International Journal of Design & Nature and Ecodynamics
Vol. 16, No. 6, December, 2021, pp. 701-707
Journal homepage: http://iieta.org/journals/ijdne

Influence of Waste Cork with Thinner on the Rheological Properties of Asphalt

Khalid A. Mohammed[1*], Ali I. Mansi[2], Suha M. Salih[1]

[1] Department of Chemical Engineering, College of Engineering, University of Anbar, Ramadi 310011, Iraq
[2] Department of Civil Engineering, College of Engineering, University of Anbar, Ramadi 310011, Iraq

Corresponding Author Email: khalid_awad10@uoanbar.edu.iq

https://doi.org/10.18280/ijdne.160612

Received: 3 October 2021
Accepted: 19 November 2021

Keywords:
waste cork, asphalt, rheological properties, materials, modified

ABSTRACT

Over the last two decades, the rapid and continued deterioration of the transportation network has been regarded as a major issue. There are many measures that can be taken to reduce this deterioration and improve road specifications, including improving road design, using higher quality materials, and using more efficient construction methods. This study is concerned with three principles: including investigating the impact of using waste paste on the rheological properties of bitumen; the environmental pollution that is a global problem; and the economic benefits as a result of the reusing of waste materials such as corks to produce new reusable materials like Modified-Asphalt. In this research, cork has been melted by thinner and mixed with asphalt to get a good paste with weight percentages of 1%, 3%, 5%, and 7%. After conducting the necessary tests on the samples, it was found that the addition of waste paste to virgin bitumen has softened the bitumen by decreasing the hardness and adhesiveness of the bitumen by increasing penetration with increasing cork paste content. The findings show that the current procedure can be used in cold regions because it requires less hard asphalt than that used in hot regions. It can also be used with natural asphalt, like natural rock asphalt, in various percent to give asphalt with suitable properties for use in roofing and paving roads.

1. INTRODUCTION

The uncontrolled use of the planet's natural resources in recent years has prompted societies to call for sustainable solutions to prevent exhaustion. The studies conducted on road paving nowadays are mainly related to the need to develop a mix of asphalt that is cost effective and environmentally friendly. By using less asphalt, waste, industrial goods and recycled materials, this overall goal can be reached. In the present research, the investigated asphalt formulations have been developed as binding courses. The objective of developing mixtures containing industrial residues or products was to enable them, and thus contribute to reducing noise from tires, to absorb part of the vibrations generated by traffic loads [1].

On the other hand, several industries (such as the tire and cork industries) are producing less waste, and its disposal is becoming an economic and environmental issue for businesses and communities. (For instance, price, landfill space, and so on.) Other applications for these fibers have been found [2]. Landfill is one of the oldest methods of waste disposal, but studies have shown that this landfill process has many problems that affect health and is not environmentally friendly, although it is considered the cheapest way to dispose of waste, as it constitutes a general pollution of waste. Soil and water bodies in addition to air pollution. The leakage of gases emitted from the soil affects the greenhouse effect. It also determines the current and future of the land uses [3].

The cork produced is an industrial raw material for the production since it comes from recycled cork items or virgin cork, which is the raw material generated by extracting the tree's original periderm, and it has large fractures and a twisted structure, making it unsuitable for other applications [4].

During the past two decades, much of the rapid and continuous deterioration of road networks occurred due to heavy traffic, overload, and lack of sufficient roads due to lack of funds. As a result, the asphalt concrete mixes have been subjected to higher stress because of the increasing traffic volumes, truck traffic, and higher tire stresses. In addition, the asphalt mixture indicates severe rutting at high temperatures, fatigue at fatigue temperatures, and cracking at low temperatures. To alleviate these problems, numerous kinds of measurements may be in influence, e.g., deposit cash needed for road maintenance, developed design of the roadway, usage of better classes of materials, and the use of more effective construction methods. And the asphalt mixture can also be modified by adding different types of additives. An example of this material is polymers and rubber. In this study, they used the thinner with cork [5, 6].

