Potentials of plastic oil as Buton asphalt solvent

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Abstract. Plastic is a polymer that is difficult to be decomposed, one way to decompose it through pyrolysis. Buton Asphalt (Asbuton) has a high hardness (low penetration) so Asbuton cannot be used directly. Therefore, its use must be mixed with other asphalt which is softer, lighter oil, or other solvents. This research looks the effect of quality Plastic-type Low-Density Polyethylene (LDPE) to the potential of plastic oil resulting from the pyrolysis of plastic waste as asphalt solvent in Asbuton. Based on the quality of the LDPE plastic used in this study be distinguished; LDPE-White, Mix-plastic LDPE, and Blend-Plastic LDPE. From this case study, it can be concluded that based on its chemical compound, all plastic oils produced in this study can be categorized as carbon compounds rather than hydrocarbon compounds and only oils from LDPE blend-plastics contain carbonyl groups. Therefore, the oil is more suitable to be used as a solvent or solvent.

1. Introduction

There are two types of pavement system used in Indonesia, namely: flexible pavement and rigid pavement. Flexible Pavement is the most widely used type of pavement because it is considered more economical in terms of development and maintenance [1]. Bending material is usually known as asphalt. According to the American Society for Testing and Materials, Asphalt is a material that has a dark brown to black, solid, or semi-solid consisting of natural bits or obtained from petroleum residues.

The American Association of State Highway and Transportation Office [2], the type of asphalt can be determined based on penetration rates on the asphalt used. The greater the penetration value of the asphalt, the lower the level of asphalt hardness. Each level of penetration in asphalt can be used in a mixture of asphalt aggregates such as 40/60, 60/70, 80/100 penetration. In Indonesia, the type of asphalt used is asphalt penetration 60/70 and asphalt penetration 80/100. The Buton asphalt (Asbuton) is a natural asphalt with deposits located in the area of Buton, Southeast Sulawesi. The content in asbuton consists of asphalt and minerals which have been mixed into one unit with bitumen content of 15% - 30% and minerals 70% - 85% [3]. Penetrations of less than 30 with this nature of asbuton can be used as a binder asphalt mixture. However, because asbuton has a high hardness (low penetration), asbuton cannot be used directly. Therefore, in its use, it must be mixed with other asphalt which is softer, lighter oil, or other solvents.

Previous studies have been shown that the use of solvents that are most often used in asbuton includes gasoline/Naptha, kerosene, and diesel. In this study, the solvent used in the asbuton mixture is a light
oil derived from the pyrolysis of plastic waste. Besides being used as a solvent, the utilization of the pyrolysis results of this garbage will also reduce the quantity of plastic waste that continues to grow every day. Therefore, this study aims to determine the potential of plastic oil as a solvent (solvent) asphalt. In the next section gives a brief description on the existing relevance studies and method used in this research. The finding, discussion, and conclusion of this work are presented at the end of this paper.

2. Materials

2.1 Solvents in Asbuton
Asbuton is a natural asphalt found from the island of Buton, Southeast Sulawesi. Generally, solid asbuton is formed naturally due to geological processes. The process of the formation of asbuton derived from petroleum which is pushed to the surface to infiltrate between the pivot rocks [4]. There are two main types of elements in Asbuton, namely asphalt (bitumen) and minerals. The use of this element in asphalting work will affect the planned asphalt pavement performance. Asbuton extraction which still has minerals between 50% to 60% has a relatively low level of workability so that asbuton can be used it requires solvents or solvents. Solvents that are often used in asbuton are usually derived from naphtha and kerosene. Solvents (solvents) can be added to asbuton to increase emulsification, reduce settlement, increase curing rates at low temperatures, and provide proper binder viscosity after curing. The maximum amount of solvents in asbuton is usually predetermined or contains up to 25% solvents to provide proper workability performance characteristics.

