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Influence of High RAP Content with Different Types of Fillers on HMA Resistance for Moisture Damage for Different Layers

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Abstract

Hot mix asphalt placed on "reclaimed asphalt pavement" (RAP) provides technological benefits. Concerning these mixtures at all service temperatures is moisture damage. As a result, the performance of this composition in the face of moisture at all temperatures of service constituted the objective of this investigation. Experimental methods were employed to examine the impact of humidity on the efficacy of different varieties, one of which was the tensile strength ratio (TSR). Within the context of this research, four distinct proportions of RAP (10, 15, 20, 25%) and (30,40,50,60%) were incorporated into the hot asphalt mix (HMA) for the surface and bonding layers, respectively. In order to ascertain the most favorable RAP content for both layers, an investigation of the asphalt composites' hygroscopic resistance and Marshall stability in the face of moisture damage was conducted. For three fillers and both layers, the asphalt mixture without RAP is compared to the mixes with the ideal RAP concentration in terms of ratio (TSR). The tensile strength of the (HMA) without RAP was found to be somewhat lower in the findings than that of the asphalt control mixes that contained reclaimed pavement, where the percentages were found to be slightly higher and yet more than 80%. The findings show that, in general, the performance of these mixes and integrations against moisture damage is high despite the presence of antiquated elements in the hot asphalt mix (HMA) made from RAP, which comprises aggregates and bitumen binder around the aggregate particles. Because it contains this, it can have results with "hot asphalt mixtures" containing RAP for areas with damage without worry, in addition to good natural curbs.

Keywords: RAP, HMA, Moisture Damage.

تأثير محتوى RAP العالي مع أنواع مختلفة من الحشوات على مقاومة HMA لضرر الرطوبة لطبقات الرصف

زينب مالك كريم ، علاء حسين عبد

الخلاصة:

تمتع خليط الأسفلت الساخن المضمن في "رصيف الأسفلت المستصلح" (RAP) بمزايا التكنولوجيا العالية. يعد الضرر الناجم عن الرطوبة مصدر قلق في هذه الخلائط في جميع درجات حرارة الخدمة. لذلك، يعتبر أداء هذا الخليط ضد الرطوبة في جميع درجات حرارة الخدمة هدفا لهذه الدراسة البحثية. وبهذه الطريقة تم دراسة تأثير الرطوبة على أداء الأصناف باستخدام الطرق التجريبية بما في ذلك نسبة قوة الشد (TSR). في إطار هذه الدراسة تم إضافة أربع نسب مختلفة من RAP لكل طبقة من طبقات السطح والترابط (١٠٪، ١٥٪، ٢٠٪، ٢٥٪) و(٣٠،٤٠،٥٠،٦٠)% إلى الأسفلت الساخن. تم دراسة مزيج (HMA) للطبقتين على التوالي ودراسة محتوى RAP الأمثل لكلا الطبقتين من خلال ثبات مارشال والمقاومة الاسترطابية للخلطات الإسفلتية من خلال تلف الرطوبة. تتم مقارنة نسبة (TSR) للمخاليط التي تحتوي على محتوى RAP الأمثل مع خليط الإسفلت بدون RAP لثلاث مواد حشو ولكلا الطبقتين. أظهرت النتائج انخفاضاً طفيفاً في قوة الشد لـ (HMA) التي لا تحتوي على RAP مقارنة بخلطات التحكم الإسفلتية المحتوية على الرصيف المستصلح، حيث وجد أن النسب كانت أعلى قليلاً ولا تزال أعلى من ٨٠٪. تشير النتائج بشكل عام، على الرغم من وجود مواد قديمة في الخلطة الإسفلتية الساخنة (HMA) المنتجة من RAP، والتي تشمل الركام والمواد الرابطة البيتومينية المحيطة بحبيبات الركام، إلا أن أداء هذه الخلطات كافٍ ضد التلف الناتج عن الرطوبة. وبناءً على ذلك، يمكن التوصية بـ "الخلائط الإسفلتية الساخنة" التي تحتوي على RAP للمناطق التي تعاني من أضرار الرطوبة دون القلق بشأن القيود البيئية والموارد الطبيعية.

