Effects of Filler Types and High RAP Content on the Ability of HMA to Withstand Moisture Damage

Sozan S. Rasheed[1,a*], Maha H. Nsaif[1,b] and Ammar A. M. Shubber[1,c]

[1]Civil Engineering Department, University of Technology, Baghdad, Iraq

[a]bce.20.23@grad.uotechnology.edu.iq, [b]40273@ uotechnology.edu.iq and [c]40162@ uotechnology.edu.iq

*Corresponding author

Abstract. Using hot mix asphalt (HMA) and recycled asphalt pavement (RAP) simultaneously has many technological benefits. At all service temperatures, moisture damage is a hazard with these mixes. Thus, moisture's effects on mixtures' effectiveness were studied using experimental techniques, such as the tensile strength ratio (TSR). Four different ratios of RAP for the surface layer (20, 30, 40, and 50%)) were added to the asphalt mixture (HMA) to study as well as find the content Optimal RAP for both layers RAP through Marshall stability and hygroscopic resistance of asphalt mixtures through moisture damage is examined. The ratio (TSR) of the optimal RAP content mixture is compared with the asphalt mixture without RAP for three fillers and for both layers. The findings revealed a slight reduction in tensile strength of the (HMA) that does not contain RAP in contrast to the asphalt control mix containing the reclaimed pavement, where it was found that the percentages were slightly more and still higher than 80%. The results indicate that, in general, "Hot asphalt mixtures" containing RAP can be recommended for areas that experience moisture damage without worrying about environmental and natural resource restrictions.

Keywords: Filler; high RAP content; moisture damage.

1. INTRODUCTION

Asphalt pavement recycling is a technique developed for the" rehabilitation" and "replacement of pavement structures." It suffers from structural damage and permanent and obvious deformation [1]. In this range, one of the most recycled materials in the world was reclaimed asphalt pavement (RAP) [2]. Use of the rehabilitation program for new roads since 1915 [3]. Despite this, real development and an increase in usage of RAP happened during the oil crisis in the seventies, while the cost of asphalt binder in addition to the overall shortage, as it rises close to construction sites [4]. Then, the revision of the Kyoto Protocol by the Parties in 1997, and its completion in 2005, the recycling process became visible moreover received great attention and wider use in the road construction industry [5]. Many historians indicate that different approaches to recycling asphalt pavements are appropriate, including factory hot rolling, hot rolling rehabilitation, and "on-site" cold rolling [6,7]. Despite this, one of the most popular techniques today is rehabilitation, which involves mixing RAP and virgin materials in various ratios and sizes [8].

According to studies from Europe and the United States, over 80% of recycled materials are reportedly used in road construction. However, regulations are still strict and permit the addition of "RAP" in percentages ranging from 5 to 50% when producing hot mix (HMA) and new asphalt [9]. The results of previous studies showed the response of mixtures containing RAP in proportions ranging from (0–40) % and produced with various asphalts, low moisture perishability of HMA mixtures in good proportions; super pave- ASTM D4867) [10]. According to [11], mixing40% RAP into HMA mixtures did not result in any purifying properties of the mixture. On the other hand, characteristics of the mix altered more dramatically when values of more than 40% were added. The load-displacement curve determined for the indirect tensile test was used to quantify apparent decreases in relative energy losses, which were generally reported with possible early distress. Moisture perishability was low (TSR values close to 95%). The relationship between "RAP and TSR" content can be observed for the tensile strength ratio. The TSR ratio of the origin mixture was high, above 80%, and then decreased with the increase of the ratio of RAP in the mixture [12,13]. Addition of "RAP" led to higher air voids in asphalt mixtures, and old binders in RAP made mixtures more sensitive to moisture.

This research aims to evaluate the effect of reclaimed asphalt paving (RAP) with its optimum ratio in surface and layer on the Marshall stability and moisture resistance of hot asphalt mixtures while determining the strength and hardness of the mixtures through the TSR test for mixtures containing RAP and comparing it with the asphalt mixture of origin and three types of fillers. This study included Studying "Material Characterization," including aggregates, asphalt, and fillers by applying the Marshall Mix design method, the percentage of asphalt to be added to the new HMA mixes, and the optimal RAP ratio was determined.

