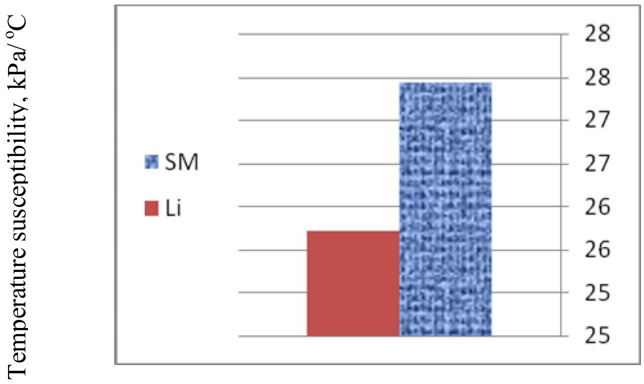
Figure(6): The effect of filler type on the properties of Marshall test, showing the limits according to Iraqi Specifications (IS) for surface course type III/A.



The effect of filler type on the ITS values at 25 °C test temperature.

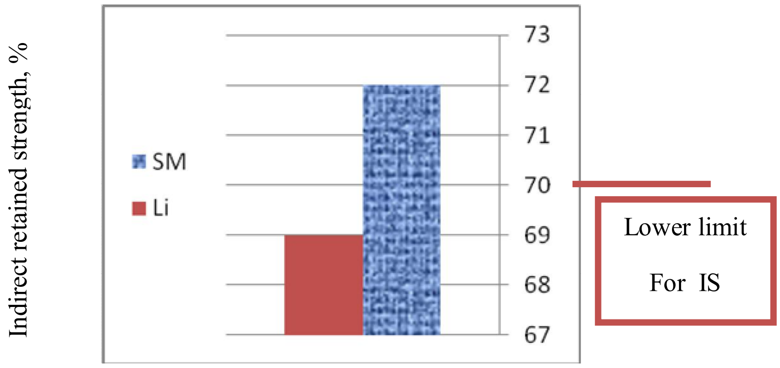


The effect of filler type on the ITS values at 60 °C test temperature.

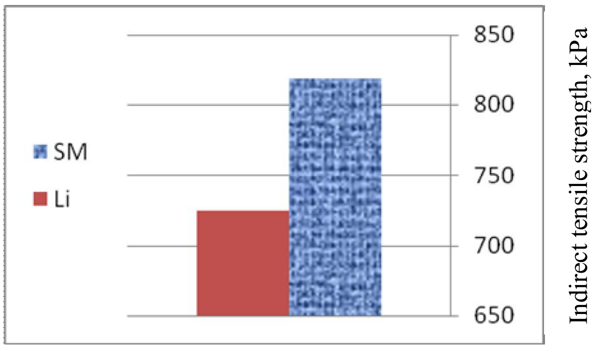


The effect of filler type on the TS.

Figure (7): The effect of using Ki as a filler on ITS and TS values at different test temperatures.



The variation of IRS values of filler types, showing the lower limit according to Iraqi Specifications (IS)



The variation of ITS values of filler types for conditioned subset (after a 60 ^{o}C water bath for 24 hours)

Figure (8): The effect of using Ki as a filler on IRS and ITS after a 60 oC water bath for 24 hours values.

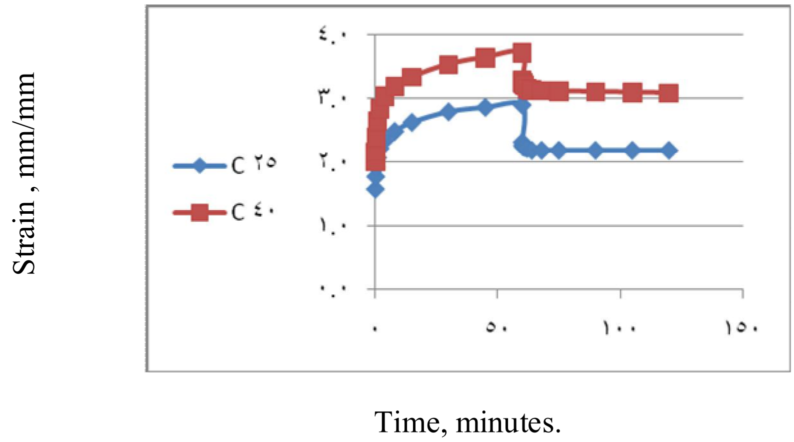


Figure (9): The effect of temperature variance on the diametrical creep test results using SM as a filler.

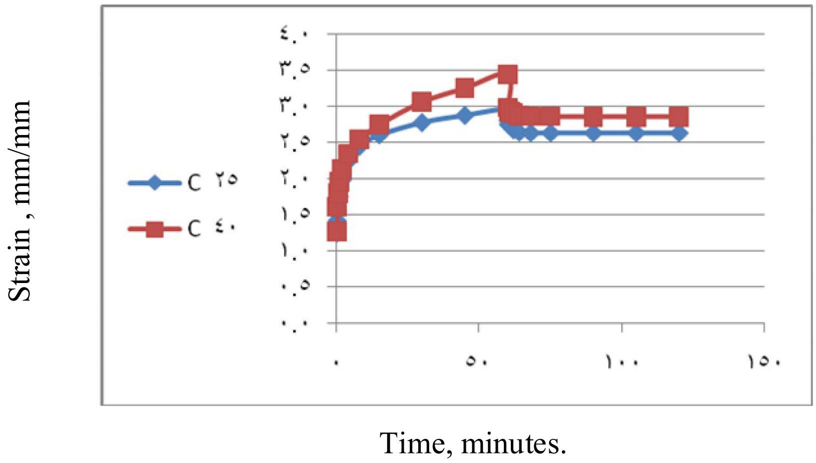


Figure (10): The effect of temperature variance on the diametrical creep test results using Li as a filler.

استخدام مخلفات مرمر السليمانية لتحسين خصائص الخلطة الاسفلتية الحارة

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الخلاصــة.
في العراق ، هناك آلاف الأطنان من مخلفات المرمر يمكن إعادة استخدامها و الاستفادة منها . و لكن هناك قليل من البحوث التي حاولت دراسة تأثير مخلفات المرمر على الخلطة الإسفلتية. و طبعا هذه الكمية الكبيرة لها اثر كبير و سلبي على البيئة و تحتاج إلى الأموال و الجهد للتخلص منها. و في هذا البحث استعضنا عن الاسمنت باستخدام مسحوق الحجر الجيري لأغراض المقارنة. تم إجراء الفحوصات اللازمة لإيجاد خصائص كل نوع من المادة المالئة و تشمل التدرج الحبيبي و الوزن النوعي و المساحة السطحية و حجم فراغات السطح و التركيب المعدني و الكيميائي و الحامضية. لإيجاد تأثير مادة مخلفات المرمر على خصائص الخلطة الإسفلتية تم إجراء عدة فحوص تشمل(مارشال) ، الشد غير المباشر ، الحساسية ضد الرطوبة بالإضافة إلى فحص (الزحف). تم التوصل إلى العديد من الاستنتاجات التي تشير إلى أهمية هذه المخلفات في تحسين خواص الخلطة الإسفلتي.

الكلمات الرئيسية: مادة مالئة،مخلفات،اسفلت،خلطات إسفلتية.