1. Introduction

The process of "rehabilitating" and/or "replacing" pavement infrastructure is known as asphalt pavement recycling. It has structural damage as well as persistent and visible deformation [1]. Reclaimed asphalt pavement (RAP) represents the most recovered materials in this category worldwide, according to [2]. The first set of data is gathered. Since 1915, new roads have been built under the repair program [3]. The oil crisis of the 1970s, however, saw a dramatic increase in the use of RAP due to the soaring cost and relative shortage of asphalt binder (also known as asphalt) at building sites [4]. Later, in 1997, the Parties made revisions to the Kyoto Protocol, and by 2005, it was completely put into effect. Throughout this time frame, the recycling process experienced notable prominence and extensive acceptance within the road-building industry [5]. According to some historians, there are a number of viable options for recycling asphalt pavements. Included in the procedures are hot rolling at the plant, cold rolling on-site, and rehabilitation using hot rolling [6, 1, and 7]. Nevertheless, rehabilitation remains one of the most often employed methods nowadays. It entails the combination of virgin materials with RAP in different proportions and sizes [8]. Research conducted in the US and Europe indicates that over 80% of recycled materials are utilised in the construction of roads. "RAP" may be used in proportions ranging from 5 to 50% to manufacture hot mix asphalt (HMA) and newly made asphalt, despite the fact that regulations are still strictly enforced [9]. Previous studies have shown the low moisture perishability of HMA mixtures in excellent proportions, as well as the response of mixes with RAP in proportions ranging from 0% to 40% and different asphalts. Certification as an ASTM super paving (D4867)[10]. There was no change to the mixture's purifying properties when 40% RAP was added to HMA mixtures, as stated in [2]. The combination's properties changed more noticeably when values higher than 40% were added.

According to the indirect tensile test load-displacement curve, larger RAP ratios were associated with apparent reductions in relative energy losses, which may indicate early distress. The moisture content was low (TSR values were nearly 95%). A recent study examined the behavior of asphaltic heated mixtures with respect to moisture. (HMA containing varying proportions of RAP materials) demonstrated that the TSR value of HMA with RAP was favorable for various paving layers and in comparison to HMA without RAP. This suggests that HMA mixtures are more resistant to moisture damage than other mixtures [11]. The tensile strength ratio makes it evident how the "RAP" and "TSR" components relate to one another. The original mixture's TSR ratio was initially far greater than 80%. Nevertheless, the ratio fell as the amount of RAP in the combination rose [12]. This is a result of "RAP" adding additional air spaces to asphalt mixes and making the mixtures more moisture-sensitive due to RAP's outdated binders.

2. Aim of the research

The objective of this study is to evaluate the effects of incorporating "reclaimed asphalt pavement" (RAP) in hot asphalt mixtures, with an emphasis on its optimal ratio in both surface and bond layers, on moisture damage resistance. In addition, the study will use the TSR test to assess the strength and hardness of RAP-containing mixes compared to the original asphalt mixture and three additional fillers. The Marshall mix design method was used to examine the "Material Characterization," including aggregates, asphalt, and fillers, and then determine the asphalt content in RAP and choose the suitable RAP content ratio for the surface and binder layers. The main purpose of mixture design is to balance flow, consistency, density, and void %. The laboratory then creates models using the HMA dense gradient mixture's exact gradation [13]. The Marshall compressor was used to compress these samples at a rate of 75 strokes per face. Tensile strength ratio (TSR) testing was used in the study's "mechanical characterization" of HMA blends. The study relied on a methodology based on:

- Characterization of asphalt binder, aggregates, and RAP (Determine the optimal RAP content in the hot mixture).
- Designing of HMA mix with RAP also determines the optimum asphalt content to be added for each layer.
- Producing and developing samples containing different types of filler (cement,kiln dust cement and hydrate lime) for tensile strength ratio testing
- Mechanical response analysis of RAP-containing HMA mixes.

3. Materials and methods:

3.1 Asphalt Cement

All of the virgin asphalt employed in the current reaction was sourced from the Al-Dora asphalt processing plant, and its penetration grade was 40/50. Table(no. 1) displays the actual features of the asphalt mix due to "standard designation" (ASTM).

3.2 Aggregates and Mixing Equation

The Al-Nabaa quarry, which was frequently used to produce asphalt mixes, provided the aggregates needed for this project. Laboratory testing was utilised to determine the "Chemical Properties" and "Physical" as needed by the ASTM "Standard Designation" for coarse and fine aggregates, as shown in Tables 2 and 3, respectively.

