Analysis of Creep Test Mixture of Asphalt Concrete Using Flyash for Runway

Anwar Efendy, and Ervina Ahyudanari
Departement of Civil Engineering
Institut Teknologi Sepuluh Nopember
e-mail: anwar_efendy95@yahoo.com; ervina@ce.its.ac.id

Abstract—**There are some factors that cause deformation on the runway, such as the pressure of repeated loads caused by large queues of aircraft. The aggregate available in nature has begun to decrease in amount caused considering that infrastructure development in Indonesia continues to increase. Therefore, new material innovations are needed to overcome this, such as the use of flyash as an artificial aggregate of geopolymers in concrete asphalt mixtures. This research was carried out in some tests including Marshall testing which intended to determine the characteristics of artificial aggregate pavement mixtures, using open gradations with specification BBA. Then testing the resistance to deformation (Creep) on the artificial aggregate gradation pavement mixture using the UTM30 Dynapave. Based on the characteristics of the Marshall test the optimum bitumen content value was obtained, with open gradations has OBC value is 6.10%. Results of Creep test (deformation) with load 400 kPa obtained, strain value is 93520 µƐ and stiffness value is 3,998 MPa (sample collapse at cycle 1559 times). It can be concluded that the pavement mixture with open graded artificial aggregate (BBA) has not able to survive deformation.**

Keyword—**Runway Pavement, Artificial Aggregate of Geopolymer, Marshall Properties, OBC, Creep Test.**

I. INTRODUCTION

AGGREGATE gradation is one of the important parts in a paved mixture. Mixed properties such as stability, stiffness, ease of work, permeability, durability, fatigue resistance, slip resistance, and water resistance are strongly influenced by aggregate gradations [1]. Gradation is one of most influencing factors for Marshall Properties of Bitumen Concrete mix, so it is required to select a best aggregates gradation. The best gradation is that gradation of aggregates which gives the highest density. When fine particles are properly packed between coarser particles, which reduces the voids space between particles is called as Best gradation [2]. In this study using BBA gradations, BBA (Béton Bitumineux pour chausées Aéronautiques) gradation is the standard airfield bitumen surfacing in France and has been used in almost all airport pavements in France, including the two runways at Paris Charles de Gaulle, and Toulouse (where the A380 is being built and tested), with a track record of over 18 years (Association Française de Normalisation, 2008). BBA materials lend themselves to easier future maintenance, requiring no specialist paving equipment or mixing plant [3].

The aggregate is one of the most important components in concrete asphalt mixture. So that there is a large extent of aggregate needed, considering that infrastructure development in Indonesia continues to increase. Thus the aggregate available in nature has begun to decrease in amount. Therefore, new material innovations are needed to overcome this, such as the use of flyash as an artificial aggregate of geopolymers in asphalt concrete mixtures.

Damage to the airport runway pavement is one of them is deformation, which causes the surface layer to occur flaking and cracking. Deformation is one type of damage to the flexible pavement caused by repetition of heavy traffic loads under high temperature conditions [4]. Deformation resistance (Creep) of asphalt mixture is attendant with mixed stiffness, and is significantly affected by temperature and loading time . There are some factors that cause deformation on the runway, such as the pressure of repeated loads caused by large queues of aircraft and hot weather in Indonesia and frequent rain.

Creep testing is important to do because weather factor, considering that the temperature in Indonesia is increasing every day where the current pavement temperature is equal to 2 times the temperature of the air around 60ºC. Creep testing in this study aims to determine the value of resistance to deformation on the surface layer of the runway based on the OBC value of the Marshall test. So that it is known how big the weight of the aircraft that can be traversed by the concrete asphalt mixture with the use of flyash as an artificial geopolymer aggregate.

II. LITERATURE REVIEW

A. Artificial Aggregates of Geopolymers

Geopolymers are new materials from inorganic polymers. What is meant by inorganic is that the polymer is formed not from nature but man-made. Geopolymers are formed because there is a geochemical reaction using the basic ingredients of alum mineral silicate and alkali [5]. The geopolymer aggregate with the geopolymerization process is one of the efforts to obtain artificial aggregates that are more environmentally approachable.

