Polytechnic Journal
Polytechnic Journal

Volume 13 | Issue 1 Article 7

Performance evaluation of reclaimed asphalt pavement rejuvenated with Waste Engine Oil and Vacuum Residue in the presence of water

Heja Gh. M. Hasan
Dept. Highway and bridges, Duhok Polytechnic University, Duhok, Kurdistan regional government-Iraq, heja.ghazi@dpu.edu.krd

Ayman A. Abdulmawjoud
Department of Civil Engineering, College of Engineering, University of Mosul, Mosul, Iraq

How to Cite This Article

M. Hasan, Heja Gh. and Abdulmawjoud, Ayman A. (2023) "Performance evaluation of reclaimed asphalt pavement rejuvenated with Waste Engine Oil and Vacuum Residue in the presence of water," *Polytechnic Journal*: Vol. 13: Iss. 1, Article 7.
DOI: https://doi.org/10.59341/2707-7799.1731

Polytechnic Journal. 2023. 13(1)
ISSN: 2313-5727
http://journals.epu.edu.iq/index.php/polytechnic

RESEARCH ARTICLE

Performance evaluation of reclaimed asphalt pavement rejuvenated with Waste Engine Oil and Vacuum Residue in the presence of water

Heja Ghazi Mohamed Hasan[1*], Ayman A. Abdulmawjoud[2]

[1] *Department of Highway and Bridge, Technical College of Engineering, Duhok Polytechnic University, Duhok, Kurdistan Region, Iraq*

[2] *Department of Civil Engineering, College of Engineering, University of Mosul, Mosul, Iraq*

***Corresponding author:** Heja Ghazi Mohamed Hasan, Department of Highway and Bridge, Technical College of Engineering, Duhok Polytechnic University, Duhok, Kurdistan Region, Iraq.

E-mail: heja.ghazi@dpu.edu.krd.

Received: 17 November 2022
Accepted: 18 January 2023
Published: 20 September 2023

DOI: https://doi.org/10.59341/2707-7799.1731

ABSTRACT

The service life of a road pavement reduces as it ages and loses quality due to exposure to various traffic loads and environmental conditions. This study investigates the possibility of reusing aged asphalt in pavement by mixing Waste Engine Oil (WEO) and Vacuum Residue (VR) to create a hybrid rejuvenator. Four types of binders, namely, virgin asphalt, aged asphalt, blended aged and virgin asphalt, and rejuvenated hybrid (WEO-VR) with aged and virgin asphalt, were evaluated using rheological and water immersion tests. The results show that WEO-VR greatly enhanced the properties of old asphalt in the presence of water based on rheological parameters. The behaviour of the rejuvenated asphalt mixture was close to that of the virgin asphalt mixture in the stripping resistance tests. Thus, 6.5 % of the total mix's WEO-VR may be used to regenerate old asphalt, paving the way for more environmentally friendly and sustainably manufactured asphalt.

Key Words: Aged asphalt, Reclaimed Asphalt Pavement (RAP), Rejuvenating agent, Vacuum Residue (VR), Waste Engine Oil (WEO).

1- INTRODUCTION

Due to environmental concerns and price differences in asphalt binders, Reclaimed Asphalt Pavement (RAP) material in asphalt mixtures has gained favor. However, the RAP binder is typically outdated and has a number of drawbacks, including poor workability, low fatigue in the resulting mixtures, and low breaking resistance. These issues may be resolved with regenerators. One of the recyclable materials that have the potential to increase the affordability and sustainability of road paving production is reclaimed asphalt pavement.

In research done by Ali et al. (2016), at low and high temperatures, the ability of 5 asphalt binder rejuvenators to regain the real performance grades of aged binders was evaluated. The included revitalizers were naphthenic oil, paraffinic oil, aromatic extracts, tall oil, and oleic acid. According to the statistics results, the performance of all rejuvenated binders was inferior to that of the unrejuvenated control binders. In addition, aging the rejuvenator for 2 to 6 hours or increasing its RAP content by up to 45 percent had no influence on its performance. In addition, the rejuvenators enhanced fatigue resistance without affecting rutting performance.

Renewing substances might be utilized to soften old asphalt. Since waste engine oil (WEO) has the same molecular structure as asphalt, it may serve as an asphalt rejuvenator. The quality of engine oil degrades over time due to constant use. Numerous studies have been undertaken to determine the viability of using WEO to restore the features of deteriorated asphalt. However, a number of studies suggest that WEO may diminish the asphalt binder's resistance to rutting. Additionally, the quality of aged asphalt is improved by combining WEO with vacuum residue VR, the most structurally varied component of petroleum. (Alvarez-Majmutov et al., 2019).

Xu and Zhang (2020) examined the dynamic diffusion behavior of rejuvenators into aged asphalt for manufacture and recycling in an effort to enhance the properties of aged asphalt. In the experiment, three rejuvenators with different chemical compositions and three markers with conventional and distinctive molecular structures were used. The primary results show that the aromatic component increased the diffusion of the rejuvenator into aged asphalt. Molecules having a smaller size and stronger polarity diffused more readily. The long-chain saturated hydrocarbon structure of dodecanoic acid has the lowest diffusion coefficient, suggesting that it is incapable of diffusing. Important functional groups will serve as a barrier to diffusion at the microscopic level.