Any waste strategy should primarily aim to decrease the damaging impact on health of human and the problem of environment from waste production and management. The use of waste cork with thinner was examined in this research in order to change the asphalt mixing characteristics. The main aims of this investigation were:

- Examine the impact of addition waste cork with thinner on the asphalt.
- Reduction waste landfill removal to realize greater amounts of cork waste reuse and valorization.
- Decreasing the impact of landfilling of waste cork on healthy and the environment.

- The development of new use of cork waste offers an opportunity to increase support for the management of cork forests and the production of cork.

2. BACKGROUND

The impact of fly ash on the mechanical characteristics of asphalt mixes was investigated by Ali et al. [7]. Fly ash can be used as a mineral filler to increase the resilience and stripping resistance of concrete. It is also considered a feasible alternative for waste fly ash disposal. This is considered to improve the properties of the asphalt mixture and reduce its cost.

Hınıslıoğlu and Ağar [8] explored the use of different plastic wastes comprising HDPE as polymer additives to enhance asphalt characteristics. The impact of mixing duration, temperature, and polyethylene concentration on Marshall Stability, flow, and Marshall Quotient was studied. The best parameters for Marshall stability, flow, and Marshall quotient were 4% polyethylene, 165°C mixing temperature, and 30 minutes of mixing time. The Marshall Quotient increased 50% above the control mix. Additionally, the utilization of these components is viewed as a way to improve the asphalt mixture and as a waste disposal ally.

Using Sulaimania marble debris, Abed and Eyada [9] improved asphalt. This trash is harmful to the environment and requires extensive recycling or disposal. The Marshall stiffness, indirect tensile strength, moisture susceptibility, and creep tests were performed as well. Many findings were reached on the necessity of employing Sulaimania Marble debris to improve asphalt characteristics.

Losa et al. [10] employed rubber crumbs in asphalt mixes, which is connected to the pavement's environmental sustainability. The results of laboratory and field experiments clearly demonstrate that this combination may improve mechanical and functional performance, reduce tire/road noise, and extend the life of wearing layers. As a result of these findings, crumb rubber modified asphalt concrete may be classed as a sustainable building material.

Pereira et al. [1] investigated cork and rubber granulates as partial aggregate replacements in asphalt. The findings showed that these waste products helped minimize tire road contact and hence improved pavement sustainability. Rubber and cork were utilized to replace 5% of the aggregate volume. Furthermore, the study indicated that the rubber has the best fatigue resistance and stiffness modulus. In terms of water sensitivity, all combinations had high maintained strength values.

Awaeed et al. [11] used leftover polyethylene terephthalate (PET) to improve asphalt characteristics. PET bottles were utilized as polymer additions in Bituminous Mixture to solve pavement issues and minimize pollution caused by over usage of plastic bottles. The optimal modifier content for waste plastic water bottles (PET) modified asphalt mixture was determined to be 8%. It provided optimum stability, eliminates air voids filled with asphalt, and has greater resilience to permanent deformations and engineering characteristics than non-modified mixtures.

Wahhab et al. [12] studied heavy oil fly ash waste for asphalt enhancement. Heavy oil fly ash is produced by power stations and desalination units burning heavy fuel oil (OFA). If illegally disposed of, oil ash can cause respiratory problems and pollute groundwater. The use of heavy oil ash in construction materials protects the environment and eliminates the need for specific ash disposal locations. Oil fly ash has been chemically treated. The results showed that modified asphalt mixes with chemically treated oil fly ash have 11% higher split tensile strength, 25% higher resilient modulus, 1400% longer fatigue life, and 55% less rutting than plain asphalt concrete mixes with the same asphalt component. Adding 2% chemically treated oil fly ash to asphalt binder enhances pavement performance.

Azahar et al. [13] showed that the quality of waste cooking oil (WCO) affects the performance of asphalt binder treated with WCO. An acid value test can assess the quality of WCO, with higher acid values causing lower rheological performance. WCO samples were tested chemically (acid value), physically (penetration and softening) and rheological (dynamic shear rheometer). After chemical treatment, the acid value of waste cooking oils dropped from 1.65 mL/g to 0.54 mg/g. The reduction in acid value improved penetration, softening point, and other tests.