B. Flyash and Alkali Activator

One of the material that contains a lot of silica and alumina which is quite large is flyash. In order for the content of the elements in this flyash material to be a strong binder, an alkali activator is needed [6]. In this study the flyash used for the manufacture of geopolymer asphalt concrete is flyash class F which is derived from the waste of PLTU Paiton Probolinggo, East Java.

The activator used was sodium silicate (Na2SiO3) and sodium hydroxide (NaOH) with a concentration of 8M and the composition of flyash and alkali at 75%: 25% and for the ratio of alkali activator using the best composition with a ratio of 1 (NaOH): 2,5 (Na2SiO3) [7].

III. METHOD

In this study used gradations of BBA, with coarse aggregates using artificial aggregate geopolymer 25% and natural aggregate 75%. This artificial aggregate has been tested and it is known that the characteristics of artificial aggregates have good characteristics [8]. The following standard specifications of aggregates are listed in Figure 1 below. In this study we will use gradation envelopes in the middle boundary that are between the upper and lower boundaries, the middle boundary gradation is used so as not to come out of the gradation envelope specifications and so that the results are maximal because the middle boundary selection is the best.

A. Determine the Estimated Bitumen Content

In testing with a Marshall tool, the first thing to do is calculate the early estimate of OBC (Pb) using Equation 1.

$$Pb = 0.035(\%\,CA + 0.045(\%FA) + 0.18(\%FF) + K \quad (1)$$

The Pb value obtained from Equation 1 is rounded up to the nearest 0.5%, then prepare Marshall specimens for asphalt content variations, namely (Pb-1.0%), (Pb-0.5%), Pb, (Pb+0, 5%) and (Pb+1.0%) each of 3 sample. Based on Figure 1 the percentage specifications of the weight values held on the BBA gradation are shown in Table 1 below.

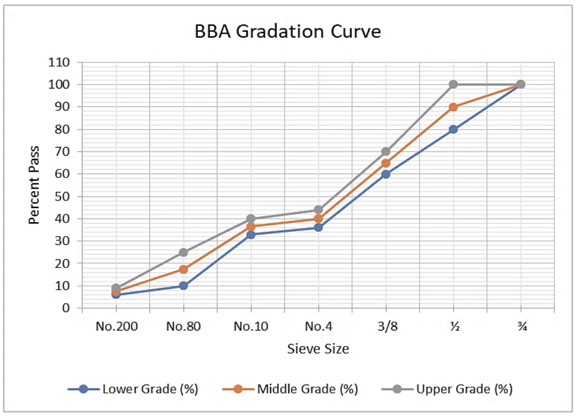

Figure 1. BBA Gradation Curve.

Table 1.
Aggregate gradation specifications (BBA)

Sieve number	Sieve size	% weight pass the sieve
¾''	19,1 mm	100
½'	12,7 mm	80 – 100
3/8'	9,25 mm	60 – 70
No. 4	4,76 mm	36 – 44
No. 10	2,38 mm	33 – 40
No. 80	0,59 mm	10 – 25
No. 200	0,074 mm	6 – 9

B. Marshall Test

Marshall Test aims to determine the optimum bitumen content, then determine the stability and flow of bitumen mixture. The specimen is bitumen mixture with a diameter of 101.6 mm (4 inches) and a height of 76.2 mm (3 inches). Compaction for the Marshall test is done by blows 75 times per field using a compactor. After the test object is compacted, then stored at room temperature for 24 hours, then the objects are weighed in air, in the water and in saturated surface dry (SSD) conditions to obtain bulk specific gravity. Then soaked at a temperature of 60±1oC for 30-40 minutes and ready to conduct stability and flow testing. Characteristics of bitumen mixtures which are Marshall parameters are density, VIM, VMA, VFA, stability, flow and Marshall Quotient[9]. The following of requirements Asphalt Concrete listed in Table 2 below.