Yang et al. (2020) examined the properties of maltene (MLT) (made of saturates, aromatics, and resins). According to the results of studies measuring viscosity and flow activation energy, saturates and aromatics are now more fluid than virgin asphalt binders. However, at high temperatures, the flow qualities of resins are comparable to or superior to those of fresh asphalt.

In another study, Hussein et al. (2020) used MLT on the aged asphalt at three different concentrations: five percent, ten percent, and fifteen percent by weight of the total binder. They investigated the penetration, softening point, penetration index (PI), viscosity, and storage stability of regenerated bitumen. As the maltene content increased, the properties of ancient bitumen improved but stiffness decreased. The temperature and duration of mixing had a considerable influence on how well the aged- virgin binders were mixed. Blending efficiency was reduced owing to the difficulties of diffusing fresh asphalt into an old binder at lower mixing temperatures. The findings suggest that 15% maltene may restore the qualities of worn-out asphalt.

Hong et al. (2020) investigated the binder properties of long- term aged base asphalt and SBS-modified asphalt binders that were rejuvenated and modified using aromatic oil and an SBS polymer-containing chemical rejuvenator. The plateau area of phase angle master curves clearly indicates the compound rejuvenator's impact on polymer modification. The asphalt binder was greatly emollient zed by aromatic oil. It enhanced low-temperature performance but lowered high-temperature performance as a result of this. The use of SBS polymer contributed to the overall efficacy of the revived asphalt binders. Combining rejuvenation and modification, the compound rejuvenator might be very effective for the hot recycling of recovered asphalt mixture.

To save maintenance costs, road authorities in Canada employ up to 100% recycled asphalt pavements (RAP) in new construction. The original properties of the old asphalt binder may be recovered and restored by rejuvenators. Utilizing waste cooking oil (WCO) as a trustworthy rejuvenator is acceptable since WCO has a high potential in the hot mix asphalt (HMA) industry (Hossein and Ahmed, 2020).

Pradhan and Sahoo (2021) conducted research that included Polanga oil as a rejuvenator as well as softer binders separately for comparative grounds owing to the urgent need to increase RAP use to investigate the performance of recycled HMA. There were 11 different combinations. The effect of softening binders and rejuvenators on recycled asphalt mixes was studied. The Thermogravimetric Analysis (TGA) of the rejuvenator's thermal stability revealed that the rejuvenated binder is stable up to 230 °C, which is higher than the asphalt mixing temperature. The research also revealed that with the addition of a rejuvenator or a softer binder, up to 60% of RAP may be efficiently integrated into the HMA without reducing performance appreciably.

Reclaimed asphalt pavement (RAP) is becoming more and more well-liked and accepted for use in road construction. Maltene was utilized as a rejuvenator by Hazim et al. (2021) to evaluate a variety of indicators associated with stripping failure. Acid and water resistance of asphalt and asphalt-water aggregate systems were evaluated using chemical and water immersion tests. The sessile drop method was used to perform wettability and work of adhesion studies. Maltene should be add in percentage of 8 and 16, respectively, on aged asphalt 30 and 50 percent, according to the test results. Maltene was utilized to enhance samples that had a significant proportion of old asphalt. However, the inclusion of maltene somewhat reduced the resistance to boiling acidic water. However, all of the rejuvenated samples showed superior performance compared to virgin asphalt.

According to Zaid et al. (2020), adding a hybrid rejuvenator, such as Waste Engine Oil-Maltene (WEO-MLT), may recover the qualities of aged asphalt, allowing it to be used in pavement. Chemical immersion and water immersion experiments were used to assess the rheological, chemical, and stripping resistance of various binders. The WEO-MLT significantly enhanced the qualities of old asphalt at fluctuating temperatures, according to the study results.

Al-saffar et al. (2022) conducted a research on the engineering properties of recycled hot-mix asphalt (HMA) combinations that were regenerated utilizing asphalt manufactured from maltene. Stripping and coating tests, Marshall properties, moisture damage, resilient modulus (MR), dynamic creep, Cantabro loss, and rutting resistance were all evaluated. As a consequence of the rejuvenated mixture outperforming the virgin and RAP combinations without maltene, the findings demonstrated that maltene was beneficial in lessening the aging impact of RAP asphalt.

Prior studies have underlined the need of utilizing recycled materials and improving them using regenerator additives. However, to the authors' knowledge, no previous studies investigated Waste Engine Oil (WEO) with Vacuum Residue (VR) as a rejuvenator of Reclaimed Asphalt Pavement (RAP). Thus, this study will examine the effectiveness of using (WEO) with (VR) as a regeneration agent to understand better its effects on the water resistance of asphalt material.

2-METHODS AND MATERIALS

2-1 Asphalt cement

The virgin asphalt binder used was originated from Lanaz refineries in Erbil, Iraq with penetration grade of 40-50. Using the milling technique, old asphalt was taken from the RAP between Zakho-Deraboon road in the Duhok District, Kurdistan Region, Iraq. RAP included 3.4% asphalt by weight. Using Methylene Chloride (CH2CL2) solvent, the asphalt binder was extracted from RAP according to ASTM D2172. In compliance with ASTM D5404, methylene chloride was separated using a rotary evaporator. Table 1 lists the features of Virgin Asphalt (VA) and Aged Asphalt. (AA).