In accordance with SCRB, the maximum nominal size of aggregate selected for the aggregate gradient in the asphalt concrete mixture for "surface" layer samples is 12.5 mm for "binder" layer samples and 19 mm for "surface" layer samples, as shown in Table(4) Fig.(1) and Table (5) Fig.(2) [14].

Asphalt mixes are created using the Marshall technique, and the ideal asphalt content is calculated using ASTM D 6926-10 [15] and ASTM D6927-15 [16].

3.3 Reclaimed Asphalt Pavement

The recovered asphalt pavement (RAP) employed in the whole combinations in the present investigation was sourced from the Baghdad Governorate in Iraq and evaluated for binder asphalt content using ASTM D6307-10 "Asphalt content by ignition." The average asphalt concentration in RAP was 4.6%, according to "Furnace" [17]. Figure 3 depicts the distribution of the aggregate gradient in RAP.

Table (1): The physical properties of asphalt binder and the specifications of standard requirements

Tests name	Standard used	Unit	Evaluate test results	Standards - limitations (according to SCRB/R9, 2003)
Penetration, 25°C	ASTM - D5	0.1 mm	42	40 - 50
Ductility, 25°C	ASTM - D113	cm	164	Grater than 100
Softening - Point	ASTM - D36	°C	52	-----
Specific - gravity, 25°C	ASTM - D70	----	1.04	-----
Flash and fire points	ASTM - D92	°C	295	> 232 °C
Rotational - Viscosity a (centistokes)	ASTM - D4402	-----	550 @ 135 °C	-----

- All tests were conducted in the asphalt laboratories of the Department of Civil Engineering, Al-Nahrain University

Table (2): Laboratory findings of coarse aggregates' physical properties

Property	ASTM Designation	Tests value	Specifications
Apparent specific - gravity	ASTM - C127	2.633	----
Bulk Specific- gravity		2.574	
Absorption, %		0.362	
Soundness	ASTM - C88	4.100	Max. 12%
Angularity	ASTM - D5821	97%	Min. 95%
Flat	ASTM - D4791	1.1%	Max. 10%
Elongation		2.8%	
Hardness, by (Los - Angeles Abrasion)	ASTM - C535	20.8%	Max. 30%

Table (3) Laboratory findings of fine aggregates' physical properties

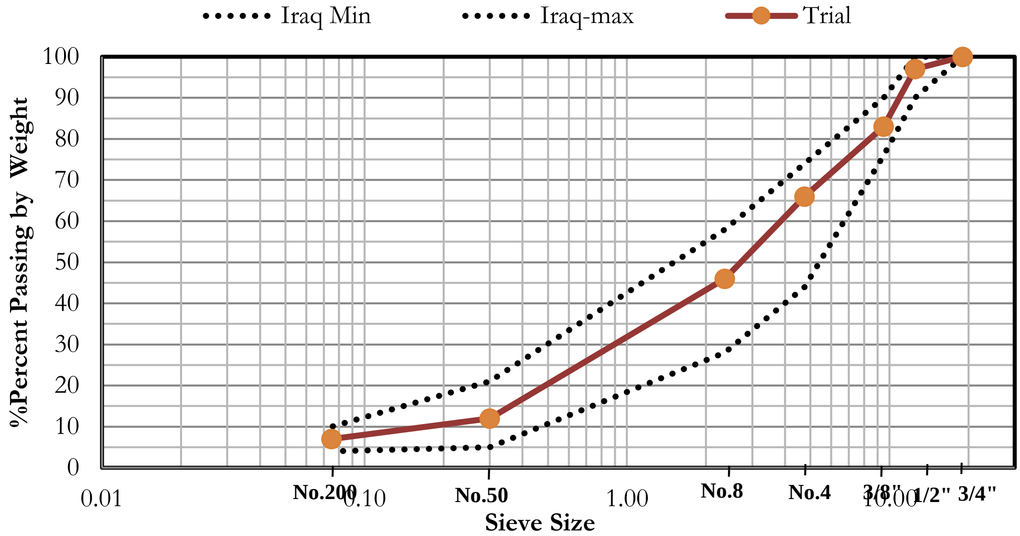
Property	ASTM Designation	Tests value	Specifications
Specific- gravity (Apparent)	ASTM - C128	2.690	------ ------
Specific- gravity (Bulk)		2.604	
Absorption , %		0.480	
Equivalent sand "clay content"	ASTM - D2419	72%	Min 45%

Table (4): The asphalt mixture's granular grade for the surface layer.