Table 2.
Requirements Asphalt Concrete for Airports Pavement

Test Property	Pavement Design for Aircraft Gross Weights of 60.000 Lbs (27216 kg) or more or Tire pressures of 100 psi or more
Number of blows	75
Stability, pounds (Newtons) minimum	2150 (9560)
Flow, 0.01 inch. (0.25 mm)	10 - 16
Target air voids (percent)	3.5 (3-4)
Percent VMA (minimum)	15%

C. Determination of Optimum Bitumen Content (OBC)

This is done using a bar-chart method, where bar charts are made shows the range of bitumen levels that meet each Marshall characteristic according to specifications. The optimum bitumen content is determined by the bitumen content which meets all characteristic specifications Marshall[10].

D. Creep Test

Creep test is done by using Universal Testing Machine (UTM) as shown in Figure 2 with parameter settings: loading function: haversine; cyclic stress loading 100 kPa (changed to 400 kPa); seating stress 5 kPa; cycle duration: 1000 millisecond (ms); cycle repetition time: 1000 ms; stress preload 20 kPa; preload time: 600 s; termination cycle count: 3600; temperature: 40°C (changed to 60°C) (BS EN 12697-25:2005). The test results were analyzed and graphed between repetitive loads and strains and creep stiffness calculated by Equation 2.

$$\text{Creep Stiffness} = \frac{stress}{strain} \quad (2)$$

Figure 2. UTM30 Dynapve.

IV. RESULTS AND DISCUSSION

A. Material Testing Result

Material testing carried out included: coarse aggregate testing, fine aggregate, filler and asphalt penetration 60/70. Coarse aggregate testing includes: filter analysis, specific gravity and absorption, angularity, sludge or clay content, aggregate stickiness to asphalt, abrasion and soundness test and results as in Table 3. Fine aggregate testing includes: filter analysis, specific gravity and absorption, angularity and fine aggregate cleanliness by sand equivalent and the results as in Table 4. The asphalt used is hard / solid asphalt with penetration of 60/70. The examinations carried out in the laboratory are penetration testing, flash point, softspot, ductility, asphalt specific gravity and examination of asphalt weight loss and the results of asphalt testing are given in Table 5.

Based on the results of material testing carried out include: testing of coarse aggregates, fine aggregates, fillers and penetration of asphalt 60/70 shown in Table 3, Table 4 and Table 5 have fulfilled the requirements in accordance with the testing standard based on General Specifications of Bina Marga 2010 Revision 3 which is equipped with American Association of State Highway and Transportation Officials (AASHTO), and American Society for Testing Materials (ASTM).

B. *Marshall Testing Result*

From the Marshall test (got two data, that is the value of stability and flow). To get the right stability value, then from reading. The dial needs to be calibrated first, then the calibration value is multiplied by the results of the correction numbers obtained based on the height of the test object. Result of value stability divided by the value of flow is called Marshall Quotient. The following of Results Marshall Properties listed in Table 6 below with Pb = 6%. Based on Table 6, it can be determined of Optimum Bitumen Content of BBA gradation using the bar-chart method listed in Figure 3 below.

Table 3.
Properties of coarse aggregate

Test	Natural aggregate	Artificial aggregate	Unit
Bulk specific gravity	2.54	1.85	gr/cm3
Apparent specific gravity	2.70	2.09	gr/cm3
Absorption	2.34	6.08	%
Abrasion	30.80	22.78	%

Table 4.
Properties of fine aggregate

Test	Natural aggregate	Unit
Bulk specific gravity	2.557	gr/cm3
Apparent specific gravity	2.767	gr/cm3
Absorption	2.965	%
Specific gravity (filler)	2,614	gr/cm3
Apparent specific gravity	2.726	gr/cm3

Table 5.
Properties of asphalt

Test	Natural aggregate	Unit
Penetration	64	0,1 mm
Softening point	51	Celsius
Ductility	150	cm
Flash point	256	Celsius
Specific gravity	1,033	

Table 6.
Results of Marshall Properties

Test Property	Requirements	Bitumen Content (%)				
		5	5,5	6	6,5	7
Stability	2150 lbs	3967	4750	4450	4193	3953
Flow	10-16 inch	14,7	14,8	14,3	14,4	16,3
Target Air Voids(%)	3.5 (3-4)	7,11	6	3,93	1,94	0,38
VMA (%)	15%	16,25	16,27	15,45	14,72	14,4

