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Biyo-yağ ile Modifiyeli Asfaltın Yapışma ve Soyulma Özelliklerinin İncelenmesi

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Öz

Plastik malzemeler düşük maliyetleri ve kolay taşınabilmeleri nedeniyle yaygın olarak kullanılmaktadır. Bunun sonucunda çevrede plastik atık miktarı sürekli artmaktadır. Özellikle COVID-19 pandemide paketleme işlemlerinde kullanılan polietilen, polipropilen, polistiren, polietilen tereftalat ve naylon gibi atık plastik malzemeler artmıştır. Bu atık plastik malzemeleri geri dönüştürmek veya yeniden kullanımı sağlamak için depolama, yakma ve gömme gibi yöntemler uygulanmaktadır. Fakat hem atık plastik malzemelerin geri dönüşümünü sağlamak hem de çevre kirliliğini azaltmak amacıyla piroliz yöntemi tercih edilmektedir. Bu çalışmada piroliz yöntemiyle granüler halde atık geri dönüştürülmüş polipropilen oksijensiz ortamda, 500˚C sıcaklıkta 45 dakika süresince yakılarak biyo-yağ elde edilmiştir. 50/70 asfalt ile %1, 2 ve 3 oranlarında biyo-yağ sıcaklık kontrollü yüksek devirli karıştırıcı yardımıyla 160˚C sıcaklıkta, 3000 rpm karıştırma hızında 30 dakika süresince homojen şekilde modifiye edilmiştir. 50/70 asfalt ve biyo-yağ ile modifiyeli asfalt kullanılarak hazırlanan gevşek asfalt karışımların su ve nem etkisi altında adezyonunu değerlendirmek için Vialit, Nicholson ve Kaliforniya soyulma testleri gerçekleştirilmiştir. Vialit deneyi sonucuna göre, 50/70 asfalta ilave edilen biyo-yağ miktarı arttıkça modifiyeli asfaltın agregalarla daha iyi bağlanma performansı göstermiştir. Nicholson soyulma testinde %1 biyo-yağ ile modifiyeli asfalt nem hassasiyetine karşı daha iyi direnç gösterirken, Kaliforniya soyulma testinde ise sıcaklık ve laboratuvar ortamında simule edilen yağmur suyu hareketine karşı farklı oranlarda biyo-yağ ile modifiyeli asfalt daha az direnç göstermiştir. Deneysel sonuçlar istatiksel yöntem kullanılarak analiz edilmiştir.

Anahtar kelimeler: Biyo-yağ, Piroliz yöntemi, Asfalt modifikasyonu, Gevşek asfalt karışım yapışma ve soyulma testleri

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Investigation of Adhesion and Stripping Properties of Asphalt Modified with Bio-oil

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Abstract

Plastic materials are widely used due to their low cost and ease of transportation. As a result, plastic waste is continuously increasing in the environment. Especially, waste plastic materials such as polyethylene, polypropylene, polystyrene, polyethylene terephthalate and nylon used in packaging processes increased during COVID-19 pandemic. Methods such as storage, burning and burying are used to recycle or reuse these waste plastic materials. However, the pyrolysis method is preferred in order to both recycle waste plastic materials and reduce environmental pollution. In this study, bio-oil was obtained by burning waste recycled polypropylene in granular form for 45 minutes at 500˚C in an oxygen-free environment with the pyrolysis method. Bio-oil at 1, 2 and 3% ratios and 50/70 asphalt were homogeneously modified for 30 minutes, at 3000 rpm and 160˚C with the help of temperature-controlled mixer. Vialit, Nicholson and California Stripping tests were carried out to evaluate adhesion of loose asphalt mixtures containing 50/70 asphalt and modified asphalt under influence of water and humidity. According to the results of the vialit test, as ratio of bio-oil, added to 50/70 asphalt increased, modified asphalt showed better bonding performance with aggregates. In Nicholson stripping test, asphalt modified with bio-oil at ratio of 1% showed better resistance to moisture susceptibility, while in California stripping test, asphalt modified with bio-oil at different ratios showed less resistance to temperature and rainwater movement, simulated in laboratory conditions. The experimental results were analyzed using statistical methods.

