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THE EFFECT OF ADDITIONAL LDPE AND POLYURETHANE ON INCREASING PERFORMANCE OF POROUS ASPHALT MIXTURES

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ABSTRACT

During the COVID-19 pandemic for more than two years, there was an acceleration in increasing LDPE household waste, especially from food packaging. The problem of plastic waste is an issue that requires more attention for reuse. Meanwhile, the urban infrastructure growth is followed by the reduction of water catchment areas, so that surface water runoff causes flooding. Responding to this, porous pavement is a solution for infrastructure development, that has a low impact on the environment. However, the fact is that porous asphalt pavement has low stability, so it is applied to low traffic loads such as pedestrian ways. To overcome this problem, a material that binds asphalt and aggregate is needed. This research aims to utilize LDPE waste to improve the performance of porous asphalt mixtures. The method used is experimental by using Marshall parameters. The results of the study with the addition of LDPE and Polyurethane obtained an increase in the value of stability by 17.35% but, decreased the value of flow by 15.18% and permeability index by 12.07%. The optimum value is adding 2% LDPE and 7.5% Polyurethane so that LDPE can be used as additional material to replace some asphalt materials in porous asphalt mixtures.

Keywords: LDPE, Polyurethane, Ashpalt Mixtures

1. INTRODUCTION

The COVID-19 pandemic conditions that occurred in Indonesia caused many Indonesians to carry out activities at home, so almost all Indonesians stored and consumed food using Low-Density Polyethylene (LDPE) packaging in packaged drinks and others. During the pandemic, many people buy their daily needs through online applications. This has increased the use of plastic as packaging for goods, which has resulted in a rapid increase in the amount of household waste. Meanwhile, infrastructure growth in the last five years has increased. This increase is followed by a reduction in green land, especially in urban areas as water catchment areas. High rainfall in the tropics causes high surface runoff, for some areas high surface water runoff causes flooding. On the other hand, groundwater conditions due to indiscriminate suctioning result in reduced groundwater storage, which in turn will have an impact on land subsidence. Based on these facts, research is needed for the development of a porous pavement layer that is expected to fill groundwater.

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There have been many studies that have developed porous pavements, but the available mixtures are still unable to accommodate the stability or compressive strength of porous pavements. Responding to the increasing number of household waste made from LDPE which must be utilized, it is necessary to conduct research to add waste to the porous pavement mixture. In addition to LDPE, additional materials that can be used to overcome waterlogging are polyurethane polymers. The porous asphalt mixture added with 2% LDPE has affected on increasing the stability value [1]. The porous asphalt mixture if added with polyurethane polymer material can improve the performance of the mixture, because polyurethane has good adhesion properties as a binder, Polyurethane is easy to react in a hot mixture. The increase in the performance of porous asphalt in question is that the asphalt stability value can increase and be able to withstand excessive deformation when the traffic load is passed on it [2].

This research purpose by adding waste material is to determine the effect of LDPE material and Polyurethane Polymer to the porous asphalt mixture on the stability, flow, and permeability values. This porous asphalt mixture can be used to overcome water run off on pedestrian ways. The utilization of plastic waste in asphalt mixtures can reduce the amount of waste and improve asphalt performance. In this research, the porous asphalt mixture will be added with LDPE which has variations in levels of 2%, 3%, and 4%, and polyurethane polymer type A: type B, 50%:50% which has variations in levels of 5%, 7.5%, and 10%. The addition of LDPE and Polyurethane materials is used as a partial replacement for the quantity of asphalt in mix design.

2. Literature Review

2.1. Porous Asphalt Mixtures

A porous asphalt mixture is a mixture used for pavement layers using asphalt binder and has a porosity value that can drain water. The aggregate gradation in this pavement layer is an open gradation with the characteristics of using more coarse aggregate compared to fine aggregate so that the asphalt mixture has a fairly large pore cavity and can be passed by water, this layer is located above a densely graded layer [3]. Asphalt mixture is a mixture of asphalt as a material that binds aggregates in the mixture. Porous asphalt mixtures are used in the surface layer of road pavements. The porous layer can drain water directly into the roadside channel as drainage so that standing water on the road surface can be handled properly. The aggregate gradation used for the manufacture of porous asphalt mixtures refers to the Australian Asphalt Pavement Association in 2004 with the characteristics of Open Graded Aggregate (OGA) 14, namely the use of the largest aggregate size with a size of 12.5 mm and the National Asphalt Pavement Association (NAPA) in 2002 [4]. The provisions of AAPA OGA 14 have variations in the asphalt content of the plan for the manufacture of porous asphalt mixtures, namely 4.5%-6.5% [5].