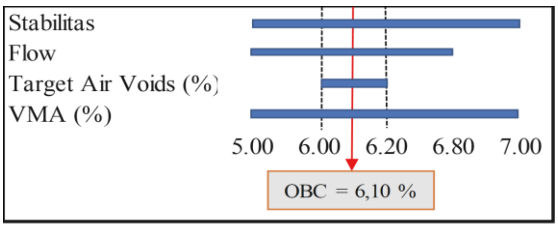

Figure 3. Optimum Bitumen Content BBA gradation.

Based on Table 6 above shows that the mixed characteristics of the Marshall test are known; the value of stability and VMA at each bitumen content meets the specifications. The value of Target air void (VIM) of five asphalt levels, four asphalt levels did not meet the specifications and the value of flow one of the five asphalt levels did not meet. Based on Figure 3 value of Optimum Bitumen Content BBA gradation is 6,10%.

C. *Creep Testing Result*

After determining the optimum bitumen content (OBC) value, the Creep test will then be carried out to determine the value of resistance deformation for runway pavement. The following results of Creep test based on optimum bitumen content values (with cyclic stress loading 400 kPa) are shown in Figure 3 and Figure 4.

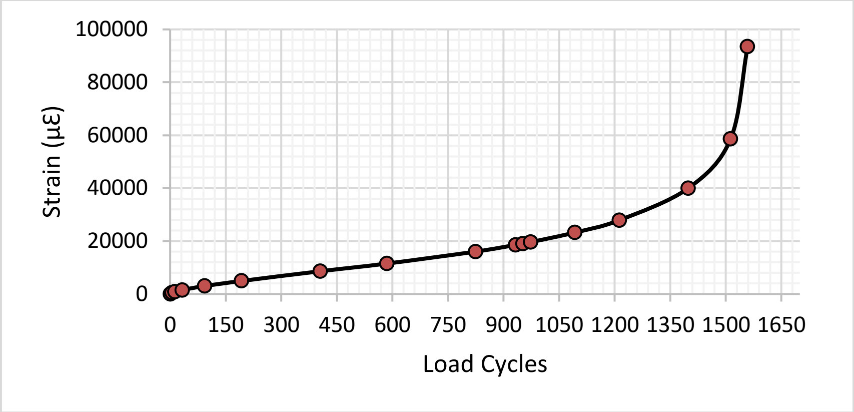

Figure 4. Strain vs Load cycles.

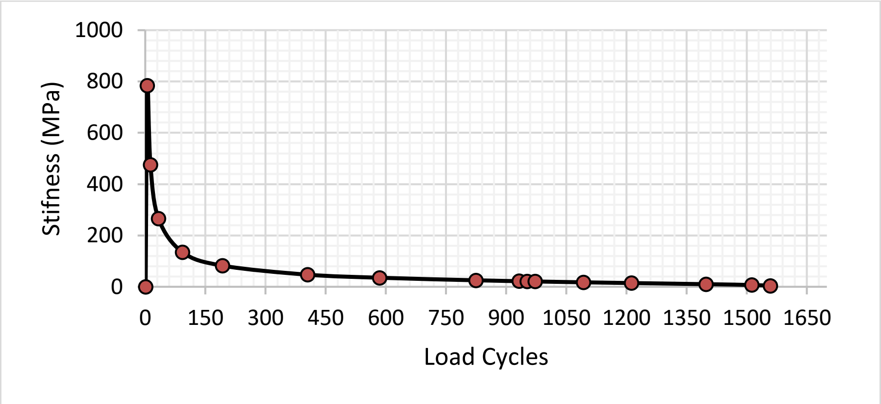

Figure 5. Stifness Vs Load cycles.

