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Use White Cement Kiln Dust As A Mineral Filler In Asphalt Mixture

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ABSTRACT

The white cement Kiln dust (WCKD) is a secondary production from the cement industry through its production operation. Environmentally, it is considered as an unwanted waste because it causes air pollution and ground congealment, and it is needed great efforts and financial support to disposal it. In this study, the WCKD was used partially instead of limestone as a filler in the asphalt mix, where it was used by ratios of 0%,25%,50%,75% and 100% from the weight of limestone. An evaluation of the mechanical characteristics was conducted by carrying out Marshall test and Indirect Tensile test, and the results showed that the increase in the WCKD percent reduces the asphalt mix density and increases the percentage of air voids, while the other characteristics (stability, Marshall Stiffness, flow and Indirect Tensile Strength) increase when the WCKD ratio is 25% and 50%. These those characteristics start decreasing when the WCKD ratio was 75% and 100%. The study showed that the optimum ratio of the WCKD is 50% from the limestone weight, and the WCKD cannot be used as a filler entirely in asphalt mix, but it can be used partially.

Key Words: Cement Dust , Cement Waste ,Fill Material ,Marshal Test ,Asphalt Mix

1. INTRODUCTION

Cement Kiln Dust (CKD) is a by-product material that generated during the production of Portland cement. Raw material are heated in the kiln, dust particles are produced and then get out with the exhaust gases at the upper end of the kiln. These gases are gradually cooled and the accompanying dust particles are captured by efficient dust collection systems. The composition of CKD is quite variable from source to another due to raw materials and process variations. It is primarily made up of a variable amount of fine calcined and uncalcined feed materials, fine cement clinker, fuel combustion by-products, and condensed alkali compounds [1].

Some of CKD is recycled back again with the clinker but the amounts are limited by alkalinity requirements for Portland cement and kiln operation issues [2].

However, most of the material is disposed of on-site without any further reusing or reclamation [3].

Waste material recycling into useful products has become a main solution to waste disposal problems. Many highway agencies are conducting wide variety of studies and research projects concerning the feasibility,

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environmental suitability, and performance of using recycled products in highway construction [4].

There are 16 cement factories in Iraq, so about 1500 to 2000 tons per day is the total production of CKD in Iraq. This large amount of waste has a negative effect on the environment and needs a lot of money and effort for recycling or disposal. Many researches referred to its uses in asphalt concrete mixtures and its uses in soil stabilization [1,3,5]. But a few investigations had been focused on its importance in asphalt concrete pavement in Iraq [6].

The aim of this study is to investigate the possibility of using CKD as a mineral filler (partially or fully) in producing Hot Mix Asphalt (HMA).

2. MATERIALS AND EXPERIMENTAL WORK

2.1 Material Properties:

2.1.1 Asphalt Binder:

A 40-50 pen. Asphalt type that brought from Baiji refinery has been used in this study. The physical properties of this type are shown in **Table (1)**.

Table (1) : Physical properties of Baiji asphalt cement

* centipoise = centistoke * density [9]

Property	Test condition	Unit	ASTM Designation No.[7]	ISSRB Specifications [8]	Results
Penetration	100gm, 5sec, 25°C	0.1mm	D-5	40-50	45
Specific gravity	25°C	------	D-70	-------	1.025
Ductility	5cm/min, 25°C	cm	D-113	>100	>120
Solubility in trichloroethylene	%	%	D-2042	>99	99
Flash point	°C	°C	D-92	>232	>242
Softening point	Ring&Ball, °C	°C	D-36	-----	46
Viscosity (rotational viscometer)	135°C	Cps (centipoise)	AASHTO T316-06 [9]	>410*	525
Residue from thin film over test D-1754					
Penetration	100gm, 5sec, 25°C	%	D-5	>55	75
Ductility	5cm/min, 25°C	cm	D-113	>25	>110

2.1.2 Aggregate:

The coarse and fine aggregates were brought from Nibaay quarries, passing from sieve 3/4 in and retained sieve No.4 with 100% crushed particles. Physical properties of the used aggregates are presented in **Table (2).** The midpoint of surface course type III/A of ISSRB[2],seen in **Table(3).**

Table(2) : Physical properties of coarse and fine aggregate

Property	Coarse agg.	Fine agg.	Test method[7]
Bulk specific gravity	2.621	2.606	ASTM C-127 And ASTM C-128
Apparent specific gravity	2.656	2.662	
%Water absorption	1.05	0.75	
% Wear (Loss Angeles)	12.16	---	ASTM C-131