2.2. Performance of Porous Asphalt

The performance of pore asphalt is a Marshall characteristic which consists of several parameters, namely stability, and flow. The characteristic of porosity in porous asphalt can be seen in the permeability parameter, the voids in the mixture through which water is passed are an illustration of the time required for water to flow into the porous asphalt mixture [6]. The porous asphalt mixture is designed to have larger air voids than conventional pavements so that standing water on the road surface can pass through the voids in the mixture more quickly. The pore pavement is made with the concept of Low Impact Development (LID) as a green open area that has a good drainage system. Pore asphalt has several advantages, namely, it can reduce traffic noise and can reduce the risk of slipping for road users due to the presence of large voids in the mixture. Pore asphalt has a disadvantage, namely the weak bond in the mixture which makes the durability decrease. According to the Australian Road Standard in 2002, the stability of porous asphalt must be >500 kg, flow 2-6 mm and permeability >0.01 cm/s.

2.3. Plastic Waste LDPE

Low-Density Polyethylene (LDPE) plastic waste is a plastic that is often found in everyday life, such as in food and beverage packaging [7]. The largest composition of waste is from households, namely 46%, while 27% of the 46% of total household waste is sourced from leftover food wrappers (SIPSN, 2021). The COVID-19 pandemic has caused many people to consume plastic-wrapped food and drinks. LDPE has a melting point of 105-115°C which is flexible and difficult to decompose [8]. Porous asphalt mixtures can use coffee drink packaging made from LDPE as a substitute for asphalt material in the mixture.

2.4. Polyurethane Polymer

Polyurethane polymer (-NHCOO-) is a combination of 2 types of substances that react, namely type A (isocyanate) and type B (polyol), the two substances when reacted will form a liquid that can glue and bind other chemicals. Type A substances (isocyanates) provide rigidity properties to Polyurethane substances, while Type B substances (Polyols) provide high flexibility properties to Polyurethane substances. Polyurethane has a melting point of 75-137°C which is easy to react with other chemicals and water absorption of 0.15 – 0.19%, suitable as a water-resistant coating [9]. Polyurethane, has good adhesion properties in porous asphalt mixtures for coatings that can withstand excessive deformation, water resistance, high melting resistance, can prevent corrosion, and provide elastic properties that have the potential to increase the stability of porous asphalt mixtures.

3. Research Methodology

3.1. Collecting Data

The research was conducted in a laboratory using experimental methods. This research was conducted to test the material consisting of aggregate, asphalt, and asphalt mixture. Aggregate testing consists of aggregate sieve analysis, specific gravity and absorption (coarse and fine aggregates), and aggregate abrasion. Asphalt testing consists of ductility, flash and fire point, softening points, density, penetration, coating, and stripping. All material tests used are to the specifications of the Indonesian National Standard (SNI). Asphalt mixture testing consists of Marshall, specific gravity maximum, and permeability. The stages of data collection carried out in the development of a porous asphalt mixture are presented in the form of a flow chart as in Figure 1.