Based on Figure 4 and Figure 5 the value of strains with a load of 400 kPa is 93520 µƐ and for stiffnes values calculated using Equation 2, the results obtained 3,998 MPa and deformations occur in repetition of the load 1559 times. With the repetition of repetitive loads accompanied by high temperatures resulting in the specimen experiencing strain or deformation and becoming not rigid, so that the required pavement mixture with a value of stability is close to the high limit and the flow value is near the low limit. Value of stability is influenced by aggregate gradation, asphalt content, aggregate friction, interlocking and cohesion, besides the compaction process and aggregate quality also influence, and particles more angular aggregates with a rougher surface will increase the stability of the mixture.

$$\text{Creep Stiffness} = \frac{stress}{strain}$$

$$= \frac{373{,}9}{93520} \; x \; 10^{6}$$

$$= 3{,}998 \text{ MPa}$$

D. Discussion

One of the objectives of the mixed characteristics that must be possessed by concrete asphalt is Stability, stability testing aims to measure the resistance of an asphalt concrete mixture to deformation during loading traffic or maximum capability of a test object in holding loads until plastic melt occurs. To determine the value of the stability of the mixture used the Marshall test method. Marshall testing method is a test method that is carried out to measure the maximum load that can be borne before the test object collapses (Marshall Stability) and permanent deformation of a specimen before collapse (Marshall Flow) and its derivative which is a comparison between the two, called Marshall Quotient (MQ).

Permanent deformation of the asphalt mixture is a damage that occurs at high pavement temperatures after loading. As the pavement temperature increases, the asphalt mixture becomes softer and more vulnerable. Permanent deformation occurs when the asphalt mixture changes shape when loaded and then does not recover back to its original position (unrecoverable). Over time, permanent deformation can cause rutting.

High stability values do not guarantee the ability to accept repeated loads with high loads. For this reason, the test of pavement mixture cannot be tested only with Marshall test but the test must be comprehensive. So that the pavement mixture in this study is not suitable for use on airport runways for commercial aircraft services, but the pavement mixture is able to withstand smaller types of aircraft such as aircraft with loads below 400 kPa.

It is known that with the high value of stability or mixture, the value of deformation resistance is low. Conversely, if the value of the mixture's value is lower, the deformation resistance value is high. Factors that influence the stability value of concrete asphalt, namely internal friction that can come from surface roughness of aggregate grains, contact area between grains or grain shape, aggregate gradation, mixed density and asphalt thickness. As well as the cohesive power determined by asphalt penetration, changes in viscosity due to temperature, loading rate, chemical composition of asphalt, the effect of time and age of asphalt. The procedure in this study is not adjusted to the conditions in the field, where testing of conditions in the field is not the same as the laboratory test. The Creep testing in this laboratory is done unconfined or is not given a limit or buffer / barrier so that when deformation / collapse occurs on the test object, the mixture material will scatter everywhere and the results of this test are not optimal as seen in Figure 6 below.

Therefore, for further research it is expected to conduct a confined Creep test or be given a limit or buffer / barrier so that when deformation / collapse occurs on the test object, the mixed material will not scatter everywhere. So that the testing carried out in the laboratory is the same as the tests carried out in the field conditions to get maximum results.

Figure 6. Samples Experiencing Collapse.

V. CONCLUSION

From the results of research and data analysis that has been done, conclusions can be taken as follows:

Marshall property of asphalt concrete mixture using artificial aggregate on open gradation (BBA) is as follows: for stability values and VMA from five asphalt content meet the requirements. While the flow value is not included in the requirements for the asphalt content of 7.00% and the Target Air Voids or VIM only meet the requirements for asphalt content of 6.00%.

Based on Marshall testing the optimum bitumen content (OBC) value for open gradation (BBA) which is 6.10%.

The deformation resistance value for the mixture of natural aggregate and artificial aggregate is 75%: 25% with a load of 400 kPa is 93520 με and sample collapses at load cycles 1559 times. Therefore, it was stated that the pavement mixture with open graded artificial aggregate (BBA) with 6.10% OBC only able to withstand the occurrence of deformation with the total of repetitions of the load of 1559 times when given a load of 400 kPa and examples of aircraft capable of crossing the runway are the Beech 55 56 series (Baron), Cessna T303 (Crusader) and Convair 340, 440, 540.

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