Table(3) : Selected Mix Gradation

sieve		% Passing	
in	mm	Use Gradation	Gradation limits
3/4	19	100	100
1/2	12.5	95	90 -100
3/8	9.5	83	76 – 90
No.4	4.75	59	44 – 74
No.8	2.36	43	28 – 58
No.50	0.3	13	5 – 21
No.200	0.075	7	4 - 10

2.1.3 Mineral Filler:

Two types of fillers were used in this study They were brought from two local sources in Iraq which are Limestone dust(Li), from Karbala lime factory, and Cement Kiln dust(CKD) defined previously from Al-Qa'am cement factory-Iraq.

The Physical properties of two types are found in the laboratory and shown in **Table (4).** Chemical composition of each type shown in **table (5**).

Table (4) : Physical Properties of Mineral Fillers

Properties		% Passing		
Sieve size		ISSRB	Li	CKD
in	mm			
No. 30	0.6	100	100	100
No. 50	0.3	95-100	100	100
No. 200	0.075	70-100	97	96
Plasticity index		<4	3.47	1.1
Specific gravity		-----	2.67	2.51

Table (5) : Chemical Compositions of Mineral Fillers

Filler type	Li	CKD
Chemical Compositions*		
SiO_2	2.53	12.69
Al_2O_3	0.59	2.43
Fe_2O_3	0.22	4.30
CaO	51.15	51.10
MgO	1.06	0.98
SO_3	1.12	3.70
L.O.I.	42.40	23.22
Cl	----	0.40
Na_2O	-----	0.16
K_2O	-----	0.97
Ph	7.51	12.7

*this test was conducted in Kubaisa cement factory laboratories.

2.2 Experimental Programme

Several tests were made on the mechanical performance of asphalt concrete mixtures have been conducted to study the effect of (CKD) on the performance of HMA mixture.

2.2.1 Marshall Test:

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 [6].Five mixtures were prepared and tested. For all types of mixtures, the aggregate gradation and asphalt content (4.8% weight of total mix) are similar excluding the filler type and amount which differs from one mix to another as follows (the percentage indicates the filler amount in each mix), 1- 100% Li(control) , 2- 75%Li+25%CKD, 3- 50%Li+50%CKD, 4- 25%Li+75%CKD,and 5- 100% CKD.

2.2.2 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 three 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 ^{o}C and 60 ^{o}C) 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 [6].

The ITS values were computed as follows[10]

$$ITS = 2000\ P / \pi\ t\ D \qquad (1)$$

where:

ITS =Indirect tensile strength, kPa

P = maximum load, N

t = specimen height immediately before tensile test, mm and

D = specimen diameter, mm .

3. INDIRECT RETAINED STRENGTH (Moisture Damage Resistance) 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 [11]. The test was conducted according to ASTM D-4867 [7]. Two subsets of the three specimen were prepared in the same method described for Marshall method. The unconditioned subset was tested for ITS after 30 minutes of 25 ^{o}C water bath. The conditioned subset was subjected to saturation condition by vacuum and then immersed in a water bath of 60 ^{o}C for 24 hours. Then the specimens were left in a water bath of 25 ^{o}C for one hour before testing for ITS. The Indirect Retained Strength (IRS) values were determined as follows [10]:

$$\% \text{ IRS} = \frac{ITS(conditioned\ subset)}{ITS(unconditioned\ subset)} \times 100 \qquad (2)$$

4.RESULTS AND DISCUSSIONS

4.1 Marshall Test Results:

The results of all Marshall tests are summarized in **Table (6)** with different cement kiln dust content and shown in figs. (1-5). Each results is the average value of three tested specimens.

