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Study Characteristics of Porous Asphalt Using Aggregates from Karangasem with 60/70 Penetration Bitumen

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ABSTRACT

Porous asphalt is a type of pavement designed to increase the coefficient of friction on the pavement surface. The porous asphalt functions as drainage to drain water in the top layer vertically and horizontally. The method used in this research is an experimental method by making different tests in the laboratory. Stages of works include examining the 60/70 penetration bitumen, aggregate testing, mixing, and preparation of the sample with the variation of asphalt level of 5%, 5.5%, 6%, 6.5%, and 7% with 2x50 Marshall compaction. Volumetric measurement and Marshall testing to get optimum asphalt level. The next test is the cantabro test, permeability test, ITS test, and UCS test at optimum asphalt level. As the results of this study, it was obtained that the value of the optimum asphalt level was 6.15%, the value of Marshall characteristics, namely stability 636.32 kg (specification min. 500 kg), Flow 4.0 mm (specifications 2-6 mm), Marshall Quotient 159.15 kg/mm (specification max. 400 kg/mm), and Marshall VIM 19.828% (specification of 18-25%). At the optimum asphalt level the samples gave Cantabro value of 17.90% (specification max. 20%), vertical and horizontal permeability values of 0.145 and 0.152 cm/sec (specifications 0.1-0.5 cm/sec), ITS value of 158.88 kPa, and UCS value of 916.343 kPa.



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1. Introduction

Porous asphalt is a type of pavement designed to increase the coefficient of friction on the pavement surface. The porous asphalt functions as drainage to drain water in the top layer vertically and horizontally. Indeed, the particle size used has a fraction of coarse aggregates ranging from 70% to 85% of the mixture's volume [1]. This gradation has large pores and causes the relationship between cavity aggregations (interlocking) to be very weak and easy loose, so it has a shorter service life than conventional asphalt mixtures [2]. Porous asphalt is designed with a higher air void percentage to allow water to infiltrate through surfaces faster than conventional asphalt pavement. Normally, the recommended air voids content is between 18 and 25% to provide adequate drain ability during heavy rainfall [3].