Based on a study conducted by [5], solvents used to extract pure asbuton bitumen are Trichlor Ethylene (TCE), Tetra Hydro Furan (THF), ethyl acetate, acetone, furfural, toluene, limonene, bromopropan, and turpentine. From the results of the research conducted, all data show that, even though the classification of pure Asbuton is the same as the classification of asphalt pen 60 oils, but after being mixed with aggregates in hot asphalt mixtures, pure Asbuton has a better tendency than oil asphalt. Solvents (solvents) that have been done in previous studies are the result of extraction between pure asbuton bitumen and chemicals which are still relatively difficult to obtain sources. A source of solvents that can be used through easily available materials is plastic. LDPE plastic can be used as an economical asbuton solvent by pyrolysis of plastic to produce plastic oil. This oil will be a solvent that can be used in Asbuton.

2.2 Pyrolysis of plastic waste into plastic oil
The production of plastic waste in Indonesia is very large because Indonesia's total waste production reaches 189-kilo tons/day far greater than the countries in Southeast Asia [6]. As of all the plastic waste, LDPE plastic is the most dominant type of plastic (56%) found and 75% comes from household use. This is due to the fact that plastic bags which are actually LDPE plastic are very widely used in daily life. One of the uses of plastic waste in improving the quality of asbuton is by conducting plastic pyrolysis into the oil. The process of breaking down plastic waste into liquid quality fuel products is called pyrolysis.

The pyrolysis process is the process of fractionating material by temperature. The pyrolysis process is also known as a thermal cracking process, namely the breaking of the polymer structure by heating the polymer material without oxygen or a little oxygen. The pyrolysis process starts at a temperature of around 200°C when components that are thermally unstable and volatile matter in the waste will break and evaporate together with other components. This pyrolysis process is a thermal decomposition process of organic material at high temperatures without oxygen. One of the factors that influence the pyrolysis process is temperature, which temperature has an important role in the thermal cracking reaction that occurs during the pyrolysis process.

Plastics that undergo pyrolysis process will be decomposed into materials in the liquid phase in the form of fuel oil, gas phase in the form of a mixture of gas that can be condensed or cannot be condensed and solid phase in the form of residues or tar [7]. Compared to biofuels such as biodiesel and bioethanol,
oil from plastic pyrolysis has several advantages. Pyrolysis oil does not contain water, so the caloric value is greater. In addition, pyrolysis oil does not contain oxygen so it does not cause corrosion [8]. Furthermore, Pyrolysis oils are flammable, have a pungent odor, and release soot. Although it has unsaturated properties, this plastic oil can be reprocessed until it has a saturated and stable nature [9]. The utilization of LDPE plastic waste into oil by the pyrolysis process was also carried out by [10]. The results of his research show that the pyrolysis process is needed within 2 hours at a temperature of 250°C with a pressure of 2 bar to produce 525mL of oil. However, they found that it has limitations regarding the inability of the tool to determine the value of the flashpoint.

2.3 Solvent (solvent) asphalt

The solvent is a diluent that is mixed into the asphalt cement to become somewhat liquid so that it can be used as a road construction material. Solvent usually divided by chemical structure or physical characteristics. Solvent classification based on its chemical structure, including:

1) Hydrocarbons, this group is further divided into three subgroups, namely: aliphatic, aromatic, and halogenated hydrocarbons. While the aliphatic subgroup is subdivided into saturated and unsaturated aliphatic. Hydrocarbon group solvents are almost entirely derived from petroleum distillation which is a mixture of several sub-groups (not pure compounds), so that the boiling point is in the range from minimum to maximum, not a single boiling point.

2) Oxygenated solvent, the Oxygenated solvent or solvents with oxygen atoms are solvents whose chemical structure contains oxygen atoms. Included in this category are esters, ketones, and alcohol esters.

- Solubility Solvent parameter: hydrocarbon solvents have a proportional relationship to the price of Kauri Butanol (KB); the greater the price of the KB, the greater the solubility parameter or in other words the greater the solubility of the solvent. For some aliphatic hydrocarbon solvents range from 28 - 40, while for aromatic hydrocarbons greater than 70.
- Hydrogen Bonding Index is a measure of the strength of the bond between hydrogen atoms (relatively positive) and negative atoms such as oxygen in the solvent, the price ranges from -15 to +18.