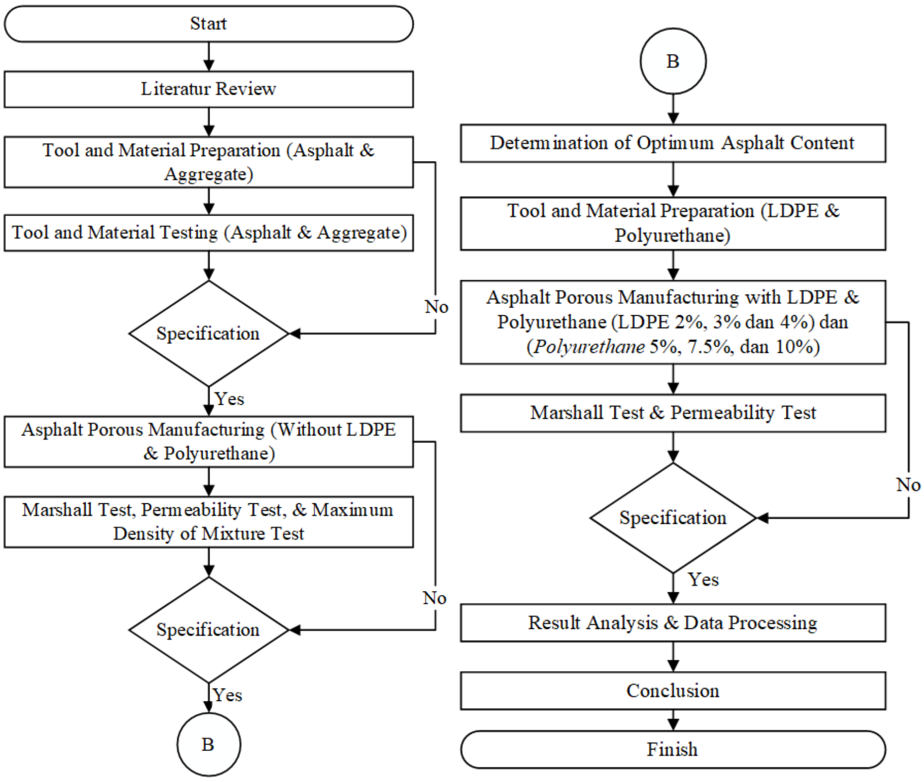

Figure 1. Research Flow Chart

This research begins with a literature review in the form of journals, articles, and books as a theoretical basis and a review of previous research. Preparation and testing of tools and materials are carried out as the next stage before manufacturing asphalt porous to obtain the optimum asphalt content value and the test object with additional waste materials in the form of LDPE and Polyurethane. Then, the manufacture and testing of test objects with predetermined levels are carried out. The test results obtained were analyzed and processed data so that conclusions and suggestions were obtained from the research carried out.

3.2. Mix Design

The design of the porous asphalt mixture is carried out by calculating the material that will be used in the manufacture of the test object. The test objects that will be made under the terms of NAPA and AAPA are 45 specimens with a weight of 1 test object of 1200 gr. In the previous tests, the Optimum Asphalt Content value was obtained by 5%. The KAO is used as asphalt content in the manufacture of test objects with additional materials of LDPE and polyurethane. Variations in the levels of LDPE used were 2%, 3%, and 4%, and the variations of polyurethane used were 5%, 7.5%, and 10% by weight of asphalt.

3.3. Porous Asphalt Test Method

The Marshall test method used in this study refers to SNI 06-2489-1991. Testing using Marshall test equipment which consists of a pressure device that is given with a load. This test is carried out to obtain numbers that measure the Marshall Stability and flow parameters. The Marshall parameter specifications obtained must be by Bina Marga 2018 Revision 2 [10]. Stability describes the magnitude of the pavement's resistance to withstand traffic loads that are passed on it to withstand deformation. Flow describes the magnitude of the vertical decrease experienced by the asphalt mixture due to the loading on it. The requirements for stability and flow values are based on the Australian road standard in 2002, respectively, at least 500 kg and 2-6 mm.

The permeability test method is the ability of water to flow through cavities in a porous asphalt mixture. Permeability value based on Australian Road Standard in 2002, which is > 0.01 cm/s. To measure the coefficient of permeability (k) a permeability tester can be used with the falling head Permeability method, where moving water flows freely through the pore spaces in the pore pavement. Permeability calculation refers to Darcy's Law.

4. Results and Analysis

4.1. Material Test (Aggregate and Asphalt)

The fine aggregate test consists of testing for specific gravity, and absorption, while the coarse aggregate test consists of specific gravity, absorption, coating, and stripping of the aggregate. The test results refer to the requirements of Bina Marga 2018 Revision 2. Aggregate material is suitable for use if it meets the requirements. Coarse and fine aggregate test results are listed in Table 1.

Table 1. Coarse and Fine Aggregate Test Results.

Aggregate Test	Specification	Results
	Fine Aggregate	
Specific Gravity	minimum 2.5 gr/cc	2.51 gr/cc
Absorption	maximum 3%	2.25%
	Coarse Aggregate	
Specific Gravity	minimum 2.5 gr/cc	2.53 gr/cc
Absorption	maximum 3%	1.38%
Abrasion	maximum 40%	27.04%
Peeling Aggregate	minimum 95%	97%

Table 1, presented the results of the overall test of coarse aggregate and fine aggregate material. Both of them have met the requirements of a minimum of 2.5 g / cc. The absorption of coarse and fine aggregates has met the requirements, namely a maximum of 3%, the wear of coarse aggregates has met the requirements of a maximum of 40% and the blanketing of aggregates has met the requirements of a minimum of 95%. Asphalt testing consists of ductility, flash point, burning point, softening point, specific gravity, and penetration. The test results must comply with the requirements of the 6th Division of Highways Division of 2018. Aggregate material is suitable for use if it meets these requirements. The recapitulation of asphalt test results is listed in Table 2.