Table 1: Properties of virgin and aged asphalt

Properties	*Virgin asphalt (VA)*	*Aged Asphalt (AA)*	*ASTM Designation No.*
Penetration (dmm)	43	14.5	D-5-13
Ductility (cm)	160	9	D-113-17
Softening point (°C)	52	67.4	D-36-14
Flash point (°C)	271	---	D-92-16
Specific gravity	1.03	---	D-70-97
Viscosity @ 135 °C (CP)	571	2130	D-4402
Viscosity @ 160 °C (CP)	145	1164	D-4402
Performance grade (PG)	70-16	86-13	

2-2 Aggregate from the RAP and new aggregate material

Fig. 1 depicts the RAP aggregate gradient and the recommended gradation limits in accordance with ASTM D3515 for dense mixes with a nominal maximum size of 19.0 mm (ASTM, 2002). In this research, the chosen gradation was in the mid of the limits, therefore RAP material was mixed with a fresh aggregate from Khaboor river, Duhok district, Kurdistan region-Iraq, such that all specimens evaluated had the same gradation. Clearly, the RAP aggregate gradation is finer than the median aggregate gradation. Given the milling process, the breakdown of the aggregate during mixing and compaction, and the movement of vehicles on the pavement over time, is anticipated. Calcium Carbonate CaCO3 with a specific gravity of 2.81 which was supplied by Kashe Factory in Duhok was used as a filler.

2-3 Rejuvenator WEO & VR

Waste Engine Oil (WEO), obtained from a local auto repair shop in the Duhok city of Iraq's Kurdistan province, was the rejuvenator used in this research. Vacuum Residue (VR), a material that is produced during vacuum distillation, was the second rejuvenator. Vacuum residue is created during the distillation of crude oil at decreased pressure. The VR, with a penetration of 182 dmm, was acquired from the (KAT) factory producing asphalt in Kirkuk, Iraq.

Based on the Rotational Viscometer test results, the WEO to VR ratio was determined. Preparing many specimens with different WEO and VR ratios. The VR was heated to between 145 and 160 °C, melted, and then combined for 20 minutes with WEO in the following ratios: 75:25, 50:50, and 25:75., following same ratios suggested in (You et al., 2018). Fig. 2 displays the viscosity data. The viscosity-temperature for WEO-VR was 60 °C and 100 °C, whereas it was 135 °C and 160 °C for virgin asphalt (VA). The figure illustrates how the flexibility of the rejuvenated asphalt rose when the amount of WEO: VR was 25:75% of the overall rejuvenator content, bringing it closer to virgin asphalt. It enhances renewed asphalt's performance at high temperatures. This conclusion was consistent with the findings of a previous study (Yaacob et al., 2020), which indicated that an asphalt rejuvenator should be used to improve the low-temperature properties of old asphalt and modifying the asphalt's rheological qualities may make it easier to soften and rut.

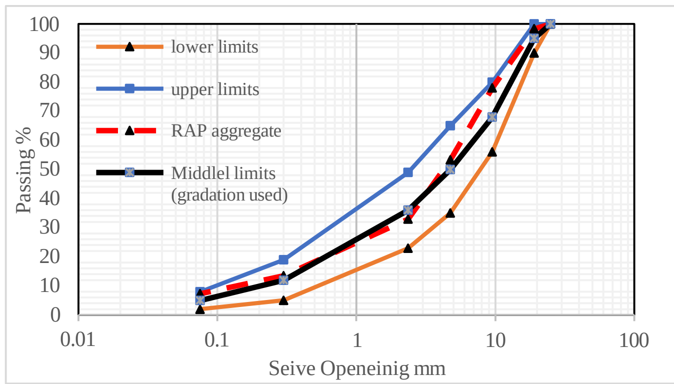

Figure 1: Selected aggregate gradation, RAP gradation and specification limit

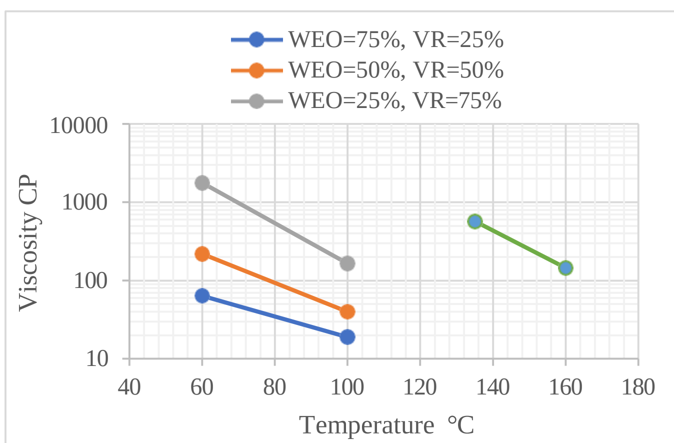

Figure 2: Viscosity result of virgin and three ratios of WEO:VR

3- SAMPLE PREPARATION AND MIX DESIGN

3-1 Asphalt cement

According to the guidance of several researchers, the asphalt cement mixes were prepared by combining 30% Aged Asphalt (AA) and 70% Virgin Asphalt (VA) (Abdulmawjoud, 2020; Mamun & Al-Abdul Wahhab, 2018; and Mazzoni et al., 2018). As stated in Table 2, a revitalized WEO with VR at a ratio of 25%:75% was applied at five percentages the asphalt cement mixes. Aged asphalt, virgin asphalt, and hybrid rejuvenators, well mixing of mixtures are highly dependent on the duration, temperature, and mixing speed conditions (You et al., 2018). Given that the properties of rejuvenated asphalt are equal to those of virgin asphalt, the concentration of WEO-VR was determined to be 6.5% by weight of the whole asphalt, as shown in Fig. 3. It was tested for penetration, softening point, ductility, and viscosity, as indicated in Table 2. Fig. 4 shows that the whole mix contains 93.5% virgin and aged asphalt and - 6.5 % rejuvenated asphalt (WEO: VR).

