

# Open Graded Asphalt Mixture Design for Environmentally Friendly Road

A Setyawan<sup>1</sup>, Suryoto, A Sumarsono, S Widyastuti

Roadmate Research Group, Civil Engineering Department, Sebelas Maret University,  
Jl. Ir. Sutami 36 A Solo 57126, Indonesia

E-mail: arysetyawan@staff.uns.ac.id

**Abstract.** The road is an important infrastructure to support various economic development. By increasing the population, the constructions of road infrastructure are obviously required and cover more land use area, consequently narrowed the areas for water absorption into the land. Therefore, it is necessary to improve more environmentally friendly of road constructions, in this case is by using open graded asphalt. Open graded asphalt is the mixture of asphalt with low fine aggregate content to produce a high percentage of air voids, which expected to be able to absorb water into the land underneath. This observation uses laboratory experiment method. Materials that are used are natural gravel and the volcanic gravel, 60/70 asphalt penetration and stone dust filler. The tests performed for the samples are Marshall test, falling head water permeability, indirect tensile strength and unconfined compressive strength. The optimum bitumen content for each type of aggregate have been found to be 2.95% for natural gravel and 4.65% for volcanic gravel. Open graded asphalt porosity is 26.52% for natural gravel, whereas the volcanic gravel is 22.31%. The vertical and horizontal permeability for natural gravel are 1.25 cm/second and 0.92 cm/second, respectively. Whereas, for the volcanic gravel is 1.43 cm/second and 1.10 cm/second, respectively. Indirect tensile strength (ITS) value for natural gravel is 59.49 KPa whereas the volcanic gravel is 74.84 KPa. The unconfined compressive strength (UCS) value for natural gravel is 1070.63 KPa, whereas the volcanic gravel is 1120.69 KPa. It is concluded that the open graded porous asphalt is only compatible for low volume traffic road and need improvement to be able to be used as standard road.

## 1. Introduction

Porous asphalt is asphalt with a low fine aggregates content to get a high air voids to be able to absorb water [1]. Types of coating for porous asphalt are very innovative way, because it is easy to pass the water into the pavement vertically and horizontally through the pore to pore capillary or by using a side channel as drainage systems. Evidences show that porous asphalt is very good for improving road traffic safety in very bad weather conditions such as heavy rain and slippery, reducing hydroplaning and have a good skid resistance, so at high speeds the wheel does not slip easily. It also reduces noise and glare at night.

On the other hand to the advantages over porous asphalt it also has some drawbacks. Porous asphalt has the lowest strength or stability compared to other asphalt mixtures due to porous asphalt compositions dominated by coarse aggregate, thus becoming fragile. However, it is an

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<sup>1</sup> To whom any correspondence should be addressed.

environmentally friendly use of materials and methods that will not adversely affect the environment, such as pollution or depletion of natural resources [2]. In this study two types of porous asphalt are investigated, the first porous asphalt used natural gravel aggregate, while the second incorporated the volcanic gravel from residuals of Merapi sand. The intention of using gravel aggregate is to avoid the process of breaking a big stone so there is no air pollution from the process at a stone crusher. The use of volcanic gravel is expected to use the waste materials from residuals of Merapi sand and it is more environmentally friendly action.

Porous asphalt mixture using a uniform graded is expected to function as drainage, anti-slip, anti-aquaplaning and noise reduction that can only be obtained through the use of a uniform graded. It also acquired a high permeability and porosity and is able to pass the surface water sufficiently [3]. The types of tests performed on a bitumen and porous asphalt mixture used are penetration, softening point, marshall properties, porosity, tensile strength indirectly, unconfined compressive strength, and the permeability of the mixture.

The objective of this study is to determine the optimum bitumen content and the mixture properties of uniform graded porous asphalt mixture contain natural and volcanic gravel such as the stability, porosity, permeability, indirect tensile strength, and unconfined compressive strength of porous asphalt mixture, which are then compared to the conventional porous asphalt.

## 2. Experimental

Aggregates are the grains of crushed stone, gravel, sand or other minerals, either natural or artificial results (Implementation Guidelines of Asphalt Concrete, Highway Agency SKBI -2.4.26.1987) [4]. Asphalt or bitumen is a viscous liquid which is hydrocarbons, contains little sulfur, oxygen, and chlorine. Asphalt as a binder in flexible pavement has viscoelastic property. Asphalt will be solid at room temperature and becomes liquid when heated. Filler is a non plastic aggregate that passes the sieve number of 200. Filler support the coarse aggregate together with fine aggregate and binder to form the skeleton of asphalt mixtures. The properties of filler depend on several factors such as grain size, grain shape and density [5]. The method used in this study is an experimental method, which is carried out by conducting trial activities to obtain the data.