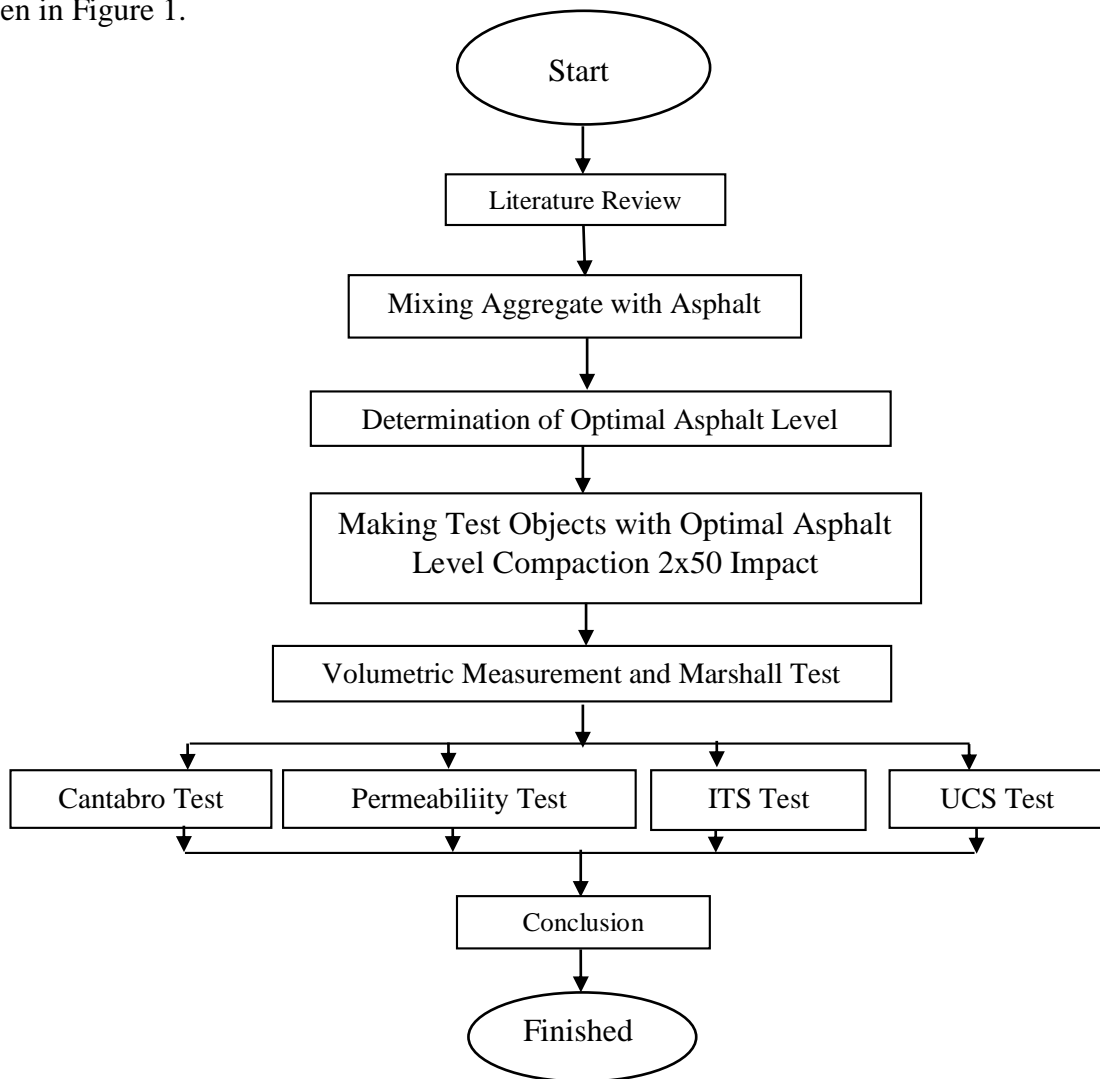
A porous asphalt mixture is dispersed and compacted on a waterproof pavement surface, Waterfalls on a porous asphalt surface seep freely into the coating surface down, then flow sideways [4]. A porous asphalt mixture is usually used for parking lot as the mixture allows water to flow into a stone recharge bed through the pavement surface and penetrate the ground under the pavement [5]. In addition to overcoming the problem of water absorption (drainage system), porous asphalt also has a high value of impurity because of the number of coarse aggregates that add to rough road surface which can reduce the risk of slipping the wheels of vehicles that cross the road in wet conditions [6]. This layer can effectively provide a higher level of safety, especially when it rains so it doesn't happen to aquaplane to produce agility on a rougher surface, and can reduce noise [7]. The implementation of porous asphalt has created awareness of many advantages over and above rapid rainfall-runoff drainage [8]. The advantage of the porous asphalt mixture is to have skid resistance to avoid slipping vehicle wheels [9]. Porous asphalt or pervious concrete, usually has a lower strength and durability than the dense-graded mixture, such as dense-graded hot mix asphalt (HMA) or conventional Portland cement concrete [10].

The high air void content also weakens the bearing capacity of the open-graded material structure and accelerates the oxidative aging of the binder and the deterioration of the aggregate-binder interface due to moisture diffusion [11]. Due to the high air void, it is easy for porous asphalt to appear the raveling and rutting damages under the complex conditions of heavy loading, high temperature, moisture, and oxygen penetration [12]. The raveling and pothole defects become the main obstacles of porous asphalt pavements and seriously affect their service life [13]. Because of these main obstacles, it is necessary to use asphalt which is expected to increase the increase in Porous Asphalt. In this study, we tried 60/70 penetration asphalt bitumen which is commonly used in Indonesia. 60/70 penetration asphalt bitumen is suitable for use in Indonesia because the area in Indonesia has hot weather and is suitable for medium and high traffic volumes. While the material is a crushed stone as coarse aggregate for making flexible pavement. The Aggregates that will be used in this study come from Karangasem Regency, Bali. So far, due to the limited experience in the Bali area in researching Porous Asphalt using local materials from Karangasem and there is no specification regarding Porous Asphalt in Indonesia, therefore research on the properties of Porous Asphalt is necessary.