Table 2: Mixing ratio of virgin and aged asphalt with WEO-VR

WEO 25% +VR 75%	*Aged (30%) + New (70%)*	*Penetration*	*Ductility*	*Softening point*	*Rotational viscosity @ 135 °C*	*Rotational viscosity @ 160 °C*
%	**%**	**1/10 mm**	**cm**	**°C**	**CP**	**CP**
0	100	35.4	59	56.7	955	283
5	95	39.9	105	54.3	787.5	236.4
7.5	92.5	44.4	131	53.8	704.2	217
10	90	50.8	128	52.5	610.3	197.7
12.5	87.5	57.5	117	51	558.8	180.7

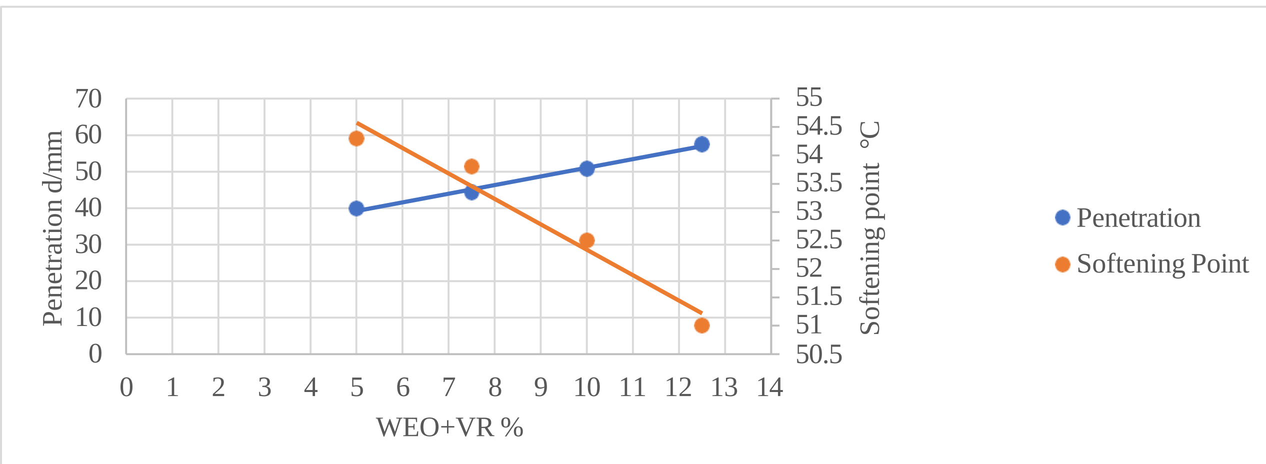

Figure 3: Selecting best ratio of rejuvenated agent

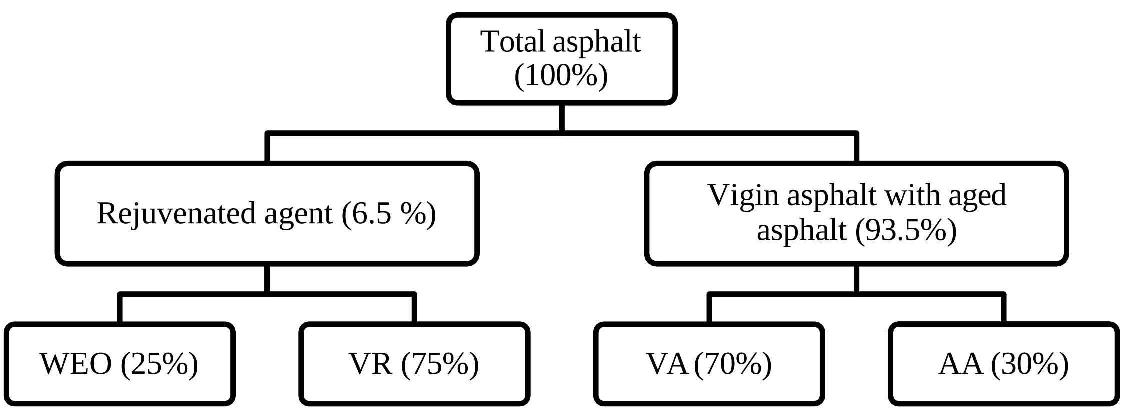

Figure 4: Percentage of each asphalt content in the total mix with rejuvenated agent percentage

3-2 Asphalt concrete mixes

The optimal asphalt content value (OAC) was determined using a Marshall method of mix design. The asphalt compositions of the samples ranged from 4.0 to 6.0 percent at 0.5 percent intervals, and they were compacted using a Marshal compactor, 75 blows to each side of the sample. The first type incorporates OAC for the new aggregate and virgin asphalt (NA100) mixture, which is 4.6 percent. In contrast to the second kind, which used just reclaimed asphalt pavement (RAP100) with a 3.4 percent asphalt composition. The third mixture contains 30% RAP and 70% fresh aggregate (NA70-RAP30). The fourth combination contains 6.5% WEO-VR and comprises 70% fresh aggregate and 30% RAP which is referred as (NA70-RAP30)+(WEO-VR). Table 3 displays the four different aggregate mixes with material percentage information. The OAC was used to detect Marshal stability and volumetric qualities.