Keywords: Bio-Oil, Pyrolysis method, Asphalt modification, Loose asphalt mixture, Adhesion and stripping tests

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1. Introduction

Although plastic materials, consisted of elements such as hydrogen, carbon, nitrogen and chloride, do not decompose in nature a long time due to molecular bonds. However, they are indispensable parts of our daily lives because they are cheap and easy to produce [1]. Accordingly, both the consumption of plastic materials and the generation of waste plastic materials increased recently. Waste plastic materials are generally divided into two groups post-industrial and post-consumer. Post-industrial waste materials are clean, consistent, good quality and generally have define components. Waste plastic materials collected from consumers are quite dirty and contain different types of foreign materials such as organic waste, wood, glass and metal [2]. Especially, waste plastics materials such as polyethylene, polypropylene, polystyrene, polyethylene terephthalate and nylon used for packaging purposes emerged during the COVID-19 pandemic [3]. Nowadays, different waste plastic materials are thrown into landfills and the environment. Waste plastic materials thrown into landfills are mixed with municipal solid waste and this situation causes environmental, air and water pollution. In addition to these methods, it is known that waste plastic materials are burned. When plastic materials such as polystyrene and poly vinyl chloride are burned, it can cause breathing, vomiting and complications in the people and especially children around. Therefore, people should not be exposed to smoke that occurred during the burning of toxic plastics such as polystyrene. Methane gas, dioxins, furans, mercury and polychlorinated biphenyls, released during the burning of waste plastic materials damages the ozone layer and causes global warming [4-8]. The pyrolysis method is a mechanical recycling method used to reduce the negative effects of waste plastic materials on both human health and environmental pollution. Mechanical recycling of waste plastic materials is the obtaining of second raw materials without significantly changing the chemical structure of the materials. The pyrolysis method is heated biomass in an oxygen-free environment, and they break down into simpler hydrocarbons. Biomass is classified as woody (stem, branch, chips of different trees), agricultural, aquatic biomass (microalgae, plants and microbes found in water), human, animal and industrial wastes. When different biomass is burned in the absence of oxygen, bio-oil, bio-char and non-condensed gas (CO, CO_2, CH_4, and H_2) are obtained. The properties of the materials obtained from the pyrolysis method are affected by the reaction conditions (temperature, residence time, particle size, components of the biomass). The amounts of cellulose, hemicellulose, lignin, volatiles, fixed carbon and ash, found in biomass affect yields of products obtained from the pyrolysis method [9-13].