**Figure 1.** (a). Natural Gravel (b). Volcanic Gravel

The first purpose of this study was to determine the optimum bitumen content and to measure the stability, porosity, vertical and horizontal permeability, UCS and ITS of porous asphalt which use natural gravel and volcanic gravel. The two gravel types of aggregate are observed in this research as presented in Figure 1. The preparation phase, at this point all the materials and equipments needed in the research study are prepared beforehand in order to run the experiment smoothly. The materials that need to be prepared is the natural gravel and the volcanic gravel, asphalt penetration 60/70 and the stone dust filler. The identification of the aggregates, includes the Los Angeles abrasion and the specific gravity of coarse and fine aggregate. The fifteen specimen were then produced at five

variations of bitumen content, three specimens for each similar bitumen content to obtain the optimum bitumen content. The total 30 specimens were produced and observed for natural gravel and volcanic gravel. Marshall Test was then performed to determine the optimum bitumen content. The specimens at their optimum bitumen contents were then objected for the vertical and horizontal permeability tests, Indirect Tensile Strength tests and Unconfined Compressive Strength tests. The data obtained from the test results are analyzed to get the conclusion according to the purpose of the research.

### 3. Results and Discussion

#### 3.1 Aggregate Properties

The examination of aggregates used was conducted in the Highway Materials Laboratory of Sebelas Maret University, Surakarta according to NFPA 03-1969 - 1990 and SNI 03 - 2417-1991[6]. The results are presented in Table 1.

**Table 1.** Results of the aggregate examinations

The properties	Unit	Natural gravel	Volcanic Gravel	Specification
Adsorption	%	3.067	3.600	Max 3
Bulk Specific Gravity	g/cc	2.280	2.208	Min 25
SSD Specific Gravity	g/cc	2.350	2.287	Min 2.5
Apparent Specific Gravity	g/cc	2.451	2.398	-
Abrasion	%	26.18	43.96	Max 40
Aggregate Affinity	%	96	97	> 95

The filler has been examined in the laboratory and give the value of specific gravity of 2.44 g/cc.

#### 3.2 Bitumen Properties

The bitumen used in this study is 60/70 penetration bitumen. The bitumen examination was conducted based on SNI 03-1737-1989 [7]. The results can be seen in Table 2.

**Table 2.** Examination of the characteristics of bitumen 60/70 penetration

Bitumen properties	Specification		Value
	Min	Max	
Penetration, 100gr, 250°C, 5 second	60	79	67.5
Softening Point, °C	48	58	48.5
Flash Point, °C	200	-	343°C
Burning Point, °C	200	-	353°C
Ductility, 25°C, 5 cm/minute	100	-	150 cm
Specific Gravity	1	-	1.0395 g/cc
Affinity, %	95	98	97.5%

#### 3.3 The Optimum Bitumen Content

In the porous asphalt made from natural gravel (cobblestone) that comes from a Kaliboto quarry of Karanganyar district obtained the optimum bitumen content of 2.95%. The porous asphalt made from volcanic gravel obtained the optimum bitumen content of 4.65%. The difference bitumen content between the natural gravel and volcanic gravel is predicted due to the texture and the adsorption of the gravel. Natural gravel has a smooth surface texture and does not absorb much asphalt since the absorption is only 3.07% so it takes a little bitumen content. The volcanic gravel has a rougher texture and asphalt absorbs a lot of absorption of 3.60% and thus require higher bitumen content.

#### 3.4 The Marshall Properties

Stability is the ability of asphalt mixtures to withstand deformation due to the traffic load without permanent deformation. The stability value is influenced by aggregate interlock and the bond of

bitumen and aggregates. The stability value of porous asphalt mixture using gravel aggregate amounted to 481.80 kg. Porous asphalt using gravel aggregate amounted to 643.98 kg. For the value stability of porous asphalt mixture using gravel and gravel aggregate uniformly graded greater than either gradation BVR (Blackwater Valley Route) on research Suwarno with a value of 434.24 kg [8].

Flow is a state change in the form of a mixture as a result of a load to the limit of collapse. Value flow indicates the level of flexibility or stiffness of the mix. Flow demonstrated high level of flexibility is high, so that cracks arising from loading can be avoided. Conversely a low flow showed a low level of flexibility and are brittle layer, so prone to rupture due to the separation between grain particles. Comparison of flow porous asphalt mixture using gravel and pebbles can be seen in Table 3. Based on Table 3, the rated flow of porous asphalt with natural gravel obtained values of 2.24 mm. While the porous asphalt with volcanic gravel obtained values of 2.51 mm. This is due to the asphalt content of porous asphalt mixture using natural gravel more than those of volcanic gravel, so that the porous asphalt mix becomes more elastic and able to follow the deformation due to the load. From research conducted by Suwarno using the BVR (Blackwater Valley Route) gradation obtained the flow value of 3.94 mm, greater than using a uniform graded porous asphalt [9].

**Table 3.** Marshall and volumetric properties at optimum bitumen content

Marshall and volumetric properties	Natural Gravel	Volcanic Gravel	BVR Gradation
Stability(Kg)	481.80	643.98	434.24
Flow (mm)	2.24	2.51	3.94
MQ (Kg/mm)	215.98	265.07	n/a
Specific Gravity	2.36	2.26	n/a
Density (g/cc)	1.73	1.75	1.77
Porosity (%)	26.63	22.88	30.91

### 3.5 The Volumetric Properties

Density is the ratio between the weight by volume based. Comparison of density of porous asphalt mixture using natural and volcanic gravel are presented in Table 3. It could be seen that density value obtained for porous asphalt with natural gravel is  $1.73\text{g/cm}^3$ , for porous asphalt with volcanic gravel is  $1.75\text{g/cm}^3$ . While the study in 2006 using the gradation BVR (Blackwater Valley Route) Agustina obtained a value of  $1.77\text{g/cm}^3$ . This is due to the ratio between the weight and volume of crushed stone is greater than the gravel aggregates, than the gradation also influences the density [9].