The Road Research Laboratory (1985) performed a chemical immersion test to examine how well asphalt adhered to aggregate in the presence of sodium carbonate (Na2CO3) and boiling water. The point at which asphalt degradation is so widespread that specks or droplets replace asphalt films is known as the stripping value. Here, 50 ml of boiling distilled water with Na2CO3 concentrations is used to submerge a 10-g sample of asphalt-covered material for 60 seconds. After extracting the substance, it was spread out on filter paper to dry. As the concentrations of sodium carbonate were steadily raised until stripping happened, the operation began with a low concentration (0.41 g of Na2CO3 /L, identified as Number 1). The maximum sodium carbonate was found in sample No. 9, at a value of 106 g/L. The Riedel and Weber (R&W) number corresponding to the lowest concentration at which stripping occurred was specified as the aggregate's stripping value. For each of the four categories, Fig. 6 depicts a sample test technique.

Table 3: The varieties of asphalt mixtures that were employed in this research

Mix Symbols	*Aggregate %*		*Asphalt %*		*Rejuvenated agent%*
	New	RAP	New	Aged	
NA100	100	0	100	0	0
RAP 100	0	100	0	100	0
NA70-RAP30	70	30	70	30	0
(NA70-RAP30)+(WEO-VR)	70	30	65.5	28	6.5

4- LABORATORY IMMERSION TESTS

According to the proportions of asphalt and aggregate materials specified in Table 3, samples of loose asphalt mixes were prepared, then they were ready for immersion testing. The various asphalt mixes utilized in these studies are shown in Fig. 5.

Figure 5: Loose mix of the four types of mixes

Figure 6: Chemical immersion tesre

4-1 Water immersion

4-1-1 Static immersion

A variety of loose asphalt-coated aggregates were tested for moisture sensitivity using water immersion methods (AASHTO T182). In a 500 ml glass container, a 100 g sample of asphalt-coated aggregate was submerged in distilled water for 16–18 hours at 25 °C. The glass container made it feasible to observe the sample and determine the proportion of the visible aggregate that still had its covering, which may be more or less than 95%. As illustrated in Fig. 7, if the combination does not match the test criteria (>95%), it is regarded as a failure and should be avoided since it might be stripped (Fauzan et al., 2016).

Figure 7: Static immersion test

4-1-2 Total water immersion

This test has improved the static immersion test (Taylor et al., 2015). To get better results, it utilized water that was 40 °C warmer. The test assisted in determining the typical amount of asphalt coating after 3 hours of immersion in water at 40 °C. Fig. 8 displays all of the test samples for total immersion in water.

4-1-3 Boiling water

Assessing the loss of adhesion in loose asphalt mixes, the boiling water test employs a visual measurement of the percentage of aggregates stripped following immersion in boiling water. This test begins with the production of loose aggregate with an asphalt coating, followed by testing in accordance with (ASTM D3625). As seen in Fig. 9-a, 250 g of the prepared sample is added to a glass beaker containing distilled water and boiled for 10 min ± 15sec. The glass beaker is withdrawn from the heat source after 10 minutes, and any free bitumen on the water's surface is scraped off to prevent the aggregate from recoating. The wet mix is poured onto a white cloth when the sample has cooled to room temperature, as shown in Fig. 9-b. Three duplicates were created by repeating the procedure for an additional two samples. Visual inspection is used to determine if less than or more than 95% of the original asphalt coating is still on the aggregates. For evaluation, a comparable quantity of the freshly coated asphalt sample is put into a different glass beaker, covered with distilled water that hasn't been heated for 10 minutes. After the water has been decanted, the mixture is poured onto a white cloth.

Figure 8: Total water immersion test

(a) (b)

Figure 9: Boiling water test, (a) samples on the heater, (b) samples after test

5- RESULTS, ANALYSIS, AND DISCUSSION

5-1 Chemical immersion

A chemical immersion test was conducted to examine how asphalt binders bonded to aggregates and how acid rain affected the binding process. As the asphalt films break down, water may have an easier time penetrating the aggregates, especially in areas where there is insufficient covering. Acid rains, which are intimately associated with urbanization and industrialization and may have a negative effect on the asphalt aggregate interface, are another potential problem. Table 4 displays the results of a chemical immersion test for each of the four kinds of mixes, represented as Riedel and Weber (R&W) values. It was noticed that asphalt that has been regenerated and contains (WEO-VR) is more resistant to the impacts of acid and boiling water than virgin asphalt (NA100). According to Table 4, neither the (NA70-RAP30) mix nor the (RAP100) mix is stripped.

In contrast, the starting points for stripping for the NA100 and rejuvenated mixture were 3 and 6 R&W number, respectively. Thus, compared with NA100 and RAP100 mix it could be concluded that virgin asphalts (VA) and rejuvenated asphalt with (WEO-VR) were more vulnerable to the acid impact. As shown in Fig. 6, the asphalt coating separated from the aggregate surface after the test.