2. PROBLEM STATEMENT AND MATERIALS

Due to poor environmental conditions and considerable traffic, Iraq's roadway pavements are currently suffering from various problems. The primary issues in extending the life cycle of flexible pavements are road pavement distresses. It is vital to improve the performance of flexible pavements in order to reduce these problems. Mixing several types of filers to increase mechanical performance and long-term behavior has produced a novel series of asphalt mixes. Recycling asphalt pavement materials creates a fresh asphalt pavement mixture and saves virgin resources, money, and energy while reducing trash. Because of the current scarcity of natural resources, several nations have begun to use RAP in asphalt mixes.

2.1 Asphalt Binder

The processing facility of AL-Doraha base asphalt supplied virgin asphalt chosen for this interaction, which had a penetration grade of (40/50). As per the (ASTM Standard Assignment), Table 1 shows the real characteristics of asphalt concrete.

Table 1: Limitations of standards and the physical properties of asphalt binder.

Tests	Standard	Unit SCRB	Value	Limitations as per to SCRB / R9, 2003
Penetration,25 °C	ASTM D 5	1/10 mm	46	**40-50**
Ductility, 25 °C	ASTM. D.113	cm	125	**>100**
Softening Point	ASTM. D.36	˚C	53	……
Specific gravity, 25°C	ASTM. D.70	-	1.040	……
Flash and fire points	ASTM D.92	˚C	29, 57°C	**> 232°C**
Rotational Viscosity	ASTM D.4402	……	552@135℃	……

2.2 Aggregates

The Al Nubaie quarry, which is frequently utilized in the creation of asphalt mixture, provided the aggregate for this project. Tables 2 and 3 exhibit characteristics of the coarse and fine aggregates. Based on the Marshall method for designing asphalt mixtures, the optimal asphalt content was calculated according to ASTM D 6926-10 and ASTM D6927-15 [19].

Table 2: Characteristics of coarse aggregate.

Property	ASTM criteria	Value	Specification
Apparent Specific Gravity	ASTM C127	2.633	------ ------
Bulk Specific gravity		2.574	
% Absorption		0.40	
Soundness	ASTMC88	4.1	**Max. 12%**
Angularity	ASTM D5821	97%	**Min. 95%**
Flat	ASTM D4791	1.12%	**Max. (10%)**
Elongation		2.9%	
Toughness	ASTM C535	21.1%	**Max. (30%)**

Table 3: Characteristics of fine aggregate.

Property	ASTM Criteria	Value	Specification
Specific gravity (Apparent)	ASTM C128	2.69	------ ------
Bulk Specific gravity		2.604	
Absorption, %		0.480	
Equivalent sand (clay content)	ASTM D2419	72%	**Min. (45%)**

2.3 Reclaimed Asphalt Pavement

RAP used in all mixes in this research was from Baghdad Governorate in the Republic of Iraq and tested to calculate the asphalt content in the asphalt mixture by ASTM D6307-10 [20] "Asphalt content by ignition. Furnace" It demonstrates that the average amount of asphalt in RAP was 4.6%. The aggregate gradient in RAP is distributed, as shown in Figure 1.

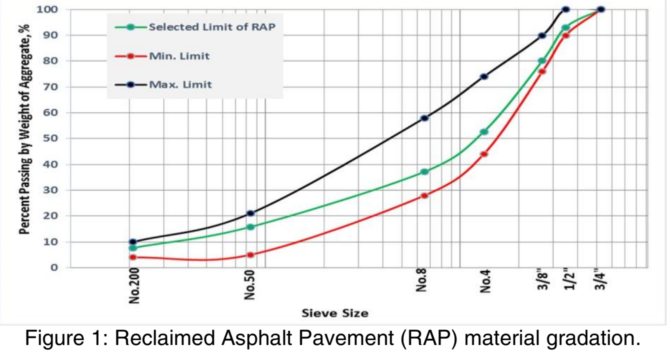

Figure 1: Reclaimed Asphalt Pavement (RAP) material gradation.

