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MOISTURE SUSCEPTIBILITY OF HMA USING CEMENT KILN DUST EFFECTS

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Abstract- Asphalt mixes may experience a decline in their qualities owing to a number of different circumstances; one of these variables is the damage caused by moisture. Because of the presence of moisture, the road pavement network in Iraq is suffering from significant revealing and stripping damage. The addition of mineral anti-stripping additives or liquid anti-stripping agents into hot-mix asphalt (HMA) mixes is one of the main methods that may be utilized to lessen the possibility of moisture damage. In order to establish how susceptible material is to damage from exposure to moisture of using cement kiln dust (CKD) waste from the cement industry and Ordinary Portland Cement (O.P.C) as modifiers to the hot asphalt mixture used as the control mixture's comparison. This will be done by comparing the sensitivity of the filler mixtures to one another. Cement kiln dust was mixed with various percentages of limestone dust, ranging from 25% by weight to 75% by weight to 100% by weight. The Marshall Properties test, indirect tensile tests, and tensile strength ratio tests were used to assess the laboratory performance of HMA mixes that had been treated to moisture conditioning. According to the findings, the ratio of indirect tensile strength to tensile strength rises when the CKD ratio is 25%, 50% by (8.9% and 12.3%) respectively, and by (6.9%) when the O.P.C. method was applied. These characteristics begin to deteriorate when the CKD ratio is between 75% and 100%.

Keywords: Cement Kiln Dust, Ordinary Portland Cement, Indirect Tensile Strength, Hot Asphalt Mixture, Moisture Damage.

1. INTRODUCTION

Black or dark brown in color, asphalt is an adhesive compound (Cementitious) made mostly of bitumen. Pavement has experienced distress as a result of a rise in high traffic load brought on by an increase in the number of cars and trucks on the road, Human actions alter the atmospheric composition, which in turn alters the planet's climate.as well as the impacts of other outside elements such as air temperatures and moisture. The presence of water in asphalt mixes may cause a reduction in both the material's strength and its durability, which is referred to as "moisture damage." Because of the presence of water, the road network in Iraq is exhibiting significant signs of degradation consisting of raveling and stripping as examples. This is due to the interplay between the gravel and asphalt. has been destroyed [1-4]. Modification of the binder is one strategy that may be used to enhance the asphalt mixture and its qualities it has. In order to improve the properties of asphalt mixtures, particularly with regard to their resistance to moisture damage, engineers have been conducting research on and developing a variety of anti-stripping additives. These additives have been used to enhance the characteristics of asphalt [5].

During the manufacturing of Portland cement, a by-product known as cement kiln dust, abbreviated CKD, is created. The heating of the raw materials in the kiln results in the production of dust particles, which are then released together with the exhaust gases at the kiln's highest point. While these gases are being cooled, efficient dust collection equipment is gathering the dust particles that have accompanied them. The composition of (CKD) may vary greatly across different sources due to the fact that both the raw ingredients and the production techniques are subject to change. Condensed alkali compounds, fine cement clinker, byproducts of fuel combustion, and a variable amount of fine calcined and unclaimed feed materials make up the majority of the material [6]. Lime (CaO) is the main ingredient in (CKD).

The current research seeks to understand the outcomes of replacing traditional Portland cement with cement kiln dust in asphalt concrete mixes. In addition to this, the impact that the concentration of cement kiln dust has on the mechanical properties of asphalt concrete mixes was investigated. In the laboratory, we tested five asphalt mixtures with different percentages of mineral filler by weight: 0%, 25%, 50%, 75%, and 100%, respectively.

2. MAIN OBJECTIVE

Using cement kiln dust as a filler material in asphalt pavement was the major focus of this investigation. The list included the following pledges in further detail:

1. Conduct research into the viability of using CKD and O.P.C as fillers in hot mix asphalts and analyze the results of those investigations.
2. Determine the sensitivity to moisture when using (CKD) and (OPC), and,
3. Compare the results to the control mixture, which consists of hot asphalt mixed with limestone dust.