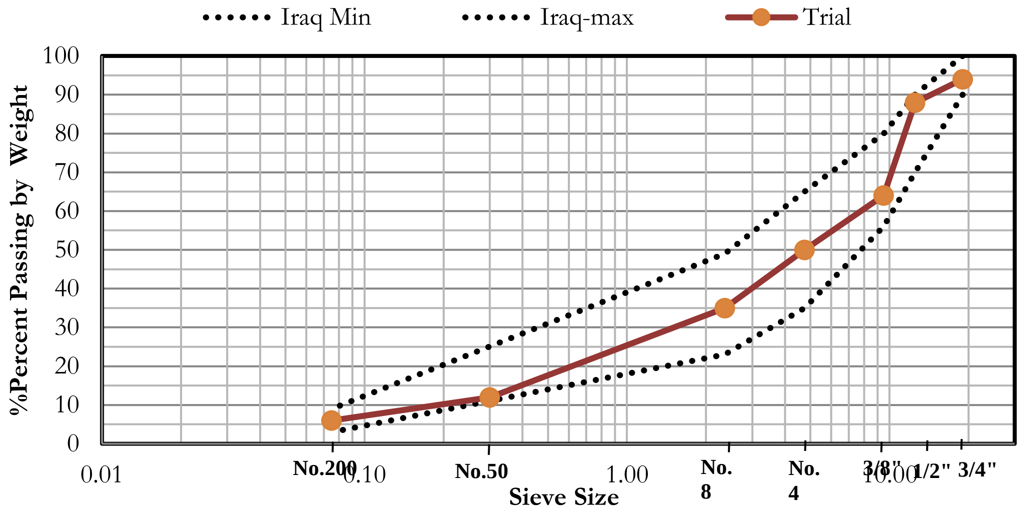
Sieve opening	Sieve opening (mm)	% passing	
		Specifications Limits [S-C-R-B]	Work choice
3/4 "	19	100	100
1/2 "	12.500	90 to 100	97
3/8 "	9.500	76 to 90	83
No. 4	4.750	44 to74	66
No. 8	2.360	28 to 58	46
No. 50	0.300	5 to 21	12
No. 200	0.075	4 to 10	7

Table (5): The asphalt mixture's granular grade for the binder layer.

Sieve opening	Sieve opening (mm)	% passing	
		Specifications Limits [S-C-R-B]	Gradation used
1 "	25	100	100
3/4 "	19	90 to100	94
1/2 "	12.500	70 to 90	88
3/8 "	9.500	56 to 80	64
No. 4	4.750	35 to 65	50
No. 8	2.360	23 to 49	35
No. 50	0.300	5 to 19	10
No. 200	0.075	3 to 9	6



Figure(1): Limitations and mean score gradations of (SCRB, 2003) for the surface layer



Figure(2): Limitations and mean score gradations of (SCRB, 2003) for the binder layer

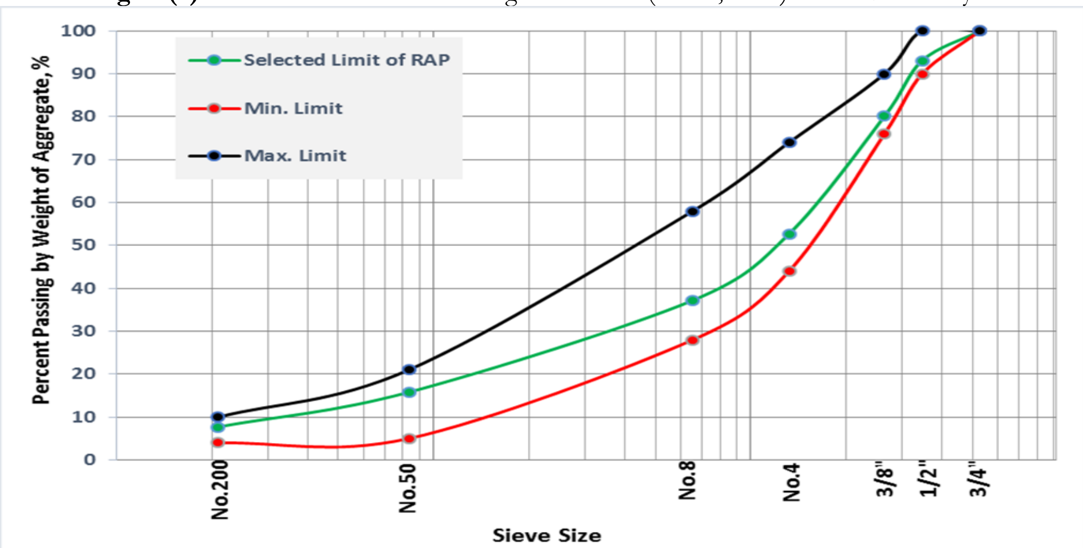


Figure (3): Gradation of reclaimed asphalt pavement (RAP).