2.4 Solvent selection factor

According to the previous study conducted by [11] the solvent selection is generally influenced by the following factors, including (1) Selectivity, the solvent must have high selectivity, the solubility of the substance to be separated in the solvent must be large, while the solubility of the impurity solid is small or neglected. Solubility Able to dissolve large solutes or according to the needs of the solvent; (2) Unmixed, Solvents must not dissolve in extraction materials; (3) Density, it has a large difference in density between the solvent and the dissolved material; (4) Reactivity, Solvents must not cause chemical changes in the components of the solute; (5) Boiling point, the boiling points of the two ingredients (solvent and dissolved) must not be too close and may not form azeotropes, and (6) Other criteria, Solvents are available in large quantities, non-toxic, non-flammable, non-explosive when mixed with air, non-corrosive.

2.5 Effect of solvent on asphalt properties

Solvent or solvent has a function as a material that reduces the viscosity of asphalt, especially Asbuton, making it easier to do work using the Asbuton. The right solvent composition will also have an optimal effect on the evaporation of existing solvents. Analysis and testing conducted by [12] on the type of solvent for asphalt extraction in asphalt concrete wearing course (AC-WC) strength explained that a solvent that has a high octane will dissolve the asphalt more completely. That is because asphalt contains Asphaltenes and maltenes asphaltenes which dissolve easily in heptane mixed with octane.
3. Methods
This study describes LDPE plastic by pyrolysis non-catalysis in the laboratory so that the results obtained from the potential of plastic oil from plastic waste as solvent (Asbuton) asphalt. The reactor used, as shown in Figure 1, is a retort equipped with a thermocouple and regulator to maintain a stable operating temperature. Retorts from these devices are 60 x 60 x 30 cm. The reactor has three liquid outlets; 1, 2, and 3. The plastic used as input has three variations in the quality of LDPE plastics, namely White LDPE plastics (P-plastics): plastics derived from white-colored plastic bags; Mix-plastic LDPE (plastic-M) is plastic that comes from a mixture of plastic bags of various colors; and LDPE-plastic Blend (plastic-B), as shown in Figure 2.

The result of pyrolysis yield in the form of plastic oil is known by weighing the liquid (oil: M-1, M-2, and M-3) produced at any given time interval. At the end of pyrolysis, the solid (residue) left in the retort is weighed to determine its weight. The amount of gas wasted from the pyrolysis process is known from the difference between the input weight and the total weight of the oil yield and residue. To see the potential of plastic oil on Asbuton, the Fourier Transforms Infrared (FTIR) analysis was performed. This analysis is used to determine the functional groups contained in the sample variations in the quality of the plastic. The test was carried out in the Chemical Engineering laboratory, Bandung Institute of Technology (ITB), Bandung of Indonesia.

Figure 1. Pyrolysis reactor equipment.

Figure 2. Typical counts and quality of LDPE plastics: (a) white LDPE; (b) Mix-plastic LDPE; (c) Blend-plastic LDPE.
4. Results and discussions

4.1 White LDPE plastics (plastics-P)

Figure 3, 4 and 5 illustrates that the oil produced by white LDPE plastic pyrolysis, namely P-1, P-2 oil, and P-3 oil has a relatively equal (infrared) X-ray absorption distribution. It has 10 absorption peaks. Also, these oils contain types of chemical chain compounds or groups, namely: single bonding alkene (CH), aromatic ring (CH), alkane (CH), double bonding alkene (C = H), hydrogen bonding alcohol and phenol (OH), amines and amides (NH). Thus, it can be said that the oil obtained from the pyrolysis of white LDPE plastic not only contains hydrocarbon compounds but also other compounds. Therefore, it is not classified as a hydrocarbon compound but classified as a carbon compound.

Figure 3. White plastic oil spectrophotometry: P-1 oil spectrophotometry LDPE.

Figure 4. White plastic oil spectrophotometry: P-2 oil spectrophotometry.

4.2 LDPE mix-plastic pyrolysis (Plastic-M)

Figure 6, 7 and 8 reveals that the FTIR test results are shown on the LDPE mix-plastic pyrolysis oil, which is M-1 oil; M-2 and M-3 oil. It seems that the distribution of infrared rays from M-2 oil and M-3 oil is relatively the same and different from the infrared distribution from M-1 oil. The infrared distribution of M-2 oil and M-3 oil has 11 absorption peaks, while M-1 oil has only 10 absorption peaks.
Even though they have different infrared peak peaks, however, these oils contain relatively similar types of compounds or major chemical chain groups.