The purpose of this research is to determine Marshall characteristics, Cantabro value, permeability value, Indirect Tensile Strength (ITS), and Unconfined Compressive Strength (UCS) at optimum asphalt level.

2. Research Method

The research flow chart is a diagram that explains the research steps. The flow chart can be seen in Figure 1.



Source: Research

Figure 1. Research Flow Chart

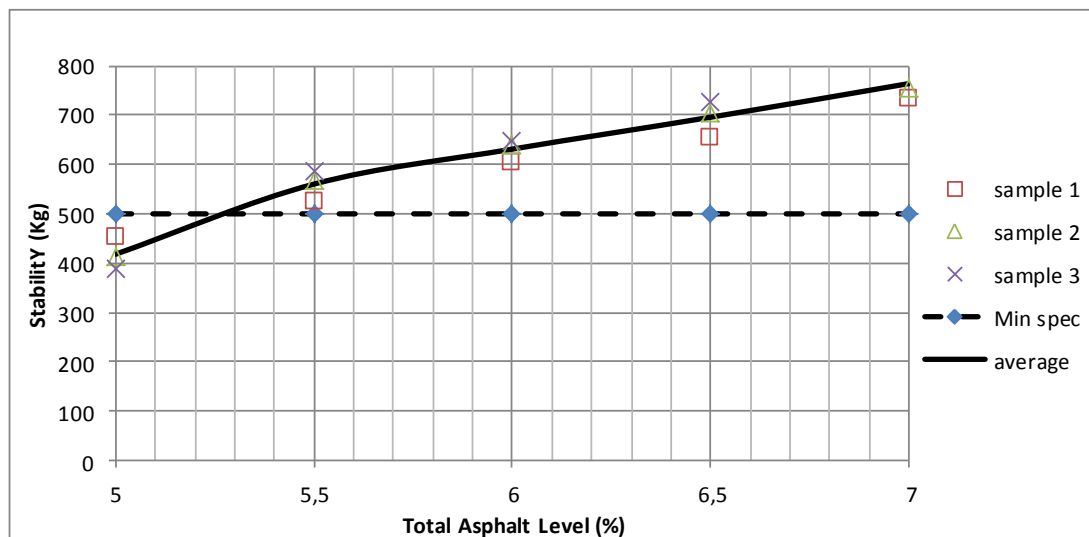
The initial stage that will be carried out in this research is the preparation of materials and tools, such as coarse aggregate (gravel), fine aggregate (sand), and filler, as well as 60/70 asphalt bitumen. The next step is to test and aggregate the proportions to obtain aggregates that meet the specifications of Porous Asphalt. For asphalt, the test is carried out according to the specifications for asphalt penetration 60/70. Furthermore, based on the proportion, the percentage value of asphalt level in the mixture is sought and the design of the test object is made. After the test object continued with the Volumetric Measurement and Marshall test, this test consists of stability, flow, marshall quotient, Void in Mix, Voids In Mineral Agregat, and Void Filled Bitumen. The stability is among the indicators of the strength of the asphalt mixture obtained by the marshall stability test [5]. Flow is the magnitude of the vertical deformation samples that occur from the beginning loading to a stable condition maximum until the sample is destroyed [14]. Marshall quotient is the quotient stability by melting with unit kg/mm [14]. Void in Mix remaining cavity volume after the asphalt concrete mix is compacted [14]. VMA is the intergranular space occupied by asphalt and air in the compacted asphalt mixture [15]. Void Filled Bitumen is part of the test object filled with asphalt. This VFB value is proportional to the VMA value [16]. From Volumetric Measurement and

Marshall test data obtained which then obtained optimum asphalt level. Then samples were made on optimum asphalt level for Marshall, permeability, UCS, ITS, and Catanbro tests. Then obtained data can be analyzed and concluded. The Cantabro Abrasion Loss (CAL) value obtained according to the maximum specification must be 20% [17]. The permeability value obtained according to the specifications should be 0.1-0.5 cm/s [18]. ITS (Indirect Tensile Strength) test is used to determine the tensile properties of the asphalt mixture at a specified temperature and loading rate, this test was carried out following JTG E20-2011, chopped basalt fibers with a length of 9 mm, the content of 0.3% and length of 12 mm and content of 0.3% were mixed into porous asphalt mixture [19]. UCS (Unconfined Compressive Strength) test is the maximum axial compressive stress that a right-cylindrical sample of material can with-stand under unconfined conditions [20].