The percentages of RAP (10%, 15%, 20%, 25%) and (30%, 40%, 50%, and 60%) were separated from the overall mixture for each layer in order to determine how high and low "RAP" percentages behaved as the amount of asphalt content decreased. Figure 4 shows the results of the RAP sieve analysis, which were split using a No. 4 sieve prior to being used in producing of asphalt mixes.

Figure (4): Samples of fractionated Reclaimed Asphalt Pavement (RAP) (coarse and fine).

3.4 Fillers Materials

A. Hydrated - lime

Hydrated-lime for the present study was procured from the city of "Karbala" and produced in compliance with Iraqi specification No. 807/1988 [18]. Table (5) lists the physical and chemical characteristics of hydrated lime.

Making use of "hydrated - lime" When included in the asphalt mixture, which is resistant to moisture damage, an "anti-erosion" component performs very well in saturated conditions. The addition of lime to a heated mixture improves the cohesion between the aggregate and asphalt. This process occurs via a chemical reaction between the asphalt and aggregate in the mixture, resulting in the formation of a soap that is soluble in water and can resist scaling. Insoluble salts are formed, and water is attracted when (lime) interacts with these particles [19]. Also, the mixture is more solid because of the microscopic hydrated lime particles that are spread throughout, and the mechanical breaking of cement and asphalt aggregates is more likely even in the absence of moisture [20].

B. Portland cement (PC)

Ordinary Portland cement was supplied from the "Karbala Governorate" and employed as a filler in asphalt mixes in accordance with Iraqi regulations and Specification No. 5/1984 [21].

Although cement is a hygroscopic material (it tends to absorb water), it interacts with water, causing the product to agglomerate and, thus, the formation of voids. Effective that contributes to increasing the bonding between asphalt and aggregates.

C. Cement kiln Dust(CKD)

As an additive for asphalt mixtures, waste cement dust from the "Karbala Governorate" was obtained and utilised. The chemical and physical properties of cement dust, as per Iraqi standards, are detailed in Table 7. [21].

Based on the findings, CKD exhibits higher purity and hence has a bigger surface area compared to regular Portland concrete. A greater surface area is primarily associated with a heightened capacity for cementation. CKD requires 40 minutes more preparation than Portland concrete. CKD has less specific gravity than Portland Concrete. Cement dust improves stability, unit weight, voids ratio, mineral aggregate flow and voids, unconfined compressive strength, indirect tensile strength, and moisture resistance in addition to filling cavities and increasing hardness. These effects are all influenced by the addition of cement dust to asphalt mixtures. Cement dust has been shown in studies to provide outcomes that are similar to those of lime, which strengthens the bonding between aggregates and asphalt mixes. As a result, cement dust can be used to substitute mineral fillers such as limestone in asphalt paving mixes [22].

Table (5): Physical and chemical properties of hydrated lime

Test		Results value
Chemical - composition %	calcium - oxide (CaO)	86.444
	Magnesium - oxide (MgO)	2.14
	Carbon - dioxide (CO_2)	2.47
"Chemical factor"		84.12
Blaine fineness, m^2 / kg		1200
Pozzolanic - Receptivity Index , %		101.04

Table (6): Portland cement's physical properties

Test type	Iraqi standard speci. No.5/1984	Result	Test type	Iraqi standard speci. No.5/1984	Result
Silicon - dioxide content SiO_2%	…..	20.34	Carbon sulfate content C_3S%	…..	38.93
Aluminum - oxide content Al_2O_3 %	…..	6.15	Carbon sulfate content C_2S%	…..	31.24
Iron - oxide content Fe_2O_3 %	…..	5.2	Carbon aluminum content C_3A%	…..	7.51
Calcium - oxide content CaO %		59.04	C_4Af	…..	7.73
Mengenesium - oxide content MgO%	Max5%	2.1	Loss on ignition	Max4%	2.02
Third content of sulfur oxide SO_3%	Max2.8%	2.13	Insoluble residue	Max1.5%	1.03

Table (7): The mechanical, chemical, and physical characteristics of cement dust.