Porosity is the percentage of pores or air voids that are present in a mixture and is the main indicator in a mixture of porous asphalt as a pore - pore is what will be the course of the water. Comparison of porosity between the natural and volcanic gravel are presented in Table 3. It could be seen that the porosity of porous asphalt mixture using natural gravel is 26.52% as compared with the use of porous asphalt with volcanic gravel is only 22.31%. From research by Agustina using the gradation of BVR (Blackwater Valley Route) derived porosity values of 30.91%, higher than those of uniform gradation with gravel types of aggregates. This is because the porosity values obtained from the ratio of the density and  $SG_{\text{mix}}$ . The higher  $SG_{\text{mix}}$ , with equal density obtained a smaller porosity.

### 3.6 The Permeability Properties

The purpose of the permeability test is to show the ability of porous asphalt mixture to absorb and drain water. The two gravel types were used to obtain vertical and horizontal permeability. The permeability of porous asphalt using gravel aggregate vertically is  $1.25\text{cm/sec}$  and horizontally is  $0.92\text{cm/sec}$ , while those using volcanic gravel aggregate values obtained vertical permeability of  $1.43\text{cm/second}$  and horizontal  $1.10\text{cm/second}$ . A higher value than those using BVR gradation on previous research by Agustina which has a vertical permeability value of  $0.40\text{cm/second}$  and horizontal  $0.43\text{cm/second}$  [7]. Data presented in Table 4 show that the use of porous asphalt mix gravel aggregate has better permeability that is vertical by  $1.43\text{cm/second}$  and horizontal amounted to  $1.10\text{cm/second}$ .

Porous asphalt mixture using gravel aggregate is vertical at 1.25cm/second and horizontal of 0.92cm/second. Research by Agustina using BVR gradation obtained value of vertical permeability of 0.40cm/second and horizontal permeability of 0.43cm/second, are smaller than using a uniform graded aggregate [4]. This is due to pores to pore connectivity of porous asphalt mixture using natural gravel and volcanic gravel is well interconnected, so that the water can drain properly. Table 4 shows the resume of permeability test results.



**Figure 5.** The sample for vertical and horizontal permeability Test

**Table 4.** The Permeability, ITS and UCS Properties

Permeability, ITS and UCS Properties	Natural Gravel	Volcanic Gravel	BVR Gradation
Coefficient of Vertical Permeability (cm/second)	1.25	1.43	0.4
Coefficient of Horizontal Permeability (cm/second)	0.92	1.41	0.43
Indirect Tensile Strength (KPa)	59.49	78.84	394.96
Unconfined Compressive Strength (KPa)	1070.63	1120.69	2310.22

### 3.7 The Indirect Tensile Strength (ITS)

ITS testing to determine the tensile strength of porous asphalt mixture. Tensile force can be used to evaluate the potential occurrence of cracks (fatigue) on porous asphalt mixture. Tensile strength values of porous asphalt mixture using gravel aggregate amounted to be 59.49 kPa, while those using gravel aggregates amounted to be 78.84 kPa. Values of ITS for uniform graded porous asphalt mixture are lesser values than those using BVR gradation, the results of previous research by Widiyanto obtained a value of 394.96kPa ITS [8]. Table 4 resumes the results from ITS tests.



**Figure 7.** The setting experiment of Indirect Tensile Strength Test

### 3.8 The Unconfined Compressive Strength (UCS)

Compressive strength testing aims to determine ability to withstand the traffic load of pavement layers vertically. Compressive strength can be used as a direct indication to determine how much load is handled by pavement. The UCS value of natural gravel porous asphalt amounted to 1070.63kPa, while those using volcanic gravel aggregates amounted to 1120.69kPa. UCS values of uniform graded porous asphalt mixture are lesser than those using BVR gradation, the results of previous research by Agustina obtained a value of 394.96kPa ITS as presented in Table 4.

## 4. Conclusion

The adsorption of aggregate and the surface texture influenced the optimum bitumen content of the mixture. The optimum bitumen content values of natural gravel porous asphalt are lower than volcanic gravel porous asphalt.

The volumetric properties: density, porosity and permeability of uniform graded gravel porous asphalt are greater than those of well graded crush stone aggregate porous asphalt, its impact on the ability of porous asphalt to drain the surface water easily. However, the strength properties: stability, tensile strength and compressive strength of uniform graded gravel porous asphalt are inferior compared to those of well graded conventional crushed stone aggregate porous asphalt.

The incorporation of uniform graded gravel porous asphalt does not meet the specifications of pavement on the road because it has low strength properties, however, it can be used as pavement for the low traffic road.

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