Table(6): Marshall test results for Mixtures with different CKD content

Mineral Filler Type		Stiffness KN/mm	Stability KN	Flow mm	Density gm/cm^3	Air Voids %
% of Li	% of CKD					
100	0	4.10	12.3	3.5	2.397	3.53
75	25	4.38	14.0	3.6	2.393	3.62
50	50	4.53	15.4	3.7	2.382	3.71
25	75	3.29	11.2	3.4	2.371	3.85
0	100	2.88	9.2	3.2	2.351	3.95
Iraqi Specifications (IS)for surface course type III/A[8]		---	Min. 8	2 - 4	---	3 - 5

From Figs.(1-5) it can be seen that the Marshall parameters for each different CKD content mixes are within the Iraqi specification (IS)[6].The CKD decrease the density of mix due to its lower specific gravity with respect to Li and that reflect inversely on the results of air voids (%AV). While, the Marshall Stability, flow and stiffness increase until the percentage of CKD content (50%) , after that the Marshall Stability, flow and stiffness are starting decreases. This is primarily due to the high surface area of CKD which will tend to absorb more asphalt [12].For the reason mentioned CKD can be used partially as mineral filler instead of the common mineral filler in producing asphalt concrete mixture. While CKD can't use it fully because the amount of asphalt should exceed the upper limits of the specification of (Iraqi roads IS)[8].

The Marshall Stiffness (MS) , stability divided by its flow, is an empirical stiffness value that used by some European engineers to evaluate the strength of asphalt mixture. A higher value of MS indicates a stiffer mixture and , hence, it indicates that the mixture had high resistance to permanent deformation [13].