Chemical components(%)	Percent%	Chemical components(%)	Percent%	Chemical components(%)	Percent%
SiO_2	8.95	SrO	0.025	ZrO_2	0.005
Al_2O_3	6.752	Pbo	0.018	NiO	0.003
Fe_2O_3	6.213	SO_3	.371	Br	0.003
CaO	69.637	V_2O_5	0.014	Y2O3	0.001
K_2O_3	7.52	CuO	0.014	MnO	0.24
TiO_2	0.212	Rb_2O	0.01	PH	13.24
K_2O	....	ZnO	0.006	LOI	….

3.5 Moisture Susceptibility

To assess the potential damage caused by moisture in the presence of RAP on both the surface and binder layers of HMA hot mix asphalt, a study conducted by [23] used an indirect tensile strength test on these mixes. For this assay, the forms were prepared and compressed using a" marshall hammer" to a content in which the proportion of air voids was (7% ± 1%). Subsamples were prepared from three samples in normal conditions (dry), and further subsamples were prepared from three samples after moisture conditioning (wet). These are the aggregates containing the optimal RAP ratio for each layer. Hydration was performed on the samples to achieve 55-80% saturation. After that, the samples were placed in a water basin at 60 °C ± 1 °C for 24 hours before being placed in a water basin at 25 °C ± 1 °C for 1 hour. For 20 minutes, dry samples were placed in a 25 °C aquarium. The samples were then examined in an indirect tensile test (IDT) at 25 °C to determine the finite forces necessary to fracture the samples. The tensile strength ratio (TSR) was calculated using the conditioned-to-unconditioned IDT ratio. Per ASTM D4867M-09, the minimum TSR value required is 80% [23]. Despite the fact that the hardness of container mixes on reclaimed pavement is low, tensile strength is still crucial and needed in a variety of asphalt applications. To prevent typical difficulties, asphalt engineers assess the properties of the asphalt formula. The indirect tensile strength test (IDT) determines tensile qualities in addition to cracking properties of pavements, as examined by a group of researchers [24]. It demonstrated a great resistance to breaking when the tensile strength was raised. All samples underwent an indirect tensile strength test (IDT) with a midpoint of 12.70 ± 0.3 mm and a constant loading rate of 5 cm/min at 25 °C until the samples failed owing to vertical distortion. As in equation (1), the maximum recorded load is used to compute the tensile strength, and the indirect tensile strength (ITS) is derived as follows:

$$TSR = \frac{R_{T2}}{R_{T1}} \quad \text{……..(1)}$$

where TSR = tensile strength ratio, R_{T2} = rate of indirect tensile force of adapted models, and R_{T1} = rate of indirect tensile force for unconditioned models. The ratio of an indirect tensile strength from a wet (conditioned) specimen to an unconditioned (dry) specimen is called the Tensile Strength Ratio (TSR). A TSR value of 80% or more is considered adequate for resistance to moisture damage.

4. Test Results and Discussion

Based on the stability results, it was determined that the mixture's optimal RAP concentrations for the surface and binder layers were 20% and 50%, respectively, which produced favorable outcomes. The findings showed that these ratios enhance tension, but that tensile strength decreases when exposed to "high temperature" and "humidity" circumstances [25]. All conditioning cycles are affected by the use of hydrated lime as a filler for TSR. In moisture damage testing, slaked lime (H.L.) was shown to raise the tensile strength ratio (TSR) more than either cement (O.P.C.) or cement kiln dust (CKD) when added to heated mixtures with the ideal RAP percentage. This is due to the fact that slaked lime filler is an effective material in the first place and that the asphalt mixture containing slaked lime has a high resistance to moisture because slaked lime reacts with the mixture, forming a soap-like layer surrounding the aggregates that prevents the peeling of the outer layers. Hence, it works as a material that is Waterproof and moistureproof. As for the asphalt mixture containing cement as a filler, in addition to being an effective filler, it is slightly less than hydrated lime. Despite this, the results for it were high TSR. As for the filler material (CKD), it is similar to cement because it contains 70 percent of the properties of cement, and for this reason, it is attributed to The convergence of the results between the asphalt mixture containing cement and the mixture containing (CKD). This is shown in Table (8) and (9). They show the results of the tensile strength ratio (TSR) for the samples and each of the surface layers and bonds, respectively.