3. Results and Discussions

3.1 Asphalt Grade Relationship With Stability

The stability is among the indicators of the strength of the asphalt mixture obtained by the marshall stability test. The relationship between asphalt level and that can be seen in Figure 2 below.



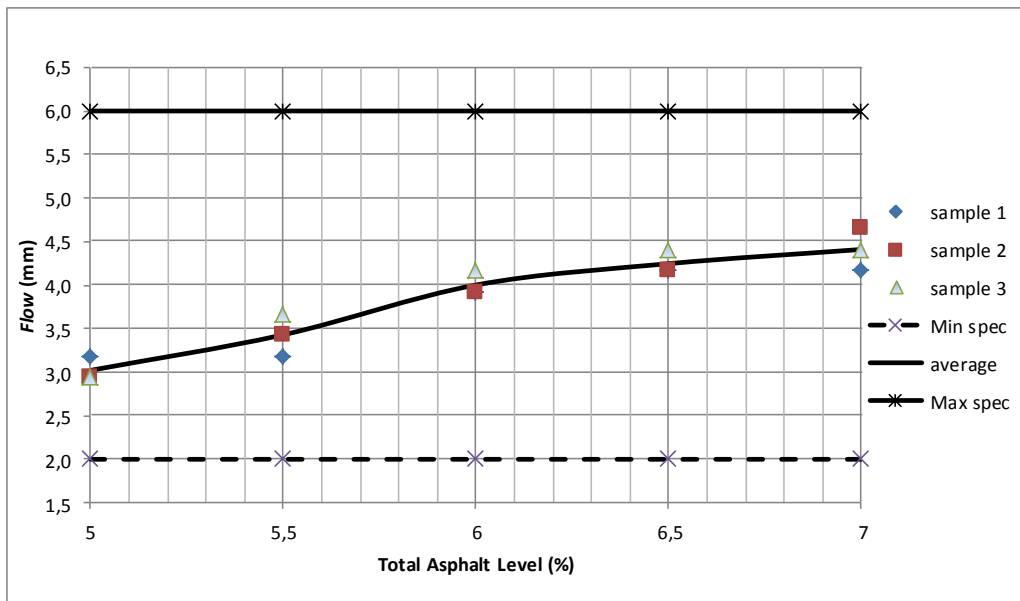
Source: Research

Figure 2. Graph of asphalt grade relationship with stability

The figure above shows, the increase in asphalt level of 5% to 7%. At 7% asphalt level is still increasing, this makes the asphalt level able to optimally lock the aggregate up to 7% asphalt level. The value is quite increased due to the high asphalt level so that the asphalt blanket results in better locking between thick aggregates. Usually the value will decrease at a certain asphalt level.

3.2 Asphalt Grade Relationship With Flow

Flow is the magnitude of the vertical deformation samples that occur from the beginning loading to a stable condition maximum until the sample is destroyed. The relationship between asphalt level and flow can be seen in Figure 3 below.