Asphalt, the primary material in pavement, becomes harmful material at temperature between 160-220˚C. Toxic gases emitted into the atmosphere during the production of asphalt mixtures cause adverse effects on both environmental pollution and human health. Thus, researchers are searching for alternative asphalt that are environmentally friendly, economical and efficient [14-15]. Also, deteriorations on pavement occur due to heavy traffic load and environmental conditions such as, humidity, temperature, UV radiation. Modifying asphalt with polymers is one of the most suitable and popular methods to create alternative asphalt, to increase the field performance and life of the pavement. Polymers, recycled from waste plastic materials in asphalt and asphalt mixtures are used to reduce environmental pollution of waste plastic materials, increase the quality of asphalt and reduce the cost of the mixture. In order to both reduce environmental pollution of waste plastic materials and improve the properties of asphalt, use of bio-oil and bio-char obtained from the pyrolysis of waste plastic materials is preferred. In the pyrolysis method, polymers such as polyethylene, polystyrene, polyvinyl chloride and polypropylene, used in the production of goods and materials preferred in our daily lives, are used [16-20]. Bio-asphalt is obtained by modifying the asphalt with bio-oil obtained from the pyrolysis of different polymers. The use of bio-oil in asphalt mixtures positively affects the rheological properties, rutting performance and fatigue life of asphalt mixtures. Additionally, an increase in the viscosity values of asphalt modified with bio-oil at high temperatures is observed [21]. Mills-Beale et al. (2014) [22] obtained bio-binder from swine manure with thermochemical liquefaction process in the absence of oxygen. They stated that bio-modified asphalt exhibited better rutting resistance at high temperatures. In the study carried out by Pratama and Saptoadi (2024) [23], waste polyethylene (PE), polypropylene (PP), polystyrene (PS), polyethylene terephthalate (PET) as biomass was used in the pyrolysis method. The highest amount of waste plastic pyrolytic oil (WPPO) was obtained from the pyrolysis of the mixture of 50% PE, 40% PP and 10% PS. According to the obtained results, it was stated that WPPO could be an alternative fuel for diesel fuel blending. In the study carried out by Fasial et al. (2024) [24], they used high-density polyethylene (HDPE), PP and PS as biomass in certain ratios (1:1:1) in the pyrolysis method. They investigated the effects of temperature (460-540˚C), residence time (30-150 min) and particle size (5-45 mm) parameters on yield of bio-oil obtained from the pyrolysis method. It was stated that the yield of bio-oil obtained from biomass decreased when particle size was less than 20 mm or more than 30 mm. It was explained that the optimum particle size of the biomass used in the pyrolysis method should be approximately 25 mm.

Polypropylene is used in suitcases, bags, shaving cream and toothpaste tubes, sterile health supplies, flowerpots, office folders, buckets, carpets, furniture, storage boxes, cosmetic box lids, household and industrial packaging. Thus, waste plastic materials contain 60-70% wt. PE+PP and 30-40% wt. PET [25-27]. In this study, waste recycled polypropylene in granular form was supplied by the Plastic Recycling Company located in Gaziantep province. Polypropylene-based-oil (PPB) material from the pyrolysis of waste recycled polypropylene in granular form for the first time in the literature was obtained. 50/70 asphalt was modified with bio-oil at ratios of 1, 2, and 3% to increase performance between 50/70 asphalt modified with bio-oil and aggregates. Bio-oil (1-3 %) was blended with 50/70 asphalt at 160˚C and 3000 rpm for 30 minutes using a temperature-controlled mixer. The Vialit test was carried out to investigate the adhesion properties of asphalt modified with bio-oil at ratios of 1, 2, and 3%. The Nicholson test was carried out to determine resistance to moisture susceptibility of loose asphalt mixtures prepared with modified asphalt. In addition, the California stripping test was conducted to examine effect of movement of rainwater, simulated in laboratory conditions and temperature on loose asphalt mixtures prepared using modified asphalt.

2. Materials

In this study, 50/70 asphalt, limestone aggregate and bio-oil (PPB) obtained from pyrolysis of waste recycled polypropylene in granular form was used.

2.1. 50/70 asphalt

Softening point is performed to determine the temperature that begins to flow of asphalt and maximum temperature before rutting deformation of asphalt mixtures begins to increase. It is stated that asphalt, has a high softening point will not flow during process and will be low temperature sensitivity [28-29]. In this study, softening point test was carried out according to TS EN 1427 standard to evaluate high temperature performance of asphalt modified with bio-oil. Generally, stiffness asphalt shows lower fatigue resistance and therefore penetration test is performed to determine stiffness of asphalt [28]. In order to determine the stiffness of modified asphalt, penetration test was carried out in comparison with TS EN 1426 standard. Rotational viscometer test carried out according to ASTM D 4402 standard in order to determine the viscosity of asphalt at high temperatures, exposed to asphalt mixtures during production and application. In addition, rolling thin film oven test (RTFOT), pressure aging vessel (PAV), dynamic shear rheometer (DSR) and bending beam rheometer (BBR) were performed to determine performance properties of asphalt (Table 1).