Salem et al. [14] replaced some fractional fine aggregate with crushed glass components. The Marshall design was used to investigate the impact of optimal asphalt composition on water resistance. The results showed that adding 10% glass debris to the asphalt mixture improved the mix's stability, durability, and skid resistance, reducing accidents and saving money. The study also reported that obtaining low-cost mixtures that decrease pollutants and save the environment.

Liu et al. [15] investigated the effects of WEO on the rheological properties of asphalt. According to authors, waste engine oil (WEO) is utilized as an asphalt modifier to enhance performance, save money, and minimize emissions. Making modified asphalt samples with waste engine oil (WEO) and varying its composition. There was no difference in rutting resistance or fatigue resistance between the two-waste engine oil (WEO) modified asphalts.

Pasandín et al. [16] investigated the use of discarded cork dust as a filler in hot-mix asphalt using laboratory adhesion testing. Its performance as a filler was compared to a commonly used natural filler and Portland cement. There is significant potential to employ waste cork dust (rich in suberin biopolymer) in bituminous mixes as a bitumen modifier, aggregate and mineral filler, given the favorable effect of polymers in asphalt. With regard to particle size distribution and aggregate-binder adhesion, the results showed that waste cork dust may be used as a bituminous filler. An option for disposing of environmental issues caused by this waste.

Mahmood et al. [17] improved natural asphalt as a water-proofing material by melting cork with benzene and mixing it with hit natural asphalt to make a good paste with weight percentages of 0%, 10%, and 20%. The properties of Modified Asphalt have been studied after and before adding cork. The results revealed that adding cork by 20% can make the modified asphalt meet the international specifications as well as the Iraqi specifications as a waterproofing material. In addition, the outcomes uncovered that it is possible to reduce the harmful effect of cork waste on the environment and humans and can be recycled into a new useful material by improving natural asphalt.

All of the reviewed literature seeks to enhance the qualities of asphalt and lower costs while maintaining those properties and being environmentally friendly. Cork waste was employed in this investigation after being mixed with thinner for the same purpose.

Table 1. Properties of Al-Dora refinery bitumen (40/50)

Test	ASTM Specification	Results	Specification Range
*Penetration at 25℃	ASTM D-5	40	40- 50
Softening point	ASTM D-36	50	45-55
*Kinematics Viscosity (centipoises at 135℃)		512	400
*Kinematics Viscosity (centipoises at 165℃)		137.5	
*Flash point	ASTM D-92	330	>232
*Fire point	ASTM D-92	360	
Specific Gravity	ASTM D-70	1.0300506	1.03
Ductility (centimeter at 25℃)	ASTM D-113	>150	>100

*basic test

3. MATERIALS AND METHOD

To understand the performance of the materials used in this study, it is necessary to know the physical and chemical properties of them, their source, the cost, and their availability in the local markets. This study describes the materials that were used under our study. These materials are:

3.1 Asphalt

Al-Dora Refinery bitumen with penetration grade (40-50) was used in this study for all mixes in the experiments. The rheological properties of asphalts are measured following the ASTM standards, and are shown in Table 1.

3.2 Cork waste

The primary components of cork are suberin cells, shaped like honeycombs, and filled with an air-like gas, which collectively account for 90% of the volume. The density of iron is around 200 kg/m^3, with a poor thermal conductivity. In the present study, used cork granules (known as cork trash) included a variety of items. Because of the lightweight, elastic, impermeable qualities, it's also a highly insulating and acoustically absorptive material. Also, because it is a robust material, it has an excellent capacity to restore the shape it loses due to any applied force. A local source provided the corks for this investigation.

The chemical composition of cork: Suberin (45%)-main cell wall element responsible for cork elastics; Lignin (27%)-isolating compound; Polysaccharide (12%)-cell wall elements that help to define the cork texture; Tannin (6%) -Polyphenolic color compound; Seroides (5%) -hydrophobic; Chemical compounds of cork.