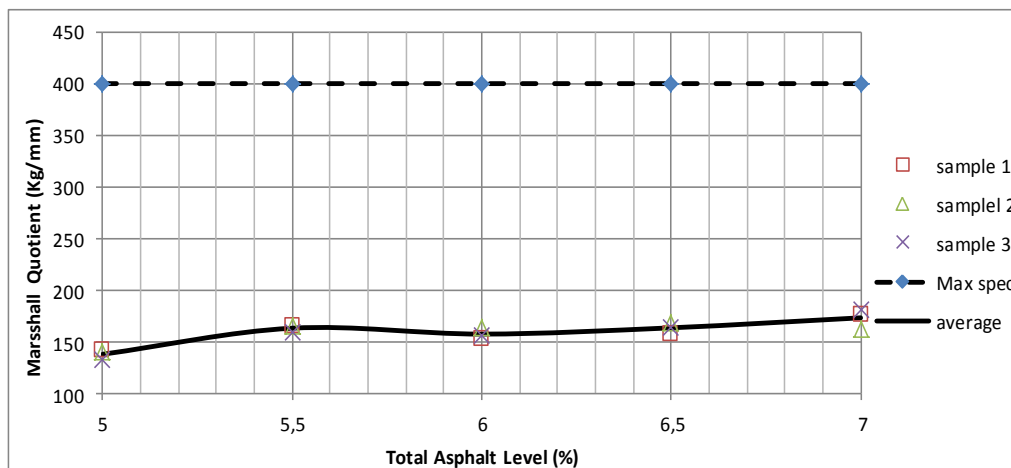
Source: Research

Figure 3. Graph of asphalt grade relationship with flow

The figure above shows, the flow value increases with increasing asphalt content. This happens because the more asphalt content, the easier it will be to deform and the greater the level of flexibility so that when the load is given it will be more able to follow changes in shape due to loading. The flow value of the Porous Asphalt mixture at 5% asphalt content; 5.5%; 6%; 6.5%; 7% in a row is 3.02 mm; 3.43mm; 4.00 mm; 4.25 mm; 4.41 mm. The specification of flow value for Porous Asphalt mixture is 2-6 mm.

3.3 Asphalt Grade Relationship With Marshall Quotient

Marshall quotient is the quotient stability by melting with unit kg/mm. The relationship between asphalt level and marshall quotient can be seen in Figure 4 below.



Source: Research

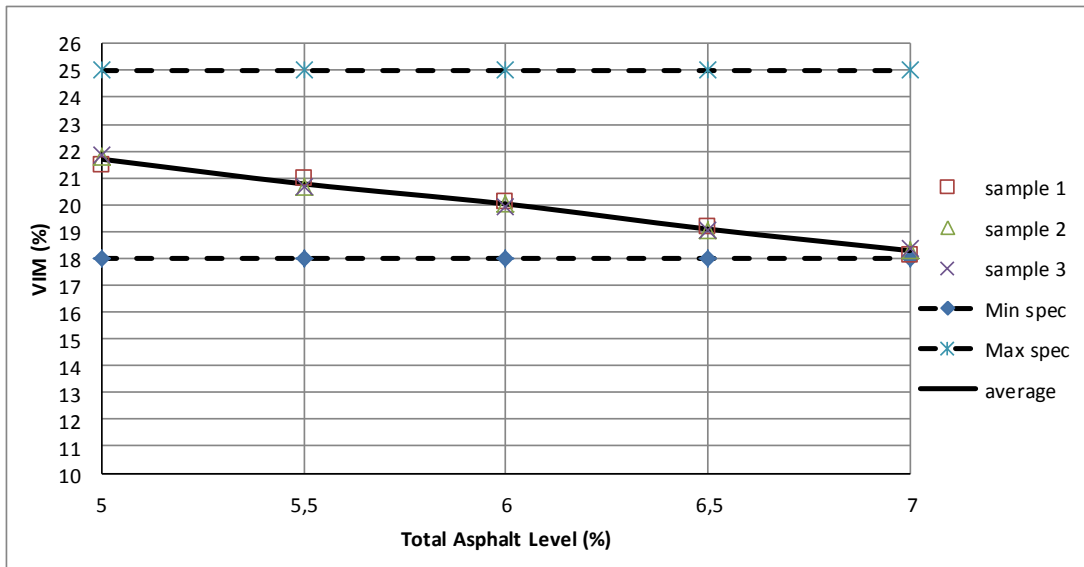
Figure 4. Graph of asphalt grade relationship with Marshall quotient

The figure above shows, the marshall quotient value at all asphalt content meets the specifications. The stiffness factor is very important to get a flexible mixture. If the mixture is not stiff enough it will easily deform, otherwise if the mixture is too stiff then the mixture will become brittle so it is easy to repeat. Marshall Quotient value for Porous Asphalt mixture at 5% asphalt content; 5.5%; 6%; 6.5%; 7% in a row is 138.30 Kg/mm; 163.48 Kg/mm; 157.78

Kg/mm; 163.84 Kg/mm; 173.51 Kg/mm. The specification of Porous Asphalt mixture has a maximum Marshall Quotient value of 400 Kg/mm.