Table 1. Physical and performance properties of 50/70 asphalt

Test	50/70 Asphalt		Standard
Penetration (25˚C)	54		TS EN 1426
Softening Point (˚C)	49.3		TS EN 1427
Ductility (5 cm/min)	>100		TS EN 13589
Rotational Viscometer (cP)	135˚C 470	165˚C 123	ASTM D 4402
Specific Gravity (gr/cm^3)	1.021		TS EN 12607-1
DSR (64˚C)			
G*/sinδ (Pa)	1555.65		
Phase Angle (˚)	88.23		
BBR (-18˚C)			TS EN 14771
Stiffness (MPa)	232.7498		
m-value	0.273		

2.2. Bio-oil obtained from waste plastic material

Polymers as additive material to increase performance of asphalt and improve properties of asphalt mixtures are used. Use of waste polymer materials in asphalt and asphalt mixtures both can reduce environmental pollution of waste materials and the problem of disposal in landfills. In these studies, carried out by Abdulkhabeer et al. (2021) [30] and Moubark et al. (2017) [31], waste polypropylene (WPP) and polypropylene which are the most popular polymer with good plastic properties was used to improve mechanical properties of asphalt and asphalt mixtures, respectively. According to obtained results, asphalt modified with polymers were increased the physical properties of asphalt mixtures containing modified asphalt. In this study, waste recycled polypropylene in granular form (Figure 1) obtained from the recycling collection and separation textile factory in Gaziantep province was provided. The pyrolysis method was used to recycle this waste plastic material. Bio-oil (PPB), bio-char and gas were obtained by burning waste recycled polypropylene in granular form with nitrogen gas in an oxygen-free environment.

Figure 1. Appearance of materials used in this study

3. Methods

In the study, pyrolysis method, Vialit, Nicholson and California tests were carried out.

3.1. Pyrolysis method

The pyrolysis method is heated biomass in an oxygen-free environment, and they break down into simpler hydrocarbons. Biomass is classified as woody (stem, branch, chips of different trees), agricultural, aquatic biomass (microalgae, plants and microbes found in water), human, animal and industrial wastes. When different biomass is burned in the absence of oxygen, bio-oil, bio-char and non-condensed gas (CO, CO2, CH_4, and H_2) are obtained. Properties of materials obtained from the pyrolysis method are affected by biomass composition, reaction conditions (temperature, residence time, particle size), presence of catalyst (catalytic and thermal pyrolysis), residence time [9, 32]. Within scope of the study, after waste recycled polypropylene in granular form in the reactor of the pyrolysis device was placed, the reactor is placed in temperature oven at 500˚C (Figure 2). During the pyrolysis method, nitrogen gas is introduced to remove oxygen from the reactor. Thus, when the studies in the literature are taken into consideration [17, 33, 34], waste recycled polypropylene in granular form was burned with nitrogen gas for 45 minutes with a ratio of 15˚C/min when the device reached a temperature of 500˚C.

Figure 2. The pyrolysis device

3.2. Modification parameters of asphalt and bio-oil

The mixing of asphalt and different plastic materials is carried out in two ways: dry and wet mixing methods. Dry mixing method is addition of asphalt at a determined ratios after adding plastic waste materials to the aggregates. In this method, the use of hard plastics, have high melting points such as PET and HDPE is commonly preferred. Since thermal behavior of asphalt modified with different polymers enhanced, the wet mixing method is used for polymer asphalt modification. Polymers have low melting temperatures such as low-density polyethylene (LDPE), PP and ethylene-vinyl acetate copolymer (EVA) are preferred in the wet mixing method. The parameters (temperature, mixing time, ratio of modifier) used in modification of asphalt with different waste plastic materials depend on only on properties of asphalt and waste plastic materials but also on specific requirements of the asphalt [35-37]. Considering the studies, conducted by Shirzad et al. (2024) [38], Dalhat and Wahhap (2017) [1], bio-oil (1-3%) was blended with 50/70 asphalt at 160°C and 3000 rpm for 30 minutes using a temperature-controlled mixer.