Table (8): The samples of surface layers' tensile strength ratio (TSR)

RAP Content, %	Filler Type	TSR, %	RAP Content, %	Filler Type	TSR, %
0	CKD	82.78	20	CKD	83.5
0	O.P.C	84.43	20	O.P.C	86.7
0	H.L	88	20	H.L	90.3

Table (9): The samples of binder layers' tensile strength ratio (TSR)

RAP Content, %	Filler Type	TSR, %	RAP Content, %	Filler Type	TSR, %

0	CKD	83.3	50	CKD	84.27
0	O.P.C	86	50	O.P.C	87.2
0	H.L	91.23	50	H.L	93.25

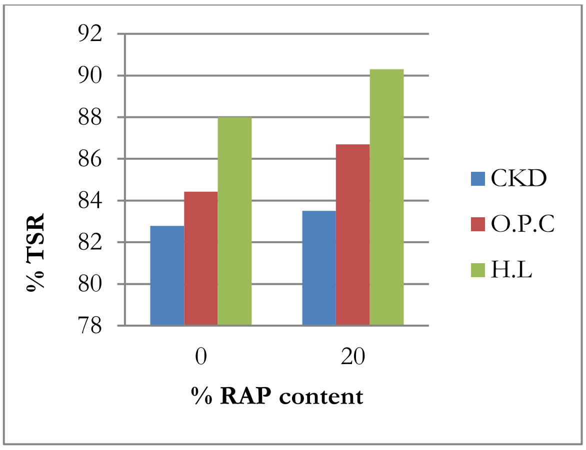


Figure (5): The saturation cycle-conditioned RAP mixtures' TSR results were using two different types of filler for the surface layers.

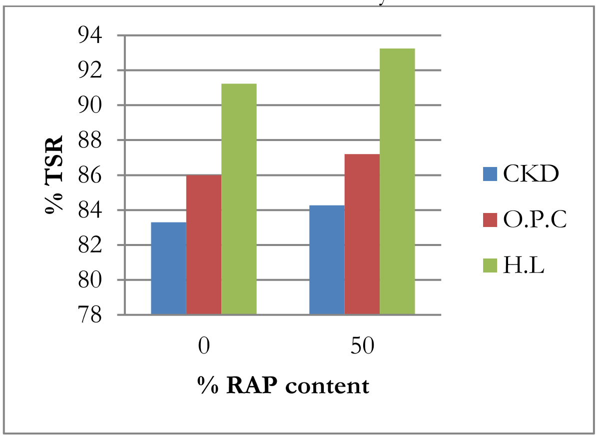


Figure (6):. The cycle-conditioned RAP mixtures' TSR results using two different types of filler for the binder layers.

5. Conclusions

Based on the study's findings and the Marshall mixes used to calculate the RAP %. As a result, the following conclusions about the study's findings and scope were reached:

1- According to the "TRS" results for each of the surface and binder layers, asphalt mixtures containing RAP exhibit a reduced susceptibility to moisture in comparison to asphalt control mixtures containing 0% RAP.

2- The hot mix asphalt with optimized RAP percentage showed better moisture resistance than the control mixture with "0" RAP, with 90.3 and 93.25 % for bonding and surface layers, respectively.

3- Results show that asphalt mixes with hydrated lime filler are more water-resistant than cement mixes. This is because lime blocks peeling and reduces damage caused by asphalt by binding its components into a soapy solution.

4- In comparison to asphalt mixtures devoid of RAP, those that included cement kiln dust as a filler and "RAP" had a moisture damage efficacy (CKD) of 83.5% for the surface layer and 84.27 for the bond, respectively, in terms of TSR value.

5- Cement kiln dust may be utilized as a cement substitute and asphalt filler due to its resistance to moisture damage and convergence in TSR percentages between optimal RAP-containing asphalt mixes and cement-containing asphalt mixtures with RAP.

6- Using waste materials like "reclaimed asphalt pavement" (RAP) and cement kiln dust (CKD) as fillers in hot asphalt mixes may reduce construction costs and protect raw materials, benefiting engineering and the economy.

6. References

[1] G.Valdés, F.Pérez-Jiménez, R. Miró, A. Martínez, R. Botella, Experimental study of recycled asphalt mixtures with high percentages of reclaimed asphalt pavement (RAP). Construction and Building Materials, 2011.