There are several approaches to explain these unexpected outcomes. When inorganic groups are present in both virgin asphalt and rejuvenated asphalt, hydration interactions are strengthened because these groups also interact with Na_2CO_3. As a result of interactions between inorganic groups and double bonds (C=C) that happened during the lifespan of the pavement, hydration and salt compounds did not affect RAP100 and NA70-RAP30. The bulk of the functional groups often reacts under the influence of oxygen, heat, humidity, UV radiation, tire pressure, and longevity, which causes the asphalt binder to be damaged.

Table 4: Chemical immersion test results

Molar concentration	*Na2CO3 (gm/liter)*	*R&W Number*	*R&W Number for:*			
			NA100	RAP100	NA70-RAP30	(NA70-RAP30)+(WEO-VR)
1/1	106	9	---	Passed	Passed	---
1/2	53	8	---	Passed	Passed	---
1/4	26.5	7	---	Passed	Passed	---
1/8	13.25	6	---	Passed	Passed	**Failed**
1/16	6.62	5	---	Passed	Passed	Passed
1/32	3.31	4	---	Passed	Passed	Passed
1/64	1.65	3	**Failed**	Passed	Passed	Passed
1/128	0.82	2	Passed	Passed	Passed	Passed
1/256	0.41	1	Passed	Passed	Passed	Passed
Distilled Water	---	0	Passed	Passed	Passed	Passed

5-2 Water immersion

Fig. 10 depicts the water seeping through asphalt films and reaching the partly covered aggregate that might worsen adhesion loss between the asphalt film and the surface. Asphalt-aggregate stripping is replaced by the asphalt-water and water-aggregate interface during wet conditions. Because, asphalt separates from the aggregate surface when water intrudes during the stripping process. Fig. 11 shows that more than (95%) of asphalt-treated aggregate samples has a strong resistance to stripping.

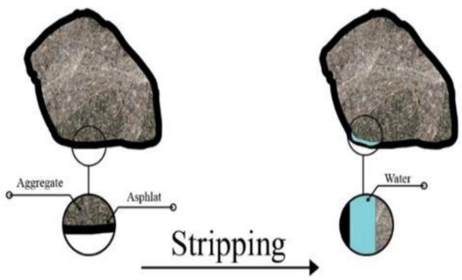

Figure 10: Asphalt stripping due to water (Xiang Liu and Xiaolong Zou, 2018)

link between polar groups C=O and S=O led to a greater resistance of RAP100 to water damage (Yang et al., 2020). NA70-RAP30, on the other hand, demonstrated 100% stripping resistance after the static immersion test, 99% after the total water immersion test, and 98% after the boiling water test. The culprit is the 30% old asphalt additive, which stiffened and decreased the connection between the aged and virgin layers, which affects the moisture resistance. Following the static immersion and boiling water tests, the rejuvenated asphalt combination (NA70-RAP30+(WEO-VR)) demonstrated stripping resistance of 99% and 98% after the total water immersion test. Due to chemical and microstructural changes that occurred throughout the aging process, the moisture damaged the value of asphalt, and a certain percentage of virgin asphalt (NA70-RAP30+(WEO-VR)) decreased.

Additionally, the poor mixing of the old and new materials is a major factor. Harden the asphalt and make microcracks more likely, increasing moisture intrusion and water damage (Luo et al., 2021). To assure the mix's resistance to water damage, it is determined that the required percentages of old asphalt should be considered.