3.3. Adhesion and stripping tests

Different factors such as aggregate properties (porosity, texture, mineralogy, chemical composition, and size), design, construction, traffic and temperature affect the adhesion of the chip seal and asphalt pavement. It is determined that the most important factors affecting adhesion between aggregate and asphalt in the chip seal are chemical composition and size of aggregates [39-41]. In addition to these factors, due to the water and traffic density on asphalt pavements, deterioration on asphalt pavements is observed as a result of the decrease in adhesion between asphalt and aggregates. The Vialit test according to the Highway Technical Specification (2013) was carried out to investigate the effect of 50/70 asphalt and asphalt modified with PPB (1-3%) and aggregates under the influence of water.

One of the most important parameters, affected performance of asphalt mixtures is resistance to moisture susceptibility. Resistance to moisture susceptibility of asphalt mixtures depends on the type of aggregate source (calcium carbonate, dolomite, granite), the chemical and physical properties of the asphalt, traffic level, environment conditions and different additives added to aggregate and asphalt. For example, asphalt modified with waste plastic modifiers have better resistance to moisture susceptibility than neat asphalt [42-43]. Therefore, Nicholson and California stripping (Figure 3) tests were carried out to investigate adhesion between 50/70 asphalt and asphalt modified with PPB (1-3%) and aggregates under the influence of water and humidity.

Figure 3. California stripping test device

3.4. Statistical analysis

Statistical analysis is preferred to examine statistically significant differences between obtained results. Kruskal-Wallis H and Mann-Whitney U tests are used as an alternative when the data does not show normally distribution. Kruskal-Wallis H Test for Oneway Analysis of Variance (ANOVA) by ranks is the nonparametric equivalent of the parametric Oneway Analysis of Variance (ANOVA). The Kruskal-Wallis H Test is preferred in cases where the statistically significant differences between three or more groups is determined, and the data is not provide with normal distribution [44-46]. In the study, the significant of changes in the values by adhesion and stripping tests according to different PPB ratios (1-3%) were examined by Kruskal-Wallis Test and Mann-Whitney tests.

4. Results

In this section, the results of adhesion and stripping tests, performed on loose asphalt mixtures prepared with 50/70 asphalt and asphalt modified with PPB (1-3%) are given.

4.1. Results of vialit test

100 limestone aggregates spread on 50/70 asphalt and asphalt modified asphalt with PPB (1-3%), distributed homogeneously on the flat steel plate used in the vialit test, were conditioned in a water bath at 40˚C temperature for 24 hours. After a 500±5 g steel ball is thrown over the conditioned the flat steel plate, the number of aggregates falling from the plates is given in Figure 4. According to the obtained results, while the number of aggregates falling from 50/70 asphalt and asphalt modified with PPB at ratio of 1% was equal, the number of aggregates falling from asphalt modified with PPB at ratio of 2% decrease. Similar to the results of the study conducted by Saltan et al. (2020) [47], as the ratio of PPB added to 50/70 asphalt increases, the adhesion of asphalt modified with PPB to aggregates increases. Considering the adhesion properties of asphalt modified with PPB to aggregates, in the study conducted by Karadağ (2023) [48], the use of this material as tack coat on the interface between binder and wearing courses was investigated.

In the study carried out by Bagampadde et al. (2013) [49], they determined that a secondary network formed as a result of the interaction of polymers with the molecules in the asphalt during the modification of 50/70 asphalt. In this study, it is thought that the second network formed during the modification of PPB with 50/70 asphalt positively affects the adhesion between the asphalt modified with PPB and the aggregates. Thus, it is thought that as the PPB ratio, added to 50/70 asphalt increases, adhesion between aggregates and modified asphalt increased. Use of asphalt modified with PPB in the chip sea, widely used in countries such as Turkey, Australia and South Africa is recommended. The use of modified asphalt will provide better performance, especially in the chip seal, exposed to heavy traffic and different temperature conditions. Moreover, the use of asphalt modified with waste material in the chip seal results is reduced consumption of natural resources.