The cork was cut into small pieces after being thoroughly cleaned and then dissolved in thinner for 10 minutes at room temperature. After that, the cork paste was added to the asphalt mixture at 0%, 1%, 3%, 5%, and 7% percentages.

3.3 Thinner

A thinner (C_4H_8O) is a volatile solvent that is used to dilute or extend oil-based paints or cleanup after use.

3.4 Preparation of samples

The preparation steps can be summarized as follows:

(1) Heating the asphalt sample to a temperature of 150℃. Then we pour the asphalt into the test molds to carry out the required tests.
(2) Conduct the required tests for the regression (penetration, softening point, rotational viscosity, flash point, fire point, ductility) before adding cork paste and thinner.
(3) Registration as a result of the initial tests before adding a cork paste.
(4) Heating new asphalt samples and packing them in special cans for the purpose of mixing.
(5) Preparing the cork and thinner dough for a period of 10 minutes.
(6) Adding cork and thinner paste to the asphalt in proportions (5%, 10%, 20%) by weight ratios.
(7) Starting mixing asphalt and cork paste at a specific speed, at a specific time, and at a certain temperature.

3.5 The mixing mechanism

The process of mixing a certain percentage of asphalt, adding to it 1% of cork paste in the first mix, 3% of cork paste in the second mix, 5% of cork paste in the third mix. And 7% of cork paste in the fourth mix. The mixing process is carried out at a temperature of (135-150)℃, with a mixing speed of 1000Rpm. The mixing period is one hour in order to achieve homogeneity between the asphalt and cork paste and thinner.

After the mixing process, we take samples from each mixture and carry out the required tests on them, and determine the percentage that gives the best specifications.

3.6 Asphalt test

After preparing the sample, conventional tests of asphalt were carried out, each according to the specifications of the American Society for Testing and Materials ASTM, where tests of penetration, ductility, specific gravity, softening point, flash and fire point, and viscosity were carried out at different temperatures [18-20].

4. RESULTS AND DISCUSSION

For the laboratory test, cork modified bitumen were produced, by adding cork blend to bitumen (40-50), produced by Al-Dora refinery, Asphalt samples were produced by mixing different percentages of cork paste (0, 1, 3, 5, and 7%) to pure bitumen. The effect of adding these percentages of cork paste on the rheological properties of asphalt will be explained in the following discussing and figures. The impact of cork waste content on the rheological properties of bitumen are stated in Table 2.

4.1 Effect of cork paste on penetration of asphalt

Penetration experience is considered the most imperative test in the field of pavement to determine the grade of hardness and strength of the bitumen and to determine the penetration degree of the material. Figure 1 shows the effect of cork waste on the degree of penetration, as the addition percentage increases the permeability of bitumen. Soft asphalt with high stitching is used in cold areas so as not to become cooled, while solid bitumen with small stitches is used in hot areas so as not to become liquid under the wheels of a vehicle. Soft asphalt is used in the mountainous northern border areas of Iraq due to its extreme cold, while solid asphalt is used in the central and southern regions due to its high temperature.

4.2 Effect of cork paste on softening point of asphalt

The experiment is especially important in the thick layers of bitumen. Bitumen is used to fill joints and cracks, and paint surfaces due to its high softening point, which means it will not flow bitumen during use. According to Figure 2, it observes the effect of adding different ratios of cork waste on the softening point bitumen with temperature, when the percentage of addition increases, the softening point value decreases. The idea of asphalt binder trend to flow at high altitudes when put on the roads means that the method of controlling the production of asphalt binder in refineries and in the making of airborne asphalt is also important.

4.3 Effect of cork paste on ductility of asphalt

The ductility experiment can be used to characterize bitumen binders' ductile and tensile properties. The test, which is usually carried out at room temperature (25℃), is said to indicate the binder's homogeneity and flow ability. Figure 3 shows the effect of cork waste on the ductility of bitumen. Accordingly, when the percentage of addition increases, the ductility of bitumen decreases.