Table 2. Asphalt Test Results.

Asphalt Test	Specification	Results
Ductility	minimum 100 cm	150 cm
Flash and Burning Point	minimum 200 ºC	318 ºC
Softening Point	48-58 ºC	56 ºC
Specific Gravity	minimum 1 gr/cc	1.14 gr/cc
Penetration	60-70	61.5

Table 2, presents the results of the overall asphalt material testing. Asphalt ductility has met the requirements, namely, at least 100 cm, the flash point and burning point of asphalt have met the requirements, namely at least 200 C, the softening point of asphalt has met the requirements, namely 48-58 C, the specific gravity of asphalt has met the requirements, namely at least 1 gr/cc and penetration already meet the requirements of 60-70. Aggregate and asphalt materials that have met the requirements of Bina Marga Division 6 of 2018 can be used in the manufacture of porous asphalt mixture test specimens with the addition of LDPE material and Polyurethane polymer.

4.2. Porous Asphalt Test

Results and analysis from Marshall testing with additional waste material that has been conducted for a combination of LDPE and *Polyurethane materials* as in Figure 2 and Figure 3. Figure 2 is a comparison of the value of the stability value of KAO to the value of stability with additional materials of LDPE and polyurethane in the porous asphalt mixture. The KAO stability value obtained is 579.30 kg which meets the requirements of the Australian Road Standard in 2002, namely the stability of porous asphalt must be > 500 kg. the addition of 2% LDPE and the variation of polyurethane content of 5%, 7.5%, and 10%, the stability values obtained are 655.59 kg, 700.97 kg, and 690.89 kg, respectively. The addition of 3% LDPE and variations in the levels of Polyurethane 5%, 7.5%, and 10%, obtained Stability values, respectively, of 512.69 kg, 499.85 kg, and 462.94 kg. With the addition of 4% LDPE and variations in the levels of polyurethane of 5%, 7.5%, and 10%, the stability values obtained are 406.67 kg, 404.77 kg, and 401.63 kg, respectively.

The addition of LDPE and Polyurethane which is getting bigger results in a decrease in the stability value which makes the mixture stiff and brittle and affects the mixture bond which makes the pore asphalt easy to break and damage. The optimum stability value is found in the addition of 2% LDPE and 7.5% Polyurethane levels, which is 700.97 kg, which is greater than the KAO Stability of 579.30 kg and has met the Australian road standard requirements in 2002. So the mixture is porous asphalt with the addition of material LDPE 2% and Polyurethane 7.5% can be recommended to be applied to pedestrian paths.