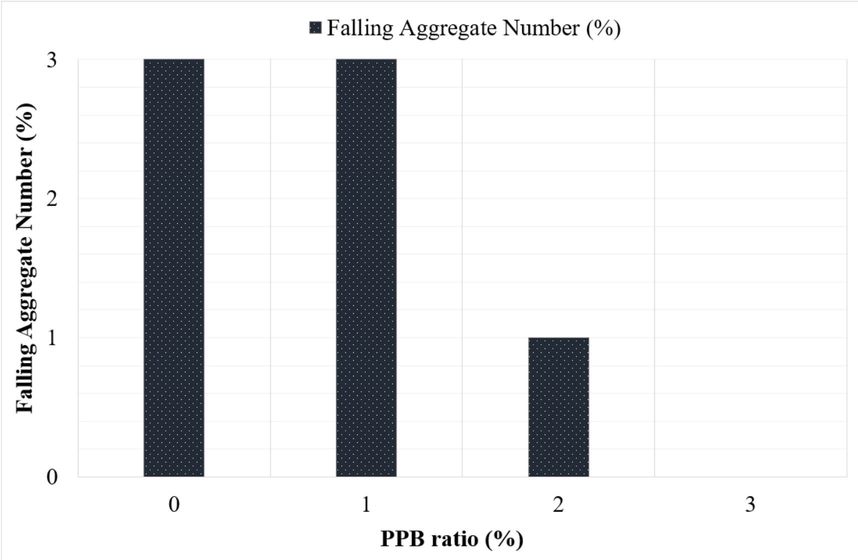

Figure 4. Results of Vialit test

4.2. Results of nicholson stripping test

Stripping occurs in the pavement due to different factors such as the decrease in bonding between aggregate and asphalt, traffic, construction practices, properties of aggregate and asphalt [50-51]. In order to reduce the stripping, occurred in the pavement, the stripping resistance of modified asphalt under influence of water and humidity was investigated. Aggregates remaining without stripping for loose asphalt mixtures containing both 50/70 asphalt and asphalt modified with PPB (1-3%) is given in Figure 5. It is seen that the percentage of aggregate remaining without stripping in all loose asphalt mixtures under influence of water and humidity provided specification limit value determined as 60%. The loose asphalt mixture containing asphalt modified with PPB at the ratio of 1% showed better resistance to the effects of water and humidity. Modified asphalt from the aggregates was stripped due to the increase of polar constituents on surface of modified asphalt and water penetrating into interface of loose asphalt mixtures prepared with asphalt modified with PPB (1-3%) during the conditioning of the Nicholson stripping test [52]. Similar to the results of the study conducted by Liu et al. (2014) [53], it was determined that moisture susceptibility of loose asphalt mixtures containing asphalt modified with PPB, has a low softening point was low.