3. SOURCE MATERIALS

The study's components, which are already being utilized to construct roads in Iraq, are easily accessible locally. Portland cement (P.C.) and cement kiln dust are produced locally (CKD). Determining how to use CKD and P.C. to strengthen the asphalt mixes' resistance to moisture damage is the goal of this research.

3.1. Pavement Binder

Because of its excellent engineering performance characteristics, such as elasticity, adhesion, and water resistance, asphalt is the material that is used the most often in the building of pavements in the modern day. In order to finish this job successfully, the 40-50 penetration grade asphalt cement was used. The Dora refinery, located south-west of Baghdad, is where we got our hands on it.

In order to ascertain the asphalt binder's physical qualities, it was put through the gamut of tests that are routinely performed in laboratories. Testing was necessary to ensure compliance with State Commission of Roads and Bridges (SCRB) regulations [7]. The findings of such tests are shown in Table 1.

3.2. Aggregate

3.2.1. Coarse Aggregate

The Al-Nibaee quarry was responsible for providing the coarse aggregate [7]. Reports that. In accordance with the requirements, the sizes of coarse aggregate must fall between the sieve sizes of three-quarters of an inch (19 mm) and number four. The physicochemical characteristics of coarse aggregates are broken out in Table 2.

3.2.2. Fine Aggregate

For the most part, the fine aggregate got from the same place as the coarse aggregate did; they came from the same quarry (crushed). The fine aggregate had a gradation it included everything from a No. 4 sieve (4.75 mm) to a No. 200 filter (0.075 mm). The properties of fine aggregates are outlined in Table 3.

3.2.3. Mineral Filler

Fillers made from minerals are often used to improve the characteristics of the combination and to fill in any gaps that may otherwise be visible. In the course of this research, three distinct kinds of fillers were used. They originated from two distinct local sources in Iraq, which are as follows: limestone dust (Li), cement kiln dust (CKD) from the Karbala lime factory used as a percent of 0%, 25%, 50%, 75%, and 100% of limestone, and ordinary Portland cement made at the Kubbesa mill and purchased at a nearby market. All of these materials were obtained in Iraq. Tables 4 and 5, respectively, reveal both substances chemical makeup and the physical attribute of the substance.

3.3. Aggregate and Gradation Selection

The coarse and fine material was sieved by hand to separate them into their respective size ranges. As shown in Table 6 and Figure 1, the gradation of the aggregate dictated the combination percent for the Type II binder course needed to complete the work.

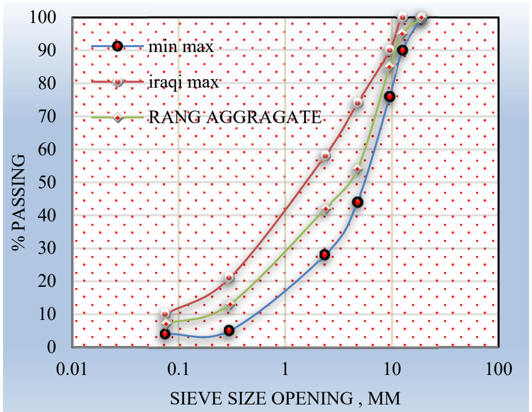

Figure 1. The Binder Course's Specification Limits and Selected Grading

3.4. Microscopically Evaluation

Figure 2 CKD by demonstrating that there is a visible granular texture inside the dust. Some of the CKD grains may be seen sticking to the bigger particles, indicating that the visible particles are really agglomerations of extremely minute CKD grains.