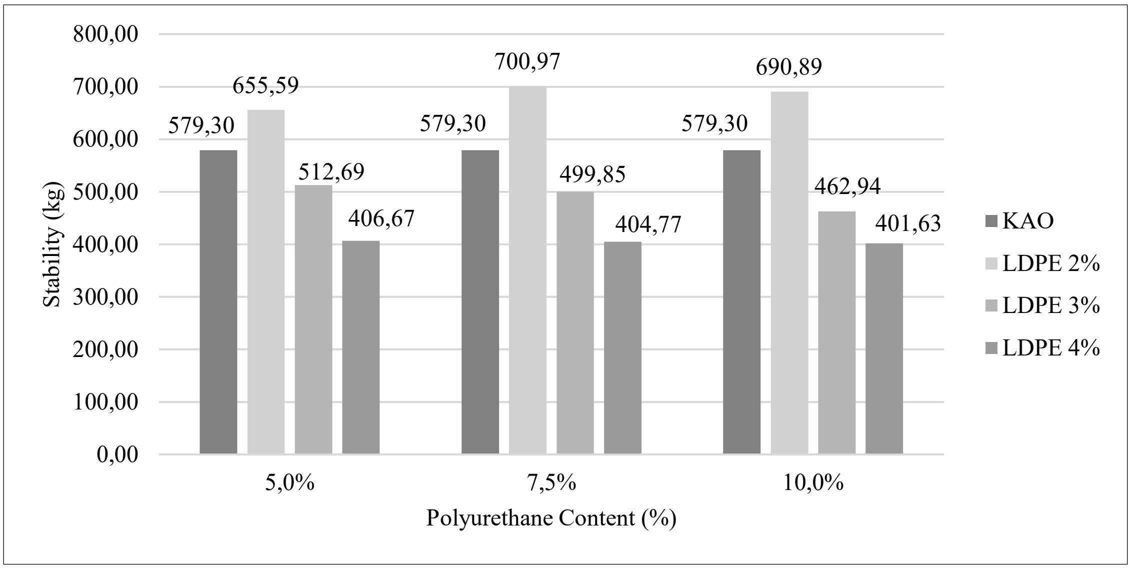

Figure 2. Comparison of Stability Values

Figure 3 is a comparison of the KAO flow value to the flow value with additional LDPE and polyurethane materials. The KAO flow value obtained is 5.27 mm and has met the requirements of the Australian Road Standard in 2002, namely flow 2-6 mm. The addition of 2% LDPE and variations in the levels of Polyurethane of 5%, 7.5%, and 10%, obtained Flow values of 4.40 mm, 4.47 mm, and 4.63 mm, respectively. The addition of 3% LDPE and variations in Polyurethane content of 5%, 7.5%, and 10%, obtained Flow values of 5.77 mm, 5.93 mm, and 6.00 mm, respectively. The addition of 4% LDPE and variations in the levels of Polyurethane of 5%, 7.5%, and 10%, obtained Flow values of 6.50 mm, 6.60 mm, and 6.97 mm, respectively. The KAO Flow value obtained is 5.27 mm.

The addition of LDPE and Polyurethane materials which are getting bigger results in an increase in the flow value, the two additional mixtures affect the bonding of the porous asphalt mixture to be easily broken because the mixture is getting brittle. The best flow value is found in the addition of 2% LDPE and 7.5% Polyurethane levels, which is 4.47 mm whose value met the Australian road standard requirements in 2002. So it can be recommended to be applied to pedestrian paths.