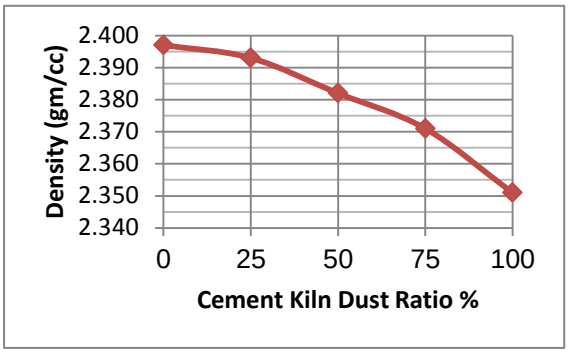

Figure. 1. Density for mixtures with different CKD content

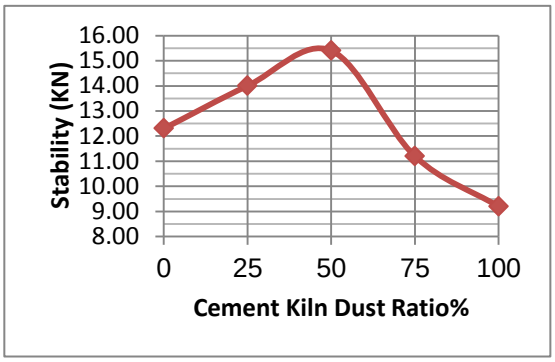

Figure. 2. Marshall Stability for mixtures with different CKD content

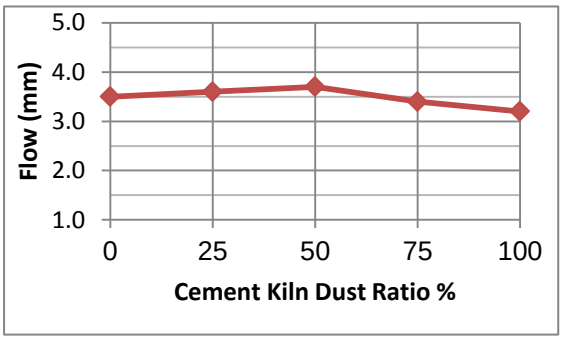

Figure. 3. Flow for mixtures with different CKD content

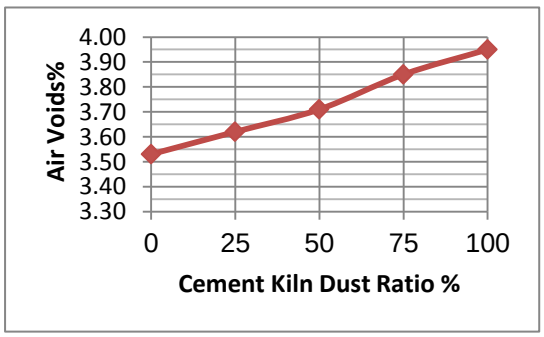

Figure.4. Air voids for mixtures with different CKD content

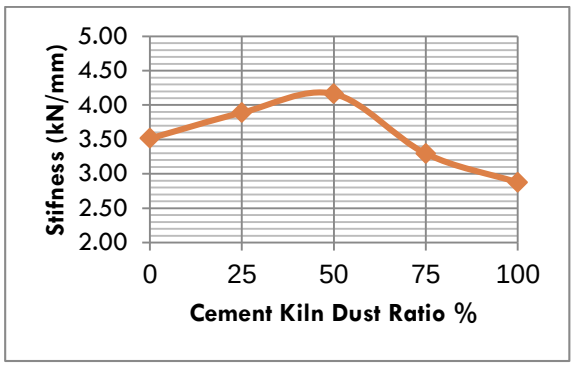

Fig. (5): stiffness for mixtures with different CKD content

4.2 Indirect Tensile Strength(ITS) results :

The ITS gives an indication about the cohesion of mixture due to adhesion between its components . The maximum load carried by the specimen was found, and the ITS at failure was determined and presented in **Table (7)** . It can be seen from **Table (7)** that the ITS and IRS increase until the percentage of CKD content (50%) , after that the ITS and IRS are starting decrease.

Table (7): ITS and IRS of Mixtures with Different CKD Content

Mineral Filler Type		ITS at 25 °C, kPa	ITS at 60 °C for 24 hr, kPa	IRS , %
% of Li	% of CKD			
100	0	1236	988	79.73
75	25	1293	1050	81.20
50	50	1391	1265	91.00
25	75	1330	1112	83.60
0	100	1225	970	79.18
Iraqi Specifications (IS)for surface course type III/A [8]		----	----	Min (70%)

CONCLUSION:

This study evaluated the use of CKD as a filler in lieu of Lime in asphalt concrete mixtures. For Marshall test, the use of CKD as a filler in hot mix asphalt concrete(for each different CKD content mixes) will increase air voids and decrease density. While, the Marshall Stability, flow , stiffness ,

ITS ,and IRS increase until the percentage of CKD content reaches (50%) , after that the Marshall Stability, flow , stiffness , ITS ,and IRS are starting decreases.

Adding CKD to the mix reflect a good effect on the cohesion of mix due to high values of ITS, also The abundant effect of CKD on IRS value refers to its importance to reduce the moisture attack. The use of cement klin dust CKD will increase the stiffness of mix as well as decrease the rutting potential of pavement. The optimum CKD content used as a filler should not exceed (50%) of live loadbecause the increase CKD tend to absorb the asphalt of mix, that will decrease the asphalt film thickness and the durability of the mix moreover the segregation tendency of the mix .

RECOMMENDATIONS:

1- Optimum CKD content was found to be 50% of limestone. Thus CKD cannot be used as a mineral filler (fully) because that will need asphalt more than ISSRB requirements

2- Using CKD in asphalt mixing can also have many environmental advantages from decrease the side effect of pollution caused by the accumulations of tons of waste in situ

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استخدام غبار السمنت الابيض كمادة مالئة في الخلطات الاسفلتية

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الخلاصة

ان غبار السمنت الابيض هو ناتج ثانوي من صناعة السمنت خلال عملية تصنيعه ويعتبر من المخلفات الغير مرغوب فيها بيئيا لما يسببه من تلوث للهواء وتحجر الاراضي ويحتاج الى جهود كبيرة وامكانيات مادية من اجل التخلص منه .في هذه الدراسة تم استخدام غبار السمنت الابيض كبديل عن الحجر الجيري كمادة مالئة في الخلطة الاسفلتية حيث استخدم بنسب (0%,25%,50%,75% و100%) من وزن الحجر الجيري, وتم تقييم الخواص الميكانيكية للخلطات الاسفلتية عن طريق اجراء فحص مارشال وفحص الشد الغير مباشر وقد اظهرت النتائج ان زيادة غبار السمنت الابيض يقلل كثافة الخلطة الاسفلتية ويزيد من نسبة الفراغات الهوائية , اما الخواص الاخرى (الثبات , الصلابة ,الجريان وقوة الشد الغير مباشر) فتزداد عند نسبة غبار السمنت 25% , 50% ثم تبدأ هذه الخواص بالنقصان عند نسبة غبار سمنت 75% و100% . اظهرت الدراسة أيضا ان النسبة المثلى لغبار السمنت الابيض هي 50% من وزن الحجر الجيري ولايمكن استخدام غبار السمنت الابيض كمادة مالئة في الخلطات الاسفلتية بصورة كليه وانما يمكن استخدامه بصورة جزئية .

كلمات مفتاحية : غبار السمنت ، مخلفات السمنت ، المادة المالئة ، فحص مارشال ، الخلطة الاسفلتية.