3.4 Asphalt Grade Relationship With Voids In Mix (VIM)

Void in Mix (VIM) remaining cavity volume after the asphalt concrete mix is compacted. The relationship between asphalt level and VIM can be seen in Figure 5 below.



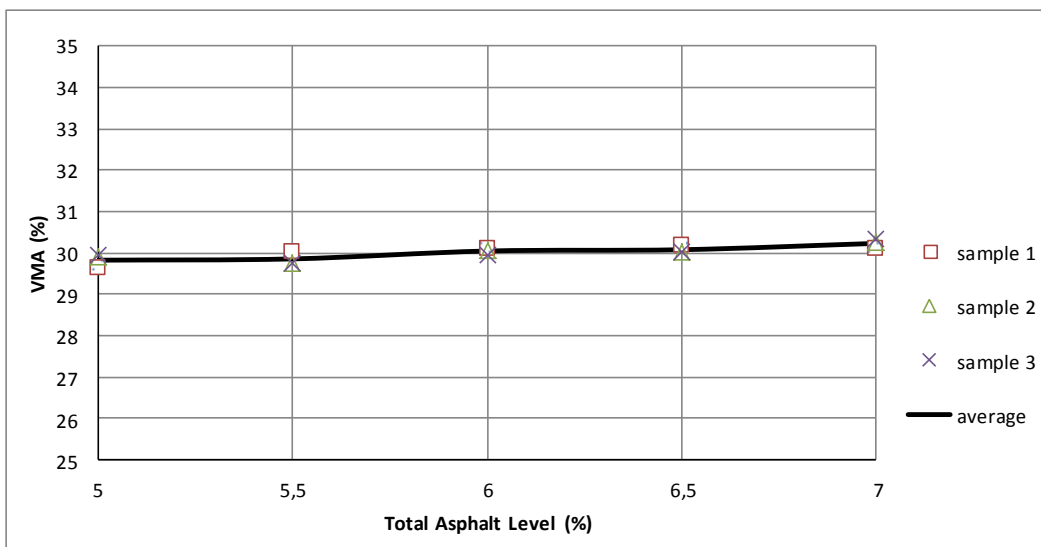
Source: Research

Figure 5. Graph of asphalt grade relationship with Void in Mix (VIM)

The figure above shows, increasing asphalt content causes the VIM value to decrease, this is because the air voids in the mixture begin to be filled with asphalt as a whole. Of all the VIM values above all meet the specifications. VIM value for Porous Asphalt mixture at 5% asphalt content; 5.5%; 6%; 6.5%; 7% in a row is 21.698%; 20.777%; 20.029%; 19.092%; 18.289%. For a mixture of Porous Asphalt, the minimum VIM value is 18% and the maximum is 25%.

3.5 Asphalt Grade Relationship With Voids In Mineral Agregat (VMA)

VMA is the intergranular space occupied by asphalt and air in the compacted asphalt mixture. The relationship between asphalt level and VMA can be seen in Figure 6 below.