4.4 Effect of cork paste on viscosity of asphalt

Viscosity is the quotient of the viscosity factor to the liquid density, a measure of resistance to the flow of liquid under the influence of gravity. The ratio between the effective shear stress and the shear rate is called the viscosity factor. This coefficient is a measure of the flow resistance of the liquid. This method covers the process of determining the motor viscosity of liquids, bitumen, road oils and washes, as well as semi-asphalt, remaining 60℃ of liquid asphalt distillation, all at a hot temperature. ranging from 135℃ to 165℃. Figures 4 and 5 show the effect of increasing the percentage of cork waste on the viscosity of bitumen.

4.5 Effect of cork paste on flash &fire point of asphalt

Bitumen materials are flammable, and mild vapors become explosive when combined with air. If the temperature used to operate the asphalt is high, measures must be taken to avoid fires, as well as testing the ignition to determine the temperature at which the rising gases of bituminous materials and this happens before the burning of the same substance. If the sample's degree of ignition is high, it will not burn when heated to the degree of fluidity. The bitumen utilized has a minimum ignition temperature of 175 degrees Celsius. The bitumen mixing temperature is typically about 162℃, and the degree of ignition of the bituminous material is typically around 230℃. Through Figure 6, note the effect of cork waste and thinner on the bitumen where it indicates that all samples are safe.

Table 2. Rheological properties of modified samples

Test	Results					Specifications
	0%	1%	3%	5%	7%	
1.Penetration	40	48	62	71	84	40-50
2.softening	50	46	44	42	38	52-60
3.kinematics viscosity (C.p at 135℃)	512	485	454	400	390	450
4. kinematics viscosity (C.p at 165℃)	137.5	132	123.5	112.5	106.5	150
5. flash point	330	290	245	230	208	>250
6. fire point	360	324	280	270	224	>250
7. Ductility (centimeter at 25℃)	>150	117	105	93	82	>100

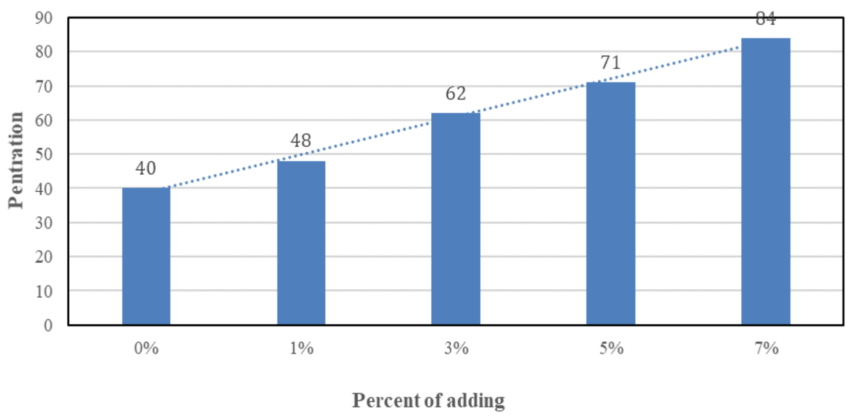

Figure 1. The relationship between penetrations with the percentage of cork paste

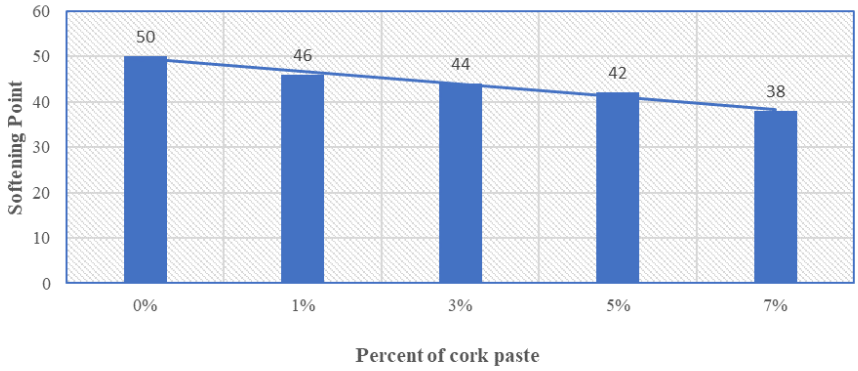

Figure 2. The relationship between softening point with the percentage of cork paste