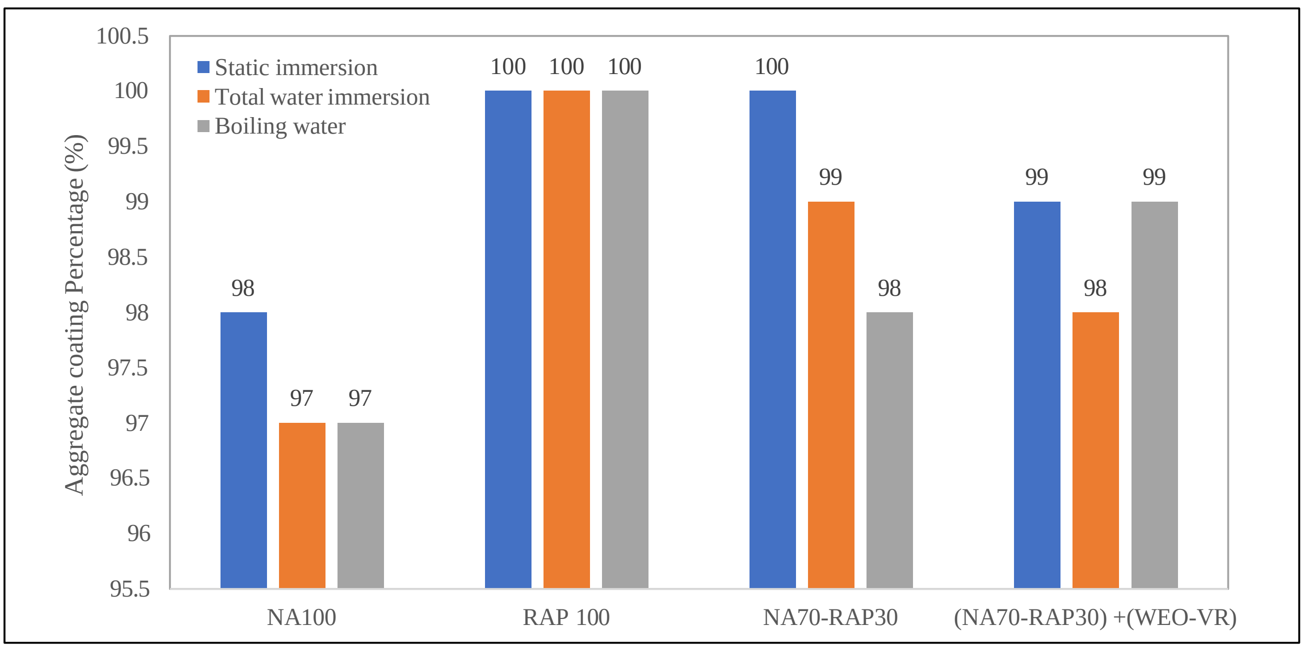

Figure 11: Result of stripping test on all four types of mixture

The aggregates in NA100 remained coated with asphalt at 97% at both (water immersion and boiling water) tests; yet, it was 98% in the static immersion test.

The coating, however, remained intact after the three RAP100 tests at a rate of 100%. The amount of polar chemical groups was directly correlated with the adhesive qualities between asphalt and aggregate. More precisely, during asphalt oxidation, a reduction in the same C-H functionalization to some degree, also an increase in the

It is possible that the aggregate's chemical composition is the major source of moisture damage in HMA. According to Al-saffar et al. (2020), generating an HMA mixture with 100 percent old asphalt might result in a weak link between the asphalt and aggregates, making the combination more susceptible to moisture. The adhesion is contingent upon the mechanical behavior of the material, particularly when a certain amount of old asphalt is used. According to the findings of static, total water immersion, and boiling water tests, the addition of 6.5 % of (WEO-VR) to NA70-RAP30 recovered the portion lost from aging, suggesting a considerable increase in resistance to moisture damage. Aggregate coating values for the NA70-RAP30 + (WEO-VR) rejuvenated asphalt binders were comparable to NA100 after water immersion testing.

Furthermore, adding (WEO-VR) will enhance the bonding between aged asphalt and new asphalt, and as the result, the softness improves. The adhesion between aged asphalt and aggregates may be improved by using an asphalt binder with the proper viscosity. To put it another way, the asphalt's water resistance is dependent on the aggregate's and binder's ability to stick together in both dry and wet situations (Tan & Guo, 2013). Aging asphalt reacts differently to various softening and rejuvenating chemicals because of differences in aggregate type, binder supplier, and rejuvenator type. There may be a decrease in bonding strength between asphalt and aggregate and resistance to moisture when the asphalt binder is exposed to severe weather for a lengthy period.

CONCULSION

Various rheological, chemical, and anti-stripping tests were used in the current study's research strategy to understand better how water affects RAP regenerated characteristics using WEO-VR. Based on the findings of the empirical investigation and the accompanying debates, a number of conclusions were formed.

1- Chemical and water immersion experiments revealed that rejuvenated asphalt held up better to water and acids than new asphalt. RAP100 and NA70-RAP30 showed no effect, either.

2- According to the results of the water immersion testing, the addition of WEO-VR to 30 percent aged asphalt enhanced the binder's anti-stripping properties, bringing them close to those of binder made from virgin asphalt.

3- After WEO-VR was added to the mix and the aging asphalt was rejuvenated, the coating test revealed a rise in the percentage of covered aggregate.

4- Incorporating 6.5 percent WEO-VR for rejuvenating HMA containing 30 percent RAP proved both practical and economical for recycling pavement.

5- It was determined that WEO-VR might potentially rejuvenate asphalt that has lost some of its original qualities.

However, further research is needed to determine the efficacy of WEO-VR-rejuvenated to recycled mixtures blends.

REFRENCES

AASHTO-T-182 (1993). Coating-and-stripping-of-bitumen-aggregate-mixtures.

Abdulmawjoud, A. A. (2020). Performance evaluation of hot mixture reclaimed asphalt pavement. Journal of Engineering Science and Technology, 15(1):477-492.

Ahmed, R. B., & Hossain, K. (2020). Waste cooking oil as an asphalt rejuvenator: A state-of-the-art review. Construction and Building Materials, 230, 116985. https://doi.org/10.1016/j.conbuildmat.2019.116985

Al-saffar, Z. H., Yaacob, H., Khairul, M., & Mohd, I. (2020). The tailored traits of reclaimed asphalt pavement incorporating maltene : performance analyses. International Journal of Pavement Engineering, 0(0), 1–14. https://doi.org/10.1080/10298436.2020.1824294

Al-saffar, Z. H., Yaacob, H., Khairul, M., & Mohd, I. (2022). The tailored traits of reclaimed asphalt pavement incorporating maltene : performance analyses. https://doi.org/10.1080/10298436.2020.1824294

Ali, A. W., Mehta, Y. A., Nolan, A., Purdy, C., & Bennert, T. (2016). Investigation of the impacts of aging and RAP percentages on the effectiveness of asphalt binder rejuvenators. Construction and Building Materials, 110, 211–217. https://doi.org/10.1016/j.conbuildmat.2016.02.013

Alvarez-Majmutov, A., Gieleciak, R., & Chen, J. (2019). Modeling the molecular composition of vacuum residue from oil sand bitumen. Fuel, 241(January 2018), 744–752. https://doi.org/10.1016/j.fuel.2018.12.096

Fauzan Mohd Jakarni, M. F. R., Yusoff, N. I. M., & Md Maniruzzaman A Aziz, Ratnasamy Muniandy, S. H. (2016). An Overview of Moisture Damage Performance Test on Various Combination of Asphalt Mixture. 2, 91–98.