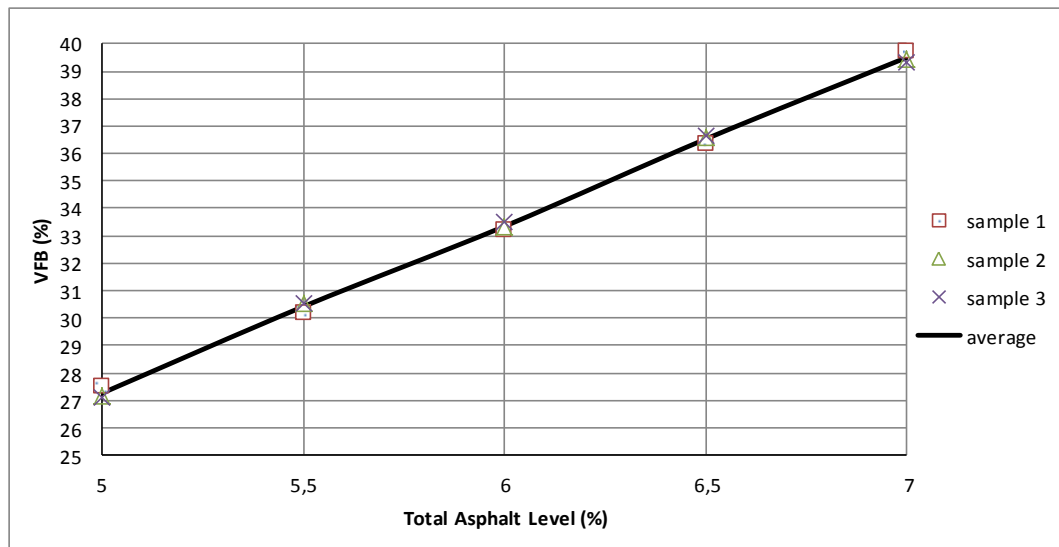
Source: Research

Figure 6. Graph of asphalt grade relationship with Void In Mineral Agregat (VMA)

The figure above shows, the VMA value of the porous asphalt mixture increases not significantly with the increase in asphalt content. A large VMA value indicates a thick blanket so as to produce an asphalt layer with high durability so that the possibility of bleeding is very high. VMA value for Porous Asphalt mixture at 5% asphalt content; 5.5%; 6%; 6.5%; 7% in a row is 29.826%; 29.857%; 30.047%; 30.079%; 30.232%.

3.6 Asphalt Grade Relationship With Voids Filled Bitumen (VFB)

Void Filled Bitumen (VFB) is part of the test object filled with asphalt. This VFB value is proportional to the VMA value. The relationship between asphalt level and VFB can be seen in Figure 7 below.



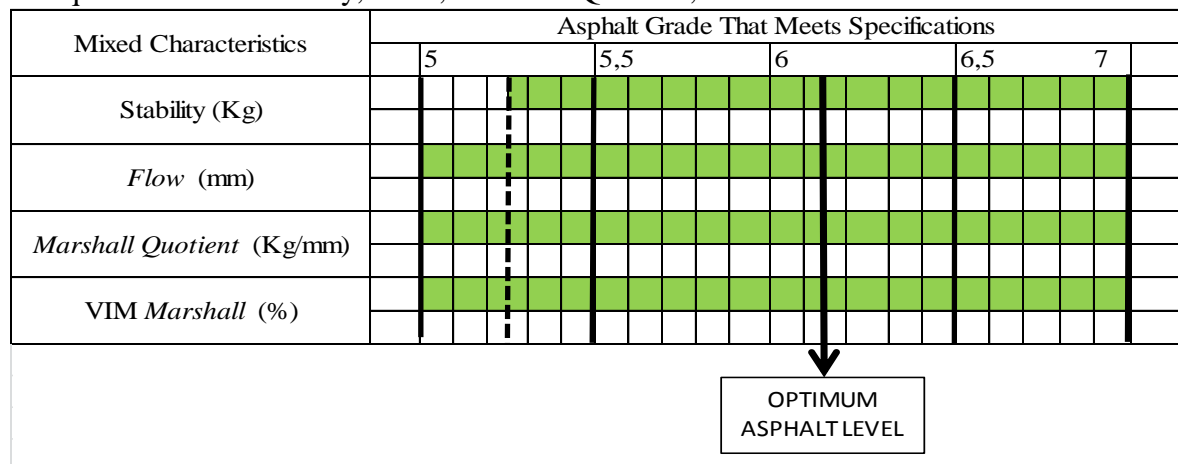
Source: Research

Figure 7. Graph of asphalt grade relationship with Void Filled Bitumen (VFB)

The figure above shows, the VFB value increases with the addition of asphalt content. This means that increasing the asphalt content will fill the voids, thereby increasing the durability and tightness of the mixture. VFB value for Porous Asphalt mixture at 5% asphalt content; 5.5%; 6%; 6.5%; 7% in a row is 27.254%; 30.414%; 33.343%; 36.527%; 39.507%.

3.7 Determining Optimum Asphalt Level

The bar-chart method used to determine the optimum asphalt level in Porous Asphalt is as shown in Figure 8. The optimum asphalt level value in Porous Asphalt can be determined by finding the middle value of the range of maximum and minimum asphalt level that meets the requirements of Stability, Flow, Marshall Quotient, and VIM- Marshall.