**Figure 5.** White plastic oil spectrophotometry: P-3 oil spectrophotometry.

**Figure 6.** Plastic-mix oil spectrophotometry: M-1 oil spectrophotometry.

**Figure 7.** Plastic-mix oil spectrophotometry: M-2 oil spectrophotometry.
Figure 8. Plastic-mix oil spectrophotometry: M-3 oil spectrophotometry.

Figure 9. Plastic-blend oil spectrophotometry: B-1 oil spectrophotometry.

Figure 10. Plastic-blend oil spectrophotometry: B-2 oil spectrophotometry.
4.3 Blend-plastic pyrolysis (Plastic-B)

Figure 9, 10 and 11 have shown that the oil produced by LDPE blend-plastic pyrolysis, namely B-1 and B-2 oils has a relatively similar distribution of infrared light absorption and differs from the spread of infrared absorbing of B-3 oil. The distribution of infrared light absorption of B-1 and B-2 oils has 11 absorption peaks while B-3 oil has 13 peaks. The B-1 and B-2 oils contain the same types of compounds or chemical chain groups, namely: single bonding alkene (CH), aromatic ring (CH), alkane (CH), double bonding alkene (C = H), aldehydes, Kenton, carboxylic acids, and esters (C = O), hydrogen and phenol (OH) bonding alcohols, amines, and amides (NH). While the B-3 oil contains a single bonded alkene (CH), aromatic ring (CH), alamides and amides (NH), amines and amides (CN), nitro compounds (NO2), alkanes (CH), double bonding alkenes (C = H), aldehydes, Kenton, carboxylic acids, and esters (C = O), hydrogen and phenol (OH) bonding alcohols, amines, and amides (NH). Thus, it can be said that the oil obtained from the LDPE blend-plastic pyrolysis does not belong to the group of hydrocarbon compounds but can be classified as carbon compounds.

![Figure 11. Plastic-blend oil spectrophotometry: B-3 oil spectrophotometry](image)

4.4 Oil categories

LDPE type plastic pyrolysis process carried out in this study produces three outputs in the form of plastic oil. All pyrolysis oils are known that plastic oil from white LDPE plastic is liquid and bright yellow to light brown. Plastic oils from the LDPE plastic mix are also liquid and brown to black. Whereas oil from the LDPE blend-palette is black and only B-1 and B-2 oils are liquid. The B-3 oil hardens (freezes) at ambient temperatures but is liquid at relatively high temperatures.

The boiling point, the oil produced by pyrolysis of white LDPE plastic, LDPE plastic mix, and LDPE blend-plastic can all be classified as gasoline, heavy gasoline (naphtha) and kerosene (kerosene). However, although the pyrolysis process of each LDPE plastic produces oil in the same category, the quality and color of the oil are different. This difference is believed to be due to differences in color, uniformity of the LDPE plastic used. All the plastic oils produced in this study, only B-3 oil is the closest to the characteristics and chemical groups of asphalt and is best used as an asphalt modifier.

5. Conclusions

There are several conclusions can be addressed according to this study:

a. Based on its chemical compounds, all plastic oils produced in this study can be categorized as carbon compounds rather than hydrocarbon compounds.

b. Based on its chemical group, only oil from LDPE blend-plastic contains carbonyl groups. Therefore, the oil is more suitable to be used as a solvent or a hydrocarbon solvent.
c. B-3 oil is more suitable to be used as a solvent than B-1 and B2 oils because it has a CSR value of 9.5 and 13 times the CSR value of B-1 and B-2 oils and is a type of hydrocarbon solvent.
d. Based on its boiling point, plastic oil produced from LDPE plastic pyrolysis carried out in this study produced 3 types of oil, namely gasoline (P1, M-1 and B-1 oils), naphtha (P-2, M-2, and B oils -2), and kerosene (oils P3, M-3, and B-3).

In this study and research, LDPE plastic oil produced by chemical blend-plastic pyrolysis has the potential to be used as an asphalt solvent, but further studies are still needed to see the effect of oil addition on asphalt rheological properties, especially asphalt with a high level of hardness such as Asbuton.

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