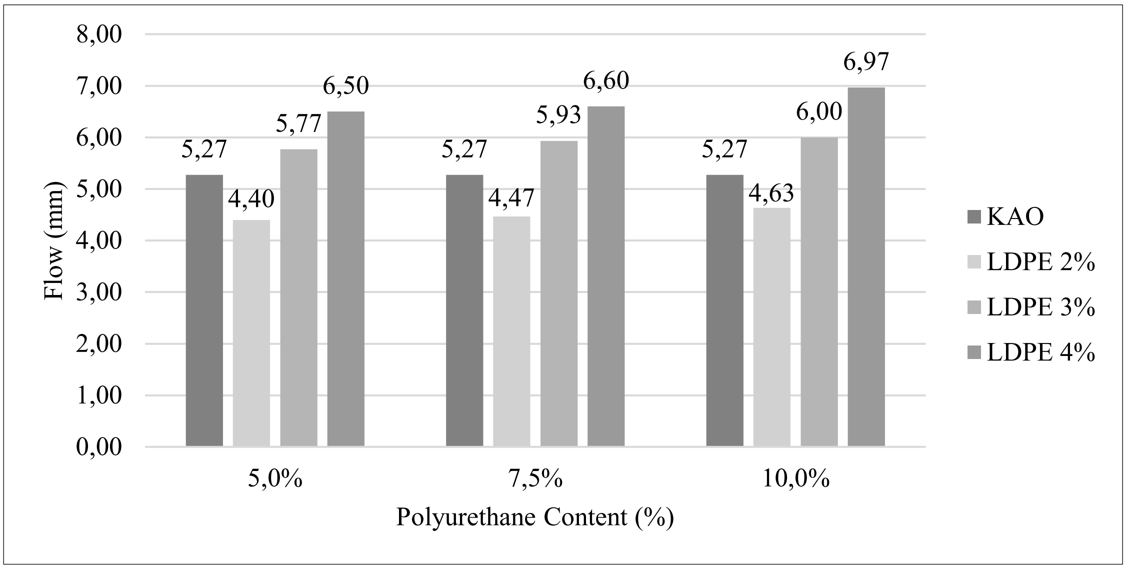

Figure 3. Comparison of Flow Values

Figure 4 is a comparison of the permeability value of KAO to the permeability value with LDPE and polyurethane additives. The KAO permeability value obtained is 0.116 cm/s which meets the requirements of the Australian Road Standard in 2002, namely, permeability > 0.01 cm/s. The addition of 2% LDPE and variations in Polyurethane content of 5%, 7.5% and 10%, the permeability coefficients were 0.104 cm/s, 0.102 cm/s, and 0.103 cm/s, respectively. The addition of 3% LDPE and variations in Polyurethane content of 5%, 7.5% and 10%, the permeability coefficients obtained are 0.104 cm/s, 0.102 cm/s, and 0.101 cm/s, respectively. The addition of 4% LDPE and variations in the levels of Polyurethane 5%, 7.5% and 10%, the permeability coefficients were 0.104 cm/s, 0.103 cm/s, and 0.100 cm/s, respectively. The overall value of the permeability coefficient with the addition of LDPE and Polyurethane when compared with the permeability coefficient of KAO of 0.116 cm/s, the value is slightly smaller than that of KAO meets the requirements because the porous asphalt mixture with the addition of LDPE and Polyurethane materials makes the cavity in the mixture slightly filled. Permeability values have met the Australian road standard specifications in 2002 so that the porous asphalt mixture can be used on pedestrian paths

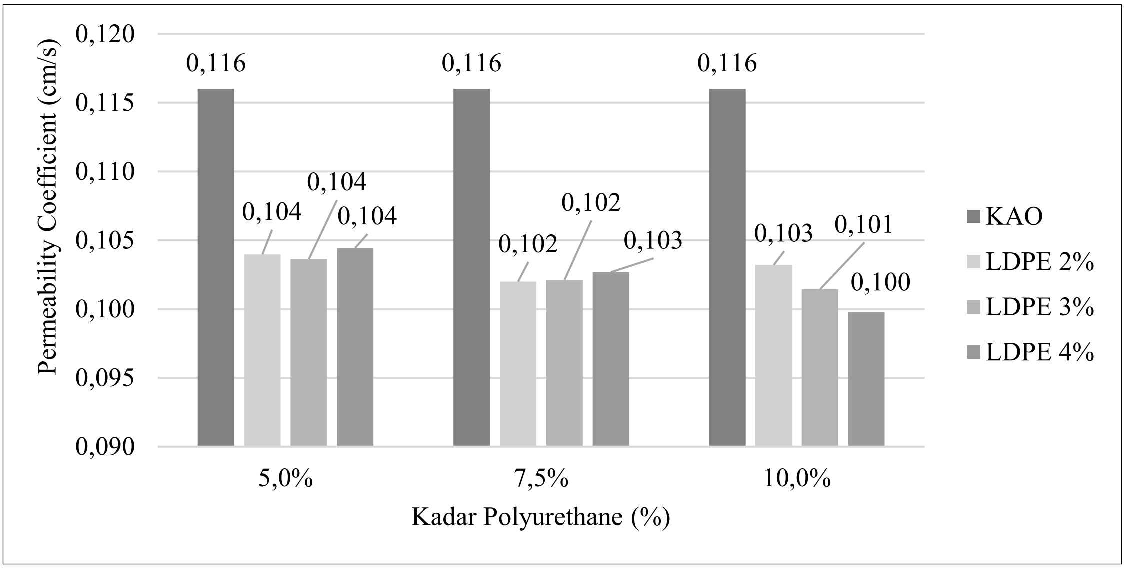

Figure 4. Comparison of Permeability Values

5. Conclusions

Based on the results of the analysis that has been carried out in this experimental research, it can be concluded as follows:

a. The addition of 2% LDPE plastic waste and 7.5% Polyurethane Polymer to the porous asphalt mixture has an effect on increasing the stability value by 17.35% and reducing the flow value by 15.18%.
b. With the addition of 2% LDPE plastic waste and 7.5% Polyurethane Polymer to the porous asphalt mixture, the permeability value of the porous asphalt mixture is reduced by 12.07%, but still meets the specifications for porous pavement according to Australian Road Standard 2002, namely the Permeability value for porous pavement > 0.01.
c. The optimum percentage addition of waste material made from LDPE and Polyurethane Polymer for porous asphalt mixtures is a mixture by adding 2% LDPE waste material and 7.5% Polyurethane Polymer, which provides a stability value of 700.90 kg and a flow of 4.47 mm and has a permeability value of 0.102. cm/s.
d. Waste material from LDPE and Polyurethane Polymer can be used in porous asphalt mix design for pedestrian applications

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