Source: Research

Figure 8. Bar-Chart of optimum asphalt level

The figure above shows, the porous asphalt mixture with aggregate from Karangasem produces the optimum asphalt level which lies between 5,29% to 7%. By taking the average, the optimum asphalt level is 6.15%.

3.8 Analysis of Porous Asphalt Mixture Characteristics at Optimum Asphalt Level

After knowing the optimum asphalt level, a sample will be made using the optimum asphalt level (6.15%) and look for its characteristics as in Table 1.

Table 1. Characteristics of Porous Asphalt mixture at optimum asphalt level

Mixed Characteristics	Optimum Asphalt Level (6.15%)	Mixed Requirements
Stability (kg)	636,32	Min. 500
Flow (mm)	4,00	2-6
MQ (Kg/mm)	159,15	Max 400
VIM (%)	19,828	18-25
VMA (%)	30,121	-
VFB (%)	34,173	-

Source: Research

3.9 Results of Cantabro Test at Optimum Asphalt Level

For durability purposes, porous asphalt wearing course should have good particle loss (raveling) resistance in itself. To compare the raveling resistance of the trial section and normal porous asphalt pavement, the particle loss values of the cores with steel wool and plain cores were measured in the Cantabro test. The Cantabro Abrasion Loss (CAL) value obtained according to the maximum specification must be 20%. The results of the cantabro durability test get a Cantabro Abrasion Loss (CAL) value of 17.90%. This value has met the specifications.

3.10 Results of Permeability Test at Optimum Asphalt Level

Permeability Testing is an opportunity to get the permeability value of Porous Asphalt. Permeability is the ability of a porous medium to flow fluid. Any material with space in between is called porous, and if the empty spaces are interconnected, it will have permeability properties. The permeability value obtained according to the specifications should be 0.1-0.5 cm/s. The results of the permeability test get the horizontal and vertical permeability values of 0.145 and 0.152 cm/second. This value already meets the specifications.

3.11 Results of Indirect Tensile Strength Test at Optimum Asphalt Level

ITS (Indirect Tensile Strength) test is used to determine the tensile properties of the asphalt mixture at a specific temperature and loading rate. This test was carried out following JTG E20-2011, chopped basalt fibers with a length of 9 mm, a content of 0.3% and a length of 12 mm, and a content of 0.3% were mixed into a porous asphalt mixture. The results of the ITS test get an ITS value of 158.88 KPa. The ITS value has no specifications.

3.12 Results of Unconfined Compressive Strength Test at Optimum Asphalt Level

UCS (Unconfined Compressive Strength) test is the maximum axial compressive stress that a right-cylindrical sample of material can with-stand under unconfined conditions. The test equipment used is a UTM (Universal Testing Machine). The results of the UCS test get a UCS value of 916,343 Kpa. UCS values are unspecified.

4. Conclusion and Suggestion

4.1 Conclusion

In accordance with the results of the study, the following conclusions can be drawn:

1. The optimum asphalt level value in Porous Asphalt mixture using aggregates from Karangasem and 60/70 penetration bitumen is 6.15% and has a Marshall characteristic value of 636.32 kg (min. 500 kg specification), Flow value of 4, 0 mm (2-6 mm specification), the Marshall Quotient value is 159.15 kg/mm (max. 400 kg/mm specification), and the Marshall VIM value is 19.828% (18-25%). All Marshall characteristic values meet the specifications of the Australian Asphalt Pavement Association (AAPA).
2. Characteristics of Porous Asphalt mixture at optimum asphalt level using aggregates from Karangasem and 60/70 penetration bitumen produces Cantabro values of 17.90% (max. 20% specification), vertical and horizontal permeability values of 0.145 and 0.152 cm/second (specifications 0.1-0.5 cm/second), the ITS value is 158.88 Kpa, and the UCS value is 916,343 Kpa.

4.2 Suggestion

In accordance with the results of the study, the following suggestions can be put forward:

1. This research is still far from perfect, for further research its use can be developed by changing the previous research variables, including:
 - Changing the type or type of asphalt.
 - Use aggregates from other areas, or use other used aggregates as coarse, fine or filler aggregates.
2. It is necessary to make the aggregate gradation and specifications for Porous Asphalt mixtures in Indonesia.

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