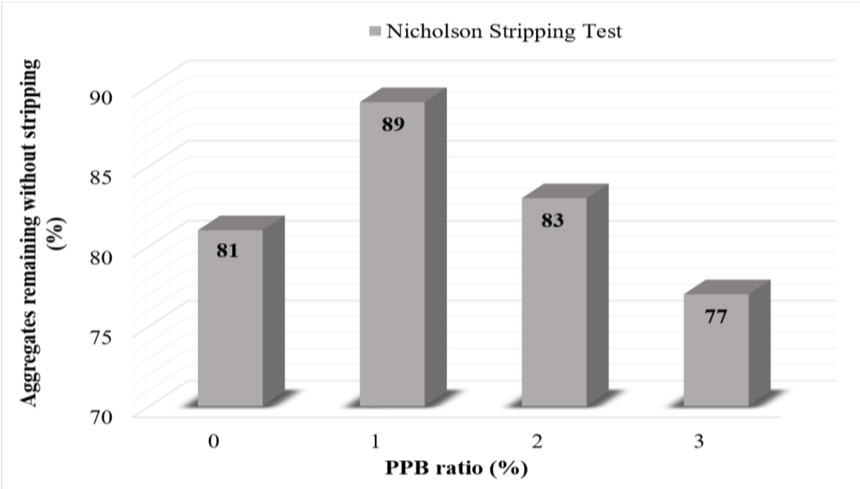

Figure 5. Results of Nicholson test

4.3. Results of california stripping test

Depending on the seasonal conditions (high temperature, rain, freeze-thaw, salty) which the pavement is exposed, the adhesion between asphalt and aggregates decreases due to water infiltration [54]. Thus, the California Stripping test was conducted to examine the effect of rain on loose asphalt mixtures prepared in the laboratory. In the California Stripping test, it is observed that stripping percentage of asphalt modified with PPB (1-3%) increased according to 50/70 asphalt (Figure 6). The loose asphalt mixture containing asphalt modified with PPB at the ratio of 2% showed the best performance. The loose asphalt mixtures containing asphalt modified with bio-oil according to 50/70 asphalt showed less resistance to water movement.

When the results of stripping tests were examined, loose asphalt mixtures prepared by using asphalt modified with PPB (1-3%) showed better stripping resistance. Since the loose asphalt mixtures were conditioned under water and moisture conditions in the Nicholson stripping test, asphalt modified with PPB at ratios of 2 and 3% which were softer than asphalt modified with PPB at ratio of 1% showed less stripping resistance. Asphalt modified with PPB (1-3%) showed lower stripping resistance than 50/70 asphalt under temperature conditions in the California stripping test due to the decrease in adhesive bond between aggregate and modified asphalt with increasing temperature [55]. Asphalt modified with PPB at ratio of 2% is considered to be the optimum ratio for stripping resistance while asphalt modified with PPB at ratio of 1% is found to be insufficient for stripping resistance, under temperature conditions. According to the obtained results, factors such as water, humidity and temperature affect adhesion and stripping performance between modified asphalt and aggregate. Considering adhesion performance of asphalt modified with bio-oil, use of asphalt modified with PPB at ratio of 3% is recommended. Considering stripping performance of modified asphalt, the use of asphalt modified with PPB at ratio of 1% should be preferred.

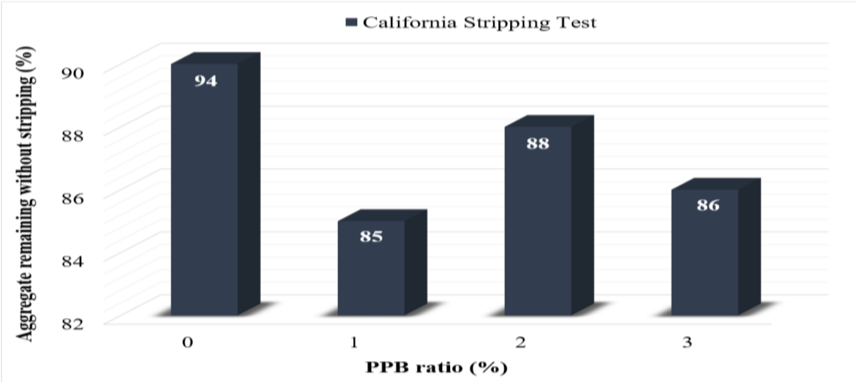

Figure 6. Results of California test

4.4. Results of statistical analysis

Kruskal-Wallis test was performed to investigate whether there was statistically significant differences between adhesion and stripping performances of loose asphalt mixtures prepared with asphalt modified with PPB (1-3%). The obtained values from these tests were interpreted for different PPB ratios which p-value is less than 0.05 meaning level. The Mann-Whitney U test was performed to understand the significance between group variables. It is observed that adhesion performance of loose asphalt mixtures prepared with asphalt modified with PPB at ratio of 3% (p-value <0.05) is statistically higher than asphalt mixtures containing PPB at ratios of 0-1% (Table 2). The difference in Vialit values was statistically insignificant when the additive ratio is 1% or 2%. It was concluded that the additive ratio of PPB should be at least 3% in order to affect adhesion performance of the 50/70 asphalt. In the adhesion test, loose asphalt mixture prepared by using asphalt modified with PPB at ratio of 3% showed 100% adhesion performance, which proved to be consistent with the statistical analysis result.