Four percentages of RAP (20, 30, 40, and 50%) were used as percentages of the overall mixture to study the behavior of high and low RAP percentages with compensation for the decline in asphalt content. Before being used to create asphalt mixtures, RAP sieve analysis was carried out and divided on a No. 4 sieve, as indicated in Figure 2.

Figure 2: Fractionated samples (coarse and fine) of the Reclaimed Asphalt Pavement (RAP).

2.4 Hydrated Lime

Hydrated lime for this study was obtained from Karbala City and manufactured According to the Iraqi specification [21]. The Chemical and physical properties of hydrated lime are presented in Table 4. Utilizing "hydrated lime "Has a positive impact when added to the asphalt mixture as an anti-erosion agent. Resistance to moisture damage performs well under saturating situations in addition to the thawing and freezing states. When lime is added to the hot mixture, it strengthens the bond between the aggregate and the asphalt binder because it interacts with the aggregate, and at the same time, the lime interacts with asphalt in the mixture to form a water-soluble soap that prevents scaling. The lime reacts with these particles, forming insoluble salts and water attraction (National Lime Association, 2003). Also, small hydrated lime particles are scattered throughout the mixture, making it more solid and enhancing the possibility of mechanically breaking cement and asphalt aggregates, even if moisture is not present.

Table 4: Chemical and physical properties of hydrated lime.

Test		Value
Chemical composition, %	CaO	87.444
	MgO	2.16
	CO_2	2.48
Chemical factor		85.12
Blaine fineness, m^2/kg		1202
Pozzolanic Receptivity Index, %		102.04

2.5 Portland Cement (PC)

Ordinary Portland cement was obtained and used as filler in asphalt mixtures from "Karbala Governorate", According to Iraqi standards and depending on specifications [22]. Table 5 shows the physical properties of Portland cement.

Table 5: Physical properties of Portland cement.

Property	Value
Specific Gravity	3.1
Passing Sieve No.200 (0.075 mm)	97%

2.6 Cement kiln Dust (CKD)

Waste cement dust was obtained and used as a filler for asphalt mixtures from "Karbala Governorate". Table 6 shows the chemical properties of the mechanical properties of cement dust depending on Iraqi standards [22]. The information indicates that CKD has a higher purity and, in this way, a higher surface area than traditional Portland concrete. Higher surface area is mainly associated with a high level of cementation ability. Then again, the primary setup time for CKD is 40 minutes longer than customary Portland concrete. Portland, The specific gravity of concrete is higher than that of CKD. The addition of cement dust affects the results of the Marshall test and the mechanical properties of the asphalt mixture in terms of an increase in stability, unit weight, voids ratio, decrease in flow and voids in the mineral aggregates, and also increased unconfined compressive strength, indirect tensile strength and resistance to moisture damage due to the fineness of the dust that fills the voids and increases its hardness Asphalt mixtures, and the bonds between asphalt and aggregates increase, as it was found through experiments that cement dust gives results close results to results that contain lime. Thus, cement dust can replace mineral fillers with limestone in asphalt paving mixtures [15].

Table 6: Chemical properties of the mechanical properties of cement dust.

Chemical components	Value, %
SiO2	14.82
Al_2O_3	5.52
Fe_2O_3	1.98
CaO	49.65
MgO	3.35
SO_3	6.33

2.7 Moisture Susceptibility

In order to identify moisture damage to samples for these combinations, the indirect tensile strength test (ASTM D4867M-09, 2014) [23] was performed on HMA hot mix asphalt in the presence of RAP and for the surface layer. The forms were produced for this test and compacted using a Marshall hammer at a 7%+ 1% air void content density. These are the aggregates with the best RAP ratios across all layers. Samples underwent hydration to achieve a 55–80% saturation level. The samples were then submerged in the water basin at 60°C plus or minus 1°C for 24 hours, followed by an hour in the water basin at 25°C plus or minus 1°C. For 20 minutes, dry samples were kept in an aquarium at 25°C. The finite forces required to fracture all samples (dry and wet) were then calculated using an indirect tensile test (IDT) at 25°C. The ratio of conditioned to unconditioned IDT served as the basis for calculating the tensile strength ratio (TSR). The required minimum TSR value is 80%.