[2] C. Jain., Wang, C. & C. Huang, Engineering properties of bituminous mixtures blended with second reclaimed asphalt pavements (R2AP). Road Materials and Pavement Design, 2009,pp 129 – 149.

[3] N. Taylor, Life expectancy of recycled asphalt paving. Recycling of bituminous pavements (L. E. Wood, Ed.). ASTM ,1997, STP662, 3–15.

[4] J. Sullivan, Pavement recycling executive summary and report, Report FHWA-SA-95-060 from the Federal Highway Administration. Washington, D.C,1996.

[5] O. Reyes, F. Pérez, R. Miro, & R. Botella, Proyecto fénix. Mezclas semicalientes, Proceedings del XV Congreso Ibero latin oamericano del Asfalto. Lisboa, Portugal,2009.

[6] D. Decker. State of the practice for use of RAP in hot mix asphalt: Journal of the Association of Asphalt Paving Technologists, 66, 704,(1997)..

[7] H.Silva, J. Oliviera, , & C. Jesus, Are totally recycled hot mix asphalts a sustainable alternative for road paving?: Journal Resources, Conservation and Recycling, 60, (2012).

[8] O. Reyes & J. Camacho,). Inform Projector ING-730 Estudio del comport mien to de mescals asphaltic as Colombians al adicionarles RAP en differences percentages y Taman. Reporte de la Universidad Military Nueva Granada. Colombia.38 – 48, 2012.

[9] W. Mengqi, W. Haifang, B.Muhunthan, & N. Kalehiwot, Influence of RAP content on the air void distribution, permeability and moduli of the base layer in recycled asphalt pavements. Proceedings of the 91st Transportation Research Board Meeting. TRB 2012.Washington, D.C., USA. 2012.

[10] M. Sondag, B.Chadbourn, & A. Drescher, Investigation of recycled asphalt pavement (RAP) mixtures. Technical report MN/RC – 2002-15. Department of Civil Engineering, University of Minnesota. USA,2002.

[11] P. Pereira ,J. Oliveira, & L. Picado-Santos, Mechanical characterization of hot mix recycled

materials. International Journal of Pavement Engineering, 5 (4), 211 – 220,(2004).

[12]] H. Hasan Joni & Y. Aqeel Alkhafaji, Laboratory comparative assessment of warm and hot mixes Asphalt containing reclaimed Asphalt pavement,(2020).

[13] ASTM International. (2011). Annual book of ASTM standards. West Conshohocken, PA.

[14] R. E. SCRB, (2003). Standard Specifications for Roads and Bridges." Section R/9, Hot-Mix Asphaltic Concrete Pavement.

[15] ASTM D6926 - 10. (2010). Standard practice for preparation of bituminous specimens using Marshall apparatus, *ASTM*.

[16] ASTM D6927 - 15, (2015). Standard Test Method for Marshall Stability and Flow of Asphalt Mixtures 1. **i**:1–7, doi: 10.1520/D6927-15.2.

[17] ASTM D6307 - 10, (1999). Asphalt Content of Hot-Mix Asphalt by Ignition Method 1. **04**: 6–10, doi: 10.1520/D6307-10.2.

[18] Iraqi Standard Specification, , "Lime That Used in Building", No 807,(1988).

[19] National Lime Association, (2003).

[20]H. Yunas. Ahmed ,A.mahmood Othman &A Abdolhalem. Mahmoud, Effect of using waste cement dust as mineral filler on the mechanical properties of hot mix asphalt,(2009).

[21] Iraqi Standard Specification, "Portland Cement", No.5, (1984).

[22]Hassan Y. Ahmed,Ayman Othman&Afaf A. Mahmoud, Effect Of using waste cement dust as a minaral filler on the mechanical properties of hot mix asphalt , (2009).

[23] ASTM D4867M-09 ,Standard Test Method for Effect of Moisture on Asphalt Concrete Paving Mixtures. ASTM, No. of pages: 5. , (2014).

[24] Charoentham, N., & Macharoen, P. (2017). A Study of Moisture Damage in Warm Mix Asphalt Concrete with Reclaimed Asphalt Pavement. Journal of the Eastern Asia Society for Transportation Studies, **12**: 1458-1476.

[25] Al-RousanT., Asi I., Al-Hattamleh O., Al-Qablan H. ,(2008). "Performance of Asphalt Mixes Containing RAP", Jordan Journal of Civil Engineering, Volume 2, No. 3.