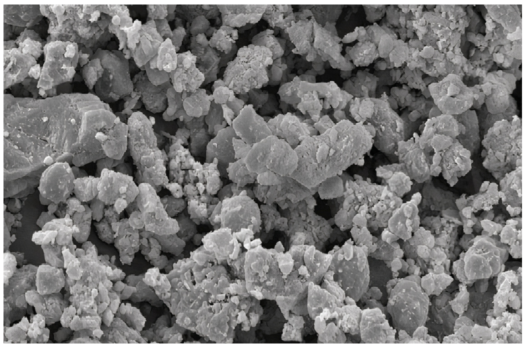

Figure 2. SEM images at 10 μm of industrial cement kiln dust (CKD) particles

4. EXPERIMENTAL PROCEDURE

4.1. Marshall Testing

This method employs loading cylindrical specimens of bitumen paving mixes on the lateral surface of the Marshall apparatus to determine the mixes' resistance to plastic flow [8]. In this particular investigation, five different asphalt cement percentages, depending on the total weight of the mix, were used to find the best asphalt content for the HMA: 4.4%, 4.7%, 5%, 5.3%, and 5.6%.

There were three different specimens developed for each kind of material. Fifteen different samples were pressed down and evaluated. A Marshall compactor was used to provide a compacting effort of 75 blows on each side to samples of hot asphalt mixture. This was done in order to imitate the circumstances of heavy traffic and modify the design criteria for the air voids content, which vary from 3 to 5%. The asphalt mixture samples were then immersed in hot water at a temperature of sixty degrees Celsius for a period of thirty to forty minutes. For each specimen, values were calculated for The Density and Specific Gravity of a Large Sample [9]. theoretical (upper) particular gravity [10], and percent air voids [11] The principal factors, more precisely bulk density, Marshall Stability, and air voids content, as determined by common standard specification, are taken into consideration in the process of determining the asphalt composition that is optimal.

4.2. Moisture Susceptibility Test

Asphalt concrete combinations' resistance to moisture was measured by [12] for tensile strength by roundabout means (ITS). With the trial approach, we created additive-free samples of each combination by compacting them at both ends with the required number of blows (40, 50, 60, and 70) to obtain a 7% air void content. Figure 3 shows that 55 total strikes were landed to obtain this percentage.

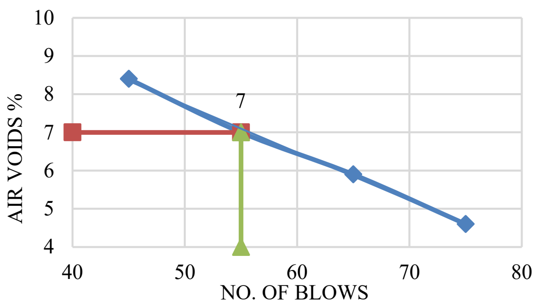

Figure 3. Number of Blows and the Percentage of Air Voids

In addition, to constructing the Marshall Specimens groups, six samples were taken: two sets of three samples, with each group being split in half. The first set of the samples were soaked in water maintained at 25 degrees Celsius for a duration of thirty minutes prior to calculating the ITS for each sample and figuring out sum of the three samples' ITS (specimens unconditioned). The second set was placed in a container with distilled water heated to 25 degrees Celsius to remove the air and bring the temperature down to safe levels. After that, the samples were chilled to a temperature of -18 degrees Celsius in the freezer for a period of sixteen hours. In order to finish the thawing cycle, after the first freezing cycle was complete, the samples were kept in a water bath at 60 degrees Celsius for an additional 24 hours. It has been removed, placed in another water bath with a temperature of 25 degrees Celsius for one hour, and the ITS has been computed (the specimens have been conditioned).

In terms of Equations (1) and (2), the tensile strength (also known as ITS) and the tensile strength ratio (also known as TSR) were computed:

$$ITS = 2000\,p / \pi t D \ \ (\text{KPa}) \tag{1}$$

where, *ITS*: stands for indirect tensile strength, (KPa),
P: for the maximum applied force needed to cause the specimen to fail (N)
t: for the specimen's thickness, (mm)
D: for its diameter (mm)

$$TSR = (Scon / Suncon) \times 100\% \tag{2}$$

A TSR of (80%) or higher is considered the bare minimum by [12].