Table 2. Results of statistical analysis

Group Variables	Dependent Variables	Kruskal-Wallis Test p-values
3% - 2%	Adhesion performance	0.281
3% - 1%		0.027*
3% - 0%		0.014*
2% - 1%		0.256
2% - 0%		0.169
1% - 0%		0.811
3% - 0%	Nicholson stripping performance	0.454
2% - 0%		0.100
1% - 0%		0.007*
3% - 2%		0.369
3% - 1%		0.052
2% - 1%		0.295
1% - 0%	California stripping performance	0.653
2% - 0%		0.061
3% - 0%		0.002*
2% - 1%		0.155
3% - 1%		0.009*
3% - 2%		0.231
*** Meaningful at 0.05 significance level**		

According to the statistical analysis results, loose asphalt mixtures prepared by using asphalt modified with PPB at ratio of 1% showed statistically better resistance to stripping than asphalt mixtures containing PPB at ratios of 0, 2, and 3%. It is observed that increase in the PPB ratio which is added to 50/70 asphalt is not statistically significant in stripping resistance of loose asphalt mixtures. The best stripping resistance of loose asphalt mixtures prepared by using asphalt modified with PPB at ratio of 1% in the Nicholson stripping test is consistent with the statistical analysis result.

In the statistical analysis of California stripping test, loose asphalt mixtures prepared by using 50/70 asphalt are statistically better resistance to stripping than asphalt mixtures containing PPB. PPB additive which is added to 50/70 asphalt is not statistically effective on stripping resistance performance of loose asphalt mixtures to temperature and water movement. The high stripping resistance to water movement of loose asphalt mixtures prepared by using 50/70 asphalt in the California stripping test is consistent with the statistical analysis result.

5. Conclusions

Plastic materials (polypropylene, polystyrene, polyethylene terephthalate and nylon), widely used in packaging during COVID-19 pandemic, caused an increase in waste plastic materials in our environment. In our study, bio-oil from waste recycled polypropylene in granular form with the pyrolysis method in order to reduce environmental pollution caused by these waste plastic materials and to improve properties of asphalt was obtained. Vialit, Nicholson and California Stripping tests were carried out to investigate adhesion of loose asphalt mixture containing asphalt modified with bio-oil under the influence of water and humidity. According to the Vialit test result, as the ratio of bio-oil added to 50/70 asphalt increased, the bonding property of modified asphalt with aggregates increased. In Nicholson Stripping test result, the loose asphalt mixture containing asphalt modified with PPB at the ratio of 1% showed better resistance to the effects of water and humidity. However, the loose asphalt mixtures containing asphalt modified with bio-oil according to 50/70 asphalt showed less resistance to rainwater movement, simulated in laboratory conditions and temperature in California Stripping test. Moreover, the obtained results are consistent with the statistical analysis method. Considering the adhesion performance of modified asphalt, use of asphalt modified with PPB at ratio of 3% is recommended. Considering stripping performance of modified asphalt, the use of asphalt modified with PPB at ratio of 1% should be preferred. This study demonstrated that bio-oil derived from recycled polypropylene enhances the adhesion properties of 50/70 asphalt while reducing environmental waste.

6. Author Contribution Statement

In the study, Author 1 contributed to, making design, the analysis of results and provision of materials. Author 2 contributed to, forming idea, examination of results and checking spelling and checking article in terms of content.

7. Ethics Committee Approval and Conflict of Interest

"There is no conflict of interest with any person/institution in the prepared article"

8. Ethical Statement Regarding the Use of Artificial Intelligence

No artificial intelligence-based tools or applications were used in the preparation of this study. The entire content of the study was produced by the authors in accordance with scientific research methods and academic ethical principles.

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