3. TEST RESULTS AND DISCUSSION

According to the mechanical properties results, it was found that the optimal ratio of RAP in the mixture was 30% which gives good results. For these ratios, the results showed that the tension is better; this, in turn, leads to a decrease in tensile strength during exposure to harsh conditions of "high temperature" and "humidity" [16]. Also, using hydrated lime as a filler apparently affects the TSR for all conditioning periods. The results of the moisture damage test show that the useof hydrated lime (H.L) in hot Recycle leads to a higher tensile strength ratio (TSR) than when using cement (O.P.C) and that cement kiln dust (CKD) in the mixture as seen in Table 7 and Figure 3.

Table 7: Tensile strength ratio (TSR).

RAP Content, %	FillerType	TSR, %	RAP Content, %	FillerType	TSR, %
0	CKD	82.78	30	CKD	83.5
0	O.P.C	84.43	30	O.P.C	86.7
0	**H.L**	**88**	**30**	**H. L**	90.3

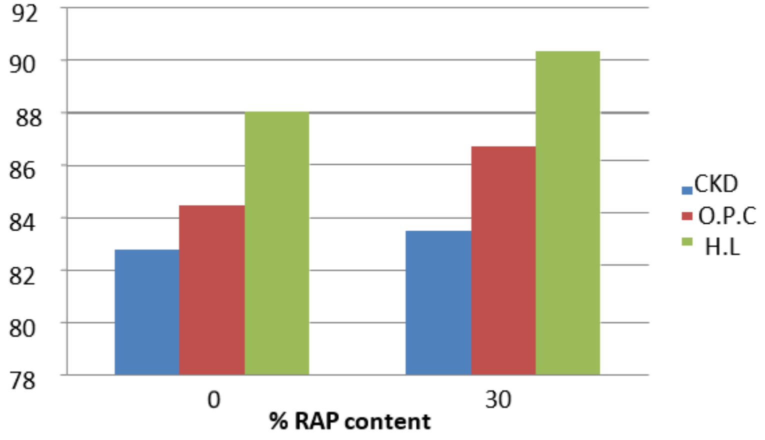

Figure 3: TSR results for RAP mixtures conditioned with saturation plus freeze-thaw cycle using different types of filler.

4. CONCLUSIONS

The following inferences were drawn from the results of this study and according to the Marshall mixtures included for the RAP percentage accordingly. Findings and scope of this study:

- The results of "TRS" showed that using the RAP additive for the asphalt mixture gives a lower sensitivity to moisture than the asphalt control mixtures that contain zero percent RAP.

- Moisture damage resistance in hot mix asphalt containing optimized RAP was improved compared to the control mixture, where the resistance reached (90.3) %.
- Depending on the results of asphalt mixtures that contain hydrated lime as a filler, their high resistance to moisture damage reached more than compared with other mixtures that have cement due to the effectiveness of lime. In addition, it links the components of the asphalt mixture to a soapy substance that prevents peeling and reduces the damage caused.
- The results confirmed the effectiveness (CKD) by examining asphalt mixtures containing cement kiln dust as a filler and containing "RAP" against moisture damage, where the TSR value reached (83.5) % and the bond, compared to asphalt mixtures without RAP.
- The convergence in percentages of the tensile strength ratio (TSR) of optimal RAP-containing asphalt mixtures containing CKD compared to cement-containing asphalt mixtures with RAP indicates that cement kiln dust can be used as a filler in asphalt and as a substitute for cement for its resistance to moisture damage.
- Depending on the results of using waste materials such as (CKD) cement kiln dust as a filler and "reclaimed asphalt pavement" RAP, in hot asphalt mixtures leads to economic and engineering benefits, in addition to reducing the cost of pavement construction and preserving raw materials.