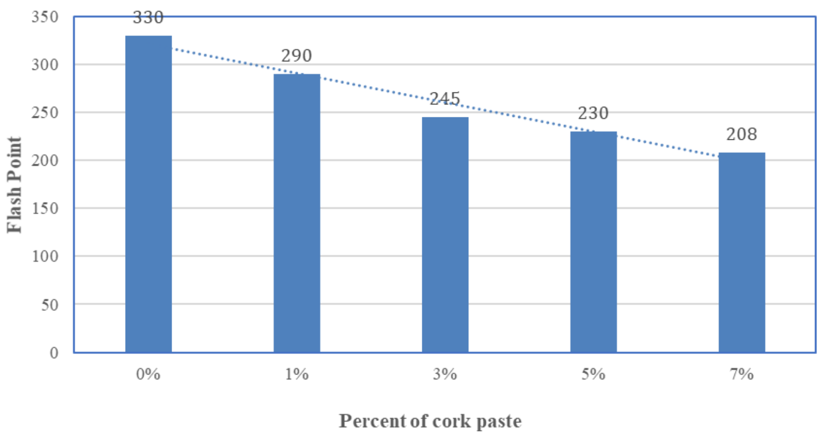

Figure 3. The relationship between ductility with the percentage of cork paste

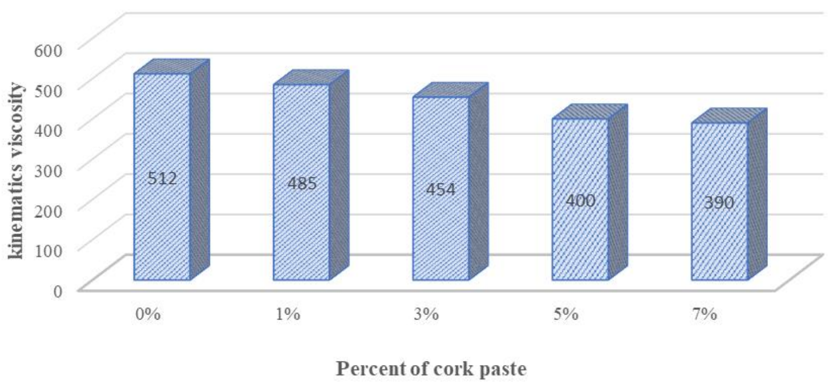

Figure 4. The relationship between viscosities at 135℃ with the percentage of cork paste

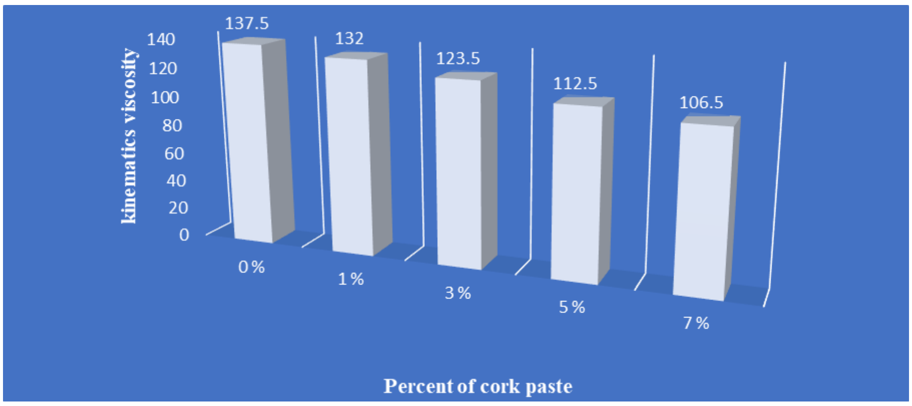

Figure 5. The relationship between viscosities at 165℃ with the percentage of cork paste