5. TEST RESULTS AND DISCUSSION

5.1. Investments by Marshall

By testing with five various percentages of asphalt cement depending on sum of the ingredients' mass, the ideal proportion of asphalt content for the HMA was found. For each proportion of asphalt, three specimens were produced. Using a nominally maximum aggregate size of 12.50 mm and a mineral filler of 7.0% limestone dust, the specimens were placed through a series of Marshall Tests, including stability, flow, and density-voids testing. The findings from these experiments were utilized to establish the ideal asphalt percentage (by weight of total aggregate).

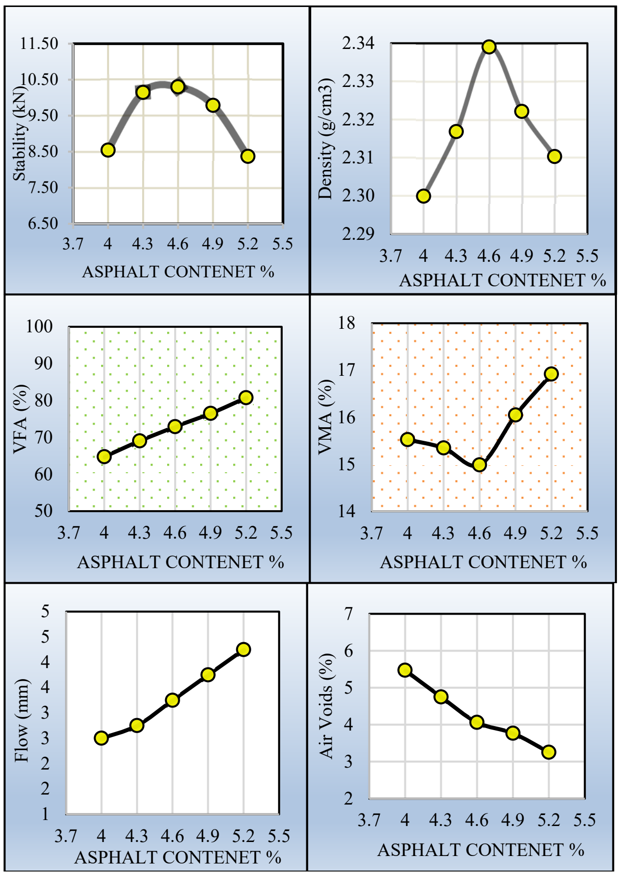

Figure 4. The Marshall Test Results for Asphalt Cement AC Control Mixture (40-50)

Averaging each set's average (three specimens for each asphalt percent). The findings of the Marshall Test. We determined that the optimal asphalt content (O.A.C.) should be equal to 4.83% of the overall mix's weight. The outcomes of the Marshall experiment are displayed in Figure 4.

5.2. Cement Kiln Dust Influence on Moisture Susceptibility (ITS)

It was shown [13] Given that the stress generated by this kind of loading is rather uniform and operates intersecting the loaded plane perpendicularly, the specimen will fail by planar fractures along the direction of stress. It was discovered that the specimen was capable of supporting a maximum load, and the indirect tensile stress at the point of failure was calculated and listed in Table 8. According to the data presented in Table 8 and Figure 5, Evidence from testing of cement kiln dust used as a mineral filler suggests, as well as Portland cement, reduce the asphalt concrete mixtures' sensitivity to moisture. These findings are based on the findings presented in those two tables. According to Table 8, it can be shown that the ITS (conditional and unconditional) values and the TSR values are growing by (5.7, 14.9%) of the control mixture when the CKD content of limestone dust is increased from 25% to 50%. This is owing to the fact that CKD contains finer particles than Li filler does, in addition to the fact that cement kiln dust and Portland cement both include a large amount of lime (CaO), which results in considerable gains the relationship between indirect tensile strength and tensile strength ratio. This is in line with what has been seen. [14], [15]. Cement kiln dust materials are considered to be alkaline materials, and when mixed with asphalt, they cause a hydrophobic state.