REFERENCES

[1] Valdés, G., Pérez-Jiménez, F., Miró, R., Martínez, A., and Botella, R. Experimental study of recycled asphalt mixtures with high percentages of reclaimed asphalt pavement (RAP). Construction and Building Materials. 2011; 25(3): 1289 – 1297

[2] Chen, J., Wang, C. and Huang, C. Engineering properties of bituminous mixtures blended with second reclaimed asphalt pavements (R2AP). Road Materials and Pavement Design. 2009; 10(1): 129 – 149.

[3] Karkush MO, Yassin S. Improvement of geotechnical properties of cohesive soil using crushed concrete. Civil Engineering Journal. 2019 Oct 7;5(10):2110-9.

[4] Karkush MO, Yassin SA. Using sustainable material in improvement the geotechnical properties of soft clayey soil. Journal of Engineering Science and Technology. 2020 Aug;15(4):2208-22.

[5] Karkush MO, Abdulkareem MS. Deep remediation and improvement of soil contaminated with residues oil using lime piles. International Journal of Environmental Science and Technology. 2019 Nov;16:7197-206.

[6] TAYLOR, N. Life expectancy of recycled asphalt pavingin: LE Wood. Recycling of Bituminous Pavements, ASTM STP. 1997.

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

[8] REYES, O., et al. Proyecto fénix. Mezclas semicalientes. In: Proceedings del XV Congreso Iberolatinoamericano del Asfalto. Lisboa, Portugal. 2009.

[9] Decker, D. State of the practice for use of RAP in hot mix asphalt. Journal of the Association ofAsphalt Paving Technologists. 1997; 66(1): 704.

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

[11] Reyes, O., and Camacho, J. Informe Proyecto ING-730 Estudio del comportamiento de mezclas asfálticas colombianas al adicionarles RAP en diferentes porcentajes y tamaño. Reporte de la Universidad Militar Nueva Granada. Colombia. 2012.

[12] Mengqi, W., Haifang, W., Muhunthan, B., and Kalehiwot N. 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.

[13] SONDAG, Michael S.; CHADBOURN, Bruce A.; DRESCHER, Andrew. Investigation of recycled asphalt pavement (RAP) mixtures. 2002.

[14] Pereira, P., Oliveira, J, and Picado-Santos, L. Mechanical characterization of hot mix recycled materials. International Journal of Pavement Engineering. 2004; 5 (4): 211-220.

[15] Hasan H. Joni and Aqeel Y. M. Alkhafaji. Laboratory Comparative Assessment of Warm and Hot Mixes Asphalt Containing Reclaimed Asphalt Pavement. Wasit Journal of Engineering Sciences. 2020; 8(2): 14-24.

[16] Sozan S. Rasheed, Hasan H. Joni, and Rasha H. Al-Rubaee. Using nano silica to enhance the performance of recycled asphalt mixtures. Periodicals of engineering and natural sciences. 2022; 10(4): 32-39.

[17] ASTM D6927 – 15. Standard Test Method for Marshall Stability and Flow of Asphalt Mixtures1. 2015. doi: 10.1520/D6927-15.2.

[18] ASTM D6307 – 10. Asphalt Content of Hot-Mix Asphalt by Ignition Method 1. 1999. doi:10.1520/D6307-10.2.

[19] SPECIFICATION, Iraqi Standard. Lime that used in building. 1988.

[20] Iraqi Standard Specification. Portland cement. No.5. 1984.

[21] Hassan Y. Ahmed, Ayman Othman, and Afaf A. Mahmoud. Effect of using waste cement dust as mineral filler on the mechanical properties of hot mix asphalt. Journal of Assiut University bulletin for Environmental Research. 2006; 9(1): 51-60.
[22] ASTM D4867M-09. Standard Test Method for Effect of Moisture on Asphalt Concrete PavingMixtures. 2014.
[23] Al-RousanT., Asi I., Al-Hattamleh O., Al-Qablan H. Performance of Asphalt Mixes Containing RAP. Jordan Journal of Civil Engineering. 2008; 2(3).