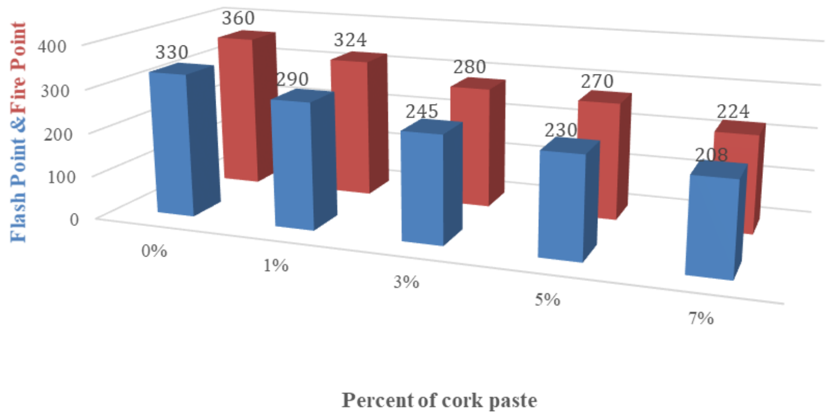

Figure 6. The relationship between Flash and Fire point with the percentage of cork paste

5. CONCLUSION

The cork blend based additive effect on the rheological properties of bitumen; the affected of these properties can be summarized as:

(1) Decrease in hardness and adhesiveness of bitumen by increasing penetration with increasing cork paste content.
(2) Decrease the durability of bitumen at a high temperature by decreasing the softening point by increasing cork paste content.
(3) The greater the proportion of cork paste is reduced by resistance to the ripper, the less viscous it becomes with increased cork paste.

Based on the material used and percentages of mixing and the laboratory test results in this study, the findings show that the current procedure can be used in cold regions because it requires less hard asphalt than that used in hot regions. It can also be used with natural asphalt like natural rock asphalt to give asphalt with suitable properties for use in paving roads in hot regions.

ACKNOWLEDGMENT

The authors would like to acknowledge the contribution of the University of Anbar (www.uoa.edi.iq) via their prestigious academic staff in supporting this research with all the required technical and academic support.