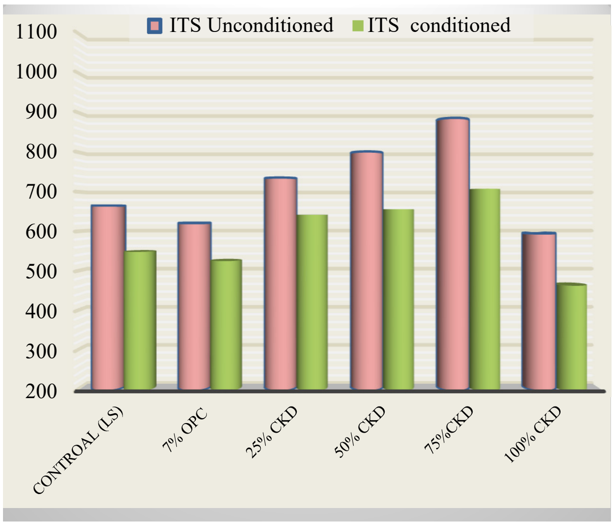

Figure 5. Effect the Percentages of CKD Content and O.P.C in ITS

This means that the aggregate does not accept water, which in turn leads to no water entering between the aggregate and the mastic asphalt, which in turn reduces the sensitivity to moisture. However, when the CKD content of the limestone is between 75% and 100%, the ITS and TSR values begin to decrease. It is possible to draw the conclusion that the reason for this decrease is because of the CKD's large surface area, it tends to take on more asphalt than the rest of the mix. When the CKD content of the limestone is increased, the amount of asphalt used must exceed the upper limits of the Iraqi standard, which results in an increase in production costs. In addition to this, a rise in the content helps to lessen the thickness of the asphalt layer, raise the mixture's endurance, and bring it closer to the stage when it can be separated. It is not possible to utilize the CKD in its whole as a filler in asphalt mix, but it is possible to use it in part. All outcomes are comparable [16-18]. Figure 6 the effect that the percentages of cement kiln dust content and Portland cement have on the ITS. The TSR and the variable ratio's connection to the control mixture are shown in Figure 6.

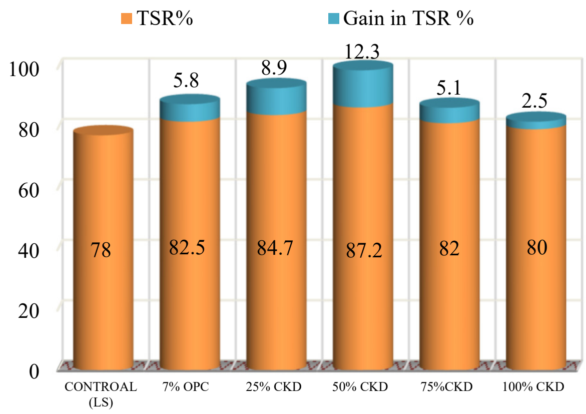

Figure 6. The tensile strength ratio and variable ratio of CKD and O.P.C

6. CONCLUSIONS

When evaluating the effect of moisture sensitivity when adding different percentages of limestone and comparing it with the control mixture, this study investigated the effect of adding waste materials represented by cement kiln dust and Portland cement. This study's objective was to investigate the impact that including waste materials would have on the materials' susceptibility to moisture. The following findings are able to be drawn as a consequence of the processes for testing, the percentages of mixing, and the components that were used in this investigation:

1) Depending on the type of filler used, the asphalt mastic exhibits differences in its typical response to an increase in filler percentage. Filler significantly affects the characteristics of the HMA mixture, and this effect is linked to the filler's own characteristics.

2) The kind of filler has a significant influence on the cohesiveness of the mixture, which can be measured utilizing ITS test. The group of cement kiln dust (CKD) has the highest indirect tensile strength (ITS) values compared to other types of fillers. O.P.C. Portland cement and limestone dust.