Hazim, Z., Saffar, A., Yaacob, H., Khairul, M., Mohd, I., Ramadhansyah, S., & Jaya, P. (2021). Impacts of Maltene on the Wettability and Adhesion Properties of Rejuvenated Asphalt Binder. Arabian Journal for Science and Engineering, 0123456789. https://doi.org/10.1007/s13369-021-05413-0

Hong, W., Mo, L., Pan, C., Riara, M., Wei, M., & Zhang, J. (2020). Investigation of rejuvenation and modification of aged asphalt binders by using aromatic oil-SBS polymer blend. Construction and Building Materials, 231, 117154. https://doi.org/10.1016/j.conbuildmat.2019.117154

Hossain, K., Karakas, A., & Hossain, Z. (2019). Effects of Aging and Rejuvenation on Surface-Free Energy Measurements and Adhesion of Asphalt Mixtures. ASCE LIBRARY, 31(7).

Hussein, Z. H., Yaacob, H., Idham, M. K., Hassan, N. A., Choy, L. J., & Jaya, R. P. (2020). Restoration of Aged Bitumen Properties Using Maltenes. IOP Conference Series: Materials Science and Engineering, 713(1). https://doi.org/10.1088/1757-899X/713/1/012014

Road Reasearch Laboratory (1985). Bituminous materials in road construction.

Luo, L., Chu, L., & Fwa, T. F. (2021). Molecular dynamics analysis of oxidative aging effects on thermodynamic and interfacial bonding properties of asphalt mixtures. Construction and Building Materials, 269(xxxx), 121299. https://doi.org/10.1016/j.conbuildmat.2020.121299

Mamun, A. A., & Al-Abdul Wahhab, H. I. (2018). Evaluation of Waste Engine Oil-Rejuvenated Asphalt Concrete Mixtures with High RAP Content. Advances in Materials Science and Engineering, 2018. https://doi.org/10.1155/2018/7386256

Materials, P. (2001). Standard Practice for Effect of Water on Bituminous-Coated Aggregate Using. 96(Reapproved), 1–2.

Mazzoni, G., Bocci, E., & Canestrari, F. (2018). Influence of rejuvenators on bitumen ageing in hot recycled asphalt mixtures. Journal of Traffic and Transportation Engineering (English Edition), 5(3), 157–168. https://doi.org/10.1016/j.jtte.2018.01.001

Pradhan, S. K., & Sahoo, U. C. (2021). Influence of softer binder and rejuvenator on bituminous mixtures containing reclaimed asphalt pavement (RAP) material. International Journal of Transportation Science and Technology, December. https://doi.org/10.1016/j.ijtst.2020.12.001

Tan, Y., & Guo, M. (2013). Using surface free energy method to study the cohesion and adhesion of asphalt mastic. CONSTRUCTION & BUILDING MATERIALS, 47, 254–260. https://doi.org/10.1016/j.conbuildmat.2013.05.067

Taylor, P., Liu, Y., Apeagyei, A., Ahmad, N., Grenfell, J., & Airey, G. (2015). Examination of moisture sensitivity of aggregate–bitumen bonding strength using loose asphalt mixture and physico-chemical surface energy property tests. International Journal of Pavement Engineering, March 2015, 37–41. https://doi.org/10.1080/10298436.2013.855312

Xiang Liu, Xiaolong Zou, X. Y. & Z. Z. (2018). Effect of material composition on antistripping performance of SBS modified asphalt mixture under dry and wet conditions. Journal of Adhesion Science and Technology, 32(14), 1503–1516. https://doi.org/10.1080/01694243.2018.1426973

Xu, M., & Zhang, Y. (2020). Study of rejuvenators dynamic diffusion behavior into aged asphalt and its effects. Construction and Building Materials, 261, 120673. https://doi.org/10.1016/j.conbuildmat.2020.120673

Yaacob, H., Hazim, Z., Saffar, A., Khairul, M., Mohd, I., Mhmood, S., & Saleem, K. (2020). Evaluating the Chemical and Rheological Attributes of Aged Asphalt : Synergistic Effects of Maltene and Waste Engine Oil Rejuvenators. Arabian Journal for Science and Engineering, 45(10), 8685–8697. https://doi.org/10.1007/s13369-020-04842-7

Yang, C., Xie, J., Wu, S., Amirkhanian, S., Zhou, X., Ye, Q., Yang, D., & Hu, R. (2020). Investigation of physicochemical and rheological properties of SARA components separated from bitumen. Construction and Building Materials, 235, 117437. https://doi.org/10.1016/j.conbuildmat.2019.117437

Yang, H., Pang, L., Zou, Y., Liu, Q., & Xie, J. (2020). The effect of water solution erosion on rheological, cohesion and adhesion properties of asphalt. Construction and Building Materials, 246, 118465. https://doi.org/10.1016/j.conbuildmat.2020.118465

You, Z., Dai, Q., & Xiao, F. (2018). Advanced Asphalt Materials and Paving Technologies. In Advanced Asphalt Materials and Paving Technologies. https://doi.org/10.3390/books978-3-03842-890-9