REFERENCES

[1] Pereira, S.M., Oliveira, J.R., Freitas, E.F., Machado, P. (2013). Mechanical performance of asphalt mixtures produced with cork or rubber granulates as aggregate partial substitutes. Construction and Building Materials, 41: 209-215. https://doi.org/10.1016/j.conbuildmat.2012.12.005
[2] Putman, B.J., Amirkhanian, S.N. (2004). Utilization of waste fibers in stone matrix asphalt mixtures. Resources, Conservation and Recycling, 42(3): 265-274. http://dx.doi.org/10.1016/j.resconrec.2004.04.005
[3] Ramos, A., Berzosa, J., Clarens, F., Marin, M., Rouboa, A. (2020). Environmental and socio-economic assessment of cork waste gasification: Life cycle and cost analysis. Journal of Cleaner Production, 249: 119316. http://dx.doi.org/10.1016/j.jclepro.2019.119316
[4] Sierra-Pérez, J., Boschmonart-Rives, J., Gabarrell, X. (2015). Production and trade analysis in the Iberian cork sector: Economic characterization of a forest industry. Resources, Conservation and Recycling, 98: 55-66. http://dx.doi.org/10.1016/j.resconrec.2015.02.011
[5] Gil, L. (1997). Cork powder waste: an overview. Biomass and Bioenergy, 13(1-2): 59-61. https://doi.org/10.1016/S0961-9534(97)00033-0
[6] Shbeeb, M.T. (2007). The use of polyethylene in hot asphalt mixtures. American Journal of Applied Sciences, 4(6): 390-396.
[7] Ali, N., Chan, J.S., Simms, S., Bushman, R., Bergan, A.T. (1996). Mechanistic evaluation of fly ash asphalt concrete mixtures. Journal of Materials in Civil Engineering, 8(1): 19-25. https://doi.org/10.1061/(ASCE)0899-1561(1996)8:1(19)
[8] Hınıslıoğlu, S., Ağar, E. (2004). Use of waste high density polyethylene as bitumen modifier in asphalt concrete mix. Materials Letters, 58(3-4): 267-271. https://doi.org/10.1016/S0167-577X(03)00458-0
[9] Abed, A.N., Eyada, S.O. (2012). The use of Sulaimania marble waste to improve the properties of hot mix asphalt concrete. Anbar Journal for Engineering Sciences, 2: 139-151.
[10] Losa, M., Leandri, P., Cerchiai, M. (2012). Improvement of pavement sustainability by the use of crumb rubber modified asphalt concrete for wearing courses. International Journal of Pavement Research and Technology, 5(6): 395.
[11] Awaeed, K.M., Fahad, B.M., Rasool, D.A. (2015). Utilization of waste plastic water bottle as a modifier for asphalt mixture properties. J. Eng. Dev., 20(2): 89-108.
[12] Wahhab, H.I.A.A., Hussein, I.A., Parvez, M.A., Shawabkeh, R.A. (2015). Use of modified oil fly ash to enhance asphalt concrete performance. Materials and Structures, 48(10): 3231-3240. http://dx.doi.org/10.1617/s11527-014-0393-5
[13] Azahar, W.N.A.W., Jaya, R.P., Hainin, M.R., Bujang, M., Ngadi, N. (2016). Chemical modification of waste cooking oil to improve the physical and rheological properties of asphalt binder. Construction and Building Materials, 126: 218-226. https://doi.org/10.1016/j.conbuildmat.2016.09.032

[14] Salem, Z.T.A., Khedawi, T.S., Baker, M.B., Abendeh, R. (2017). Effect of waste glass on properties of asphalt concrete mixtures. Jordan Journal of Civil Engineering, 11(1): 117-131.
[15] Liu, S., Meng, H., Xu, Y., Zhou, S. (2018). Evaluation of rheological characteristics of asphalt modified with waste engine oil (WEO). Petroleum Science and Technology, 36(6): 475-480. https://doi.org/10.1080/10916466.2018.1430157
[16] Pasandín, A.R., Galán-Díaz, J.J., Pérez, I. (2019). Adhesion analysis of waste cork dust as filler for bituminous mixtures. In Wastes: Solutions, Treatments and Opportunities III (pp. 1-6). CRC Press. http://dx.doi.org/10.1201/9780429289798-1
[17] Mahmood, B.A., Mohaisen, M.A., Mahmood, A.H., Eyada, S.O. (2020). Reducing the environmental impact of cork waste by improving natural asphalt as water proofing material. Indian Journal of Forensic Medicine & Toxicology, 14(4): 1247. http://dx.doi.org/10.37506/ijfmt.v14i4.11769
[18] Standard Test Method for Penetration of Bituminous Materials. American Society of Testing and Materials, 1997. Annual Book of ASTM Standards, Section 4, Volume 04.03. http://www.shxf17.com/pdf/ASTMD5-2006.pdf.
[19] Standard Test Method for Softening Point of Bitumen (Ring and Ball Apparatus)". American Society of Testing and Materials, 1995. Annual Book of ASTM Standards, Section 4, Volume 04.03. http://www.shxf17.com/pdf/ASTMD36-95.pdf.
[20] Standard Test Method for Flash Point by Cleveland Open Cup. American Society of Testing and Materials, D92-1996. Annual Book of ASTM Standards, Section 4, Volume 04.03. https://www.astm.org/d6114_d6114m-19.html.

NOMENCLATURE

PET	Plastic Water Bottles
WCO	Waste Cooking Oil
OFA	Heavy Fuel Oil
WEO	Waste Engine Oil
CPO	Crock Paste Oil