3) The kind of filler also impacts moisture deterioration; CKD demonstrates a high vulnerability to water attack with high values of TSR (8.9 and 12.3%) when CKD

content (25% and 75%) and OPC (6.3%) are compared to limestone dust.
4) The mixing process and time of the mixes would not be impacted by substituting CKD for the filler in HMA mixes.
5) Cement kiln dust cannot be fully used, because of its area the surface tends to absorb more asphalt from the mixture when the CKD content is increased, thus increasing costs.

APPENDICES

Physical and Chemical Properties for All Martial and Moisture Susceptibility Test.

Table 1. Characteristics of AC Physical Composition (40-50)

Penetration Grade 40/50		Units	ASTM Designation	Test Condition	Property
SCRB 2003 Specification	Test Results				
40-50	41.4	1/10 mm	D5	5sec., 100 gm, 25°C, 0.1mm	Penetration Test
< 3.0	0.65	Pa.sec	D4402	135 °C	Rotational Viscometer
>100	>100	Cm	D113	25°C, 5 cm/min	Ductility
>232	270	ºC	D92	---	Flash Point (ºC)
---	58	ºC	D36	---	Softening Point
---	1.04	gm/cm3	D70	25°C	Specific Gravity

Table 2. The Coarse Aggregate Physicochemical Properties

Property	ASTM Designation No.	Result	SCRB R9, 2003 Specifications
The Specific Gravity of Bulk Materials	C 127	2.578	-----
Visible Specific Gravity	C 127	2.602	-----
Absorption Rate, in Percentage	C 127	0.542	-----
% of Wear (Los Angeles abrasion)	C 131	15.789	30 Max.

Table 3. Fine Aggregate Physicochemical Characteristics

Property	ASTM Designation No.	Results	SCRB R9, 2003 Specifications
Density in Mass (S.G.)	C-128	2.61	---
Apparent Specific Gravity	C-128	2.632	---
Percent Water Absorption	C-128	0.952	---

Table 4. Chemical Compositions of Mineral Fillers

Chemical composition	Limestone	Cement Kiln Dust	Portland cement
CaO	51.1	68.63	61.52
SiO2	2.7	8.95	21.3
Al2O3	1	6.752	6.5
Fe2O3	0.16	6.213	2.2
SO3	1.16	0.371	2.3
MgO	1.2	----	1.403
L.O.I	42.6	1.464	2.4

Table 5. Physical Properties of Mineral Fillers

Property	Limestone	Cement Kiln Dust	Portland Cement
Specific gravity	2.72	2.92	3.12
% Passing N0.200	94	89.5	94.5
Color	white to gray	Light gray	gray

Table 6. Gradation of Combined Aggregate for Binder Course

Sieve Size	Sieve Size (mm)	Iraqi SCRB, R9,2003 Binder Course		Selection Gradation
		Max	Min	
3/4"	19	100	100	100
1/2"	12.5	100	90	95
3/8″	9.5	90	76	85
No.4	4.75	74	44	54
No. 8	2.36	58	28	42
No.50	0.3	21	5	13
N0.200	0.075	10	4	7

Table 7. Indirect Tensile Strength Test Results

Additives	Additive (%)	Unconditioned ITS (KPa)	Conditioned ITS (KPa)	TSR%
Control mix (Li)	0	595	464.1	78
Portland cement	7	665	555.61	83.2
Cement Kiln Dust (CKD)	25	621	526	84
	50	735	642	84.7
	75	800	656	87.2
	100	884	707.2	82

NOMENCLATURES

1. Acronyms

HMA	Hot-Mix Asphalt
CKD	Cement Kiln Dust
O.P.C	Ordinary Portland cement
Li	Limestone dust
ITS	Indirect Tensile Strength
TSR	Tensile Strength Ratio

2. Symbols / Parameters

Scon: average ITS of the samples that had been exposed to moisture
Suncon: average unconditioned ITS
P: The maximum applied force (N)
D: Diameter (mm)
t: The specimen thickness (mm)

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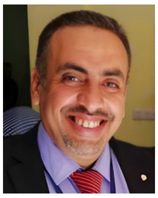

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