LABORATORY EVALUATION OF LAWELE BUTON NATURAL ASPHALT IN ASPHALT CONCRETE MIXTURE

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Abstract : The huge deposit of natural asphalt in Lawele of Buton Island, in the Province of South East of Sulawesi, has not been fully utilized for asphalt concrete mixtures. This paper describes the evaluation of the characteristics of asphalt concrete mixtures containing Lawele natural asphalt and compare to those normally used Kabungka natural asphalt. The type of gradations used are AC WC-2 with two different gradations, i.e. above the Fuller curve and crossing the Fuller curve between No. 4 and No. 8 sieves. 10% by weight of Lawele natural asphalt was selected to substitute the aggregates in the mixtures and pen 60/70 grade asphalt was also used. At optimum binder content, the mixtures resistance against water and temperature, resilient modulus and permanent deformation were evaluated. The performance of mixtures satisfied the requirements and shows better performance than those mixtures containing Kabungka natural asphalt.

Key Words : Natural asphalt, Asphalt concrete, Marshall; Resilient modulus, Wheel tracking

1. INTRODUCTION

There are two types of natural asphalts available in Buton Island of Indonesia namely rock asphalt located in Kabungka area consisted mainly as hard asphalt and the softer natural asphalt in Lawele area. The deposit amount of Lawele asphalt is around 62.5 million ton with asphalt content on the average of 21.8% (Alberta, 1989). It was unfortunate that the utilization of that type of bitumen as road making material has not been optimized yet since some difficulties still arises on its exploration and use. It is expected by the almost users that by optimizing the use of Lawele natural asphalt, will reduce the amount of imported asphalt. Asphalt concrete is normally used as road making material especially for surface course in Indonesia.

Many factors influence the performance of asphalt concrete as surface course such as stability and also durability; asphalt has a dominant role in determining the stability and durability performance of the mixture. Natural asphalt from Kabungka (hard and low asphalt content) has been widely used as an additive or substitute of asphalt replacement in asphalt concrete mixture but the performance are still not satisfied the requirement. It is therefore needed to have further investigation on the use of natural asphalt from Lawele (soft and high asphalt content) in asphalt concrete and compare the result with asphalt concrete mixture containing Kabungka natural asphalt.

2. BUTON NATURAL ASPHALT

Natural asphalt can be distinguished into lake and rock asphalts. Trinidad Lake Asphalt (TLA) is one of natural asphalt widely use as a road making material. The particle of natural asphalt available in Buton Island is classified as rock asphalt consisting of mineral and asphalt and mainly found in the area of Kabungka and Lawele. Research done by Alberta (1989) on the rheology of Buton natural asphalt shows that natural asphalt from Kabungka contains a hard asphalt and from Lawele contains a soft asphalt. The total deposit of natural asphalt in Buton Island is not less than 120 million ton, half of it with average asphalt content of 20% is found in Kabungka and the rest is in Lawele with average asphalt content of 2.8%. So far, only natural asphalt from Kabungka was mined and used in asphaltic concrete as road material in Indonesia.

Table 1. Rheology Properties of Natural Asphalt from Buton

Asphalt Origin	Asphalt Content	Penetration (100gr, 5sec, 25°C) (0.1mm)		Soften ing Point	Kinematic Viscosity (poise)			
	(%)	(25°C)	(30°C)	(°C)	(60°C)	(100°C)	(120°C)	(150°C)
Lawele	29.5	185	-	40	1215	-	7.1	1.7
Kabungka	39.7	-	32	63	-	154	-	5.1
TLA	40.9	-	3	3	-	454	-	7.6

The asphalt in particle of natural asphalt comes from Kabungka is generally hard, the penetrations vary from 0 – 5, the asphaltene content is high and the maltene content is lower than the petroleum asphalt. It is therefore the Kabungka asphalt is expected to have a good affinity property and low temperature susceptibility. The chemical composition of the Kabungka mineral can be seen in the Table 2.

Table 2. Mineral Composition of Kabungka Asphalt

Chemical Matters	Percentage (%)
$CaCO_3$	81.62 – 85.27
$MgCO_3$	1.98 – 2.25
$CaSO_4$	1.25 – 1.70
CaS	0.17 – 0.33
H_2O	1.30 – 2.16
SiO_2	6.95 – 8.25
$Al_2O_3 + Fe_2O_3$	2.15 – 2.84
LOI	0.83 – 1.12

Source : Alberta (1989)

From the exploration done on 66 point in Lawele, the thickness of Lawele asphalt is around 9 – 45 meter or on the average depth of 29.88 meter with top layer covering around 3.47 meter.

The Lawele asphalt is dominantly consisted by the soft asphalt (pen up to 200) with high solvent content (Alberta, 1991)

3. THE CHARACTERISTICS OF MATERIALS

3.1. Aggregates

The aggregates used for material component in asphalt concrete mixture were collected from Subang Area in the North of Bandung. The type of aggregate was originally derived from igneous rocks and their engineering properties are shown in Table 3.

Table 3. The Properties of Aggregates Used in the Mixture

Properties	Values	Standard Requirements
Abrasion by Los Angeles Machine (%)	14.4	Max. 40
Aggregate Impact Value (%)	15.1	Max. 30
Flakiness Index (%)	14.7	Max. 25
Affinity to Asphalt (%)	> 95	Min. 95
Sand Equivalent Test (%)	54.11	Min. 40
Coarse Aggregates - Bulk Density - SSD Density - Apparent Density	 2.60 2.66 2.77	Min. 2.5
Fine Aggregates - Bulk Density - SSD Density - Apparent Density	 2.64 2.70 2.80	Min 2.5
Absorption (%) - Coarse Aggregate - Fine Aggregate	 2.30 2.10	Max. 3
Specific Gravity of Filler	2.84	

3.2. Petroleum Asphalt

Petroleum asphalt had to be added since natural asphalt alone was not enough for the purpose of mixing to have a proper asphalt mixture. The petroleum asphalt used in this investigation was obtained from the local contractor and supplied by the petroleum company in Cilacap. The engineering properties of petroleum asphalt used was investigated for two conditions, before and after loss on heating and the results are satisfied the requirements and shown on Table 4.

For the determination of temperature for mixing and compaction purposes, viscosity test using Brook Field's apparatus were done at various temperature, i.e. 135^{o}C, 150^{o}C , 165^{o}C as shown in Figure 1. Mixing and compaction temperatures were then determined using the viscosity values of 170 ± 20 cSt and 280 ± 30 cSt respectively. It was found that the temperature for mixing is 160^{o}C and for compaction is 140^{o}C.

Table 4. The Properties of Petroleum Asphalt of Pen 60/70

Properties	Values	Standard Requirements	Units
Penetration (25°C, 100 gr, 5 secs)	67	60 - 79	0.1 mm
Softening Point	52	48 - 58	°C
Ductility (25°C, 5 cm/min)	> 140	Min. 100	Cm
Solubility in C_2HCl_3	99.8	Min. 99	% weight
Flash Point, COC	318	Min. 200	°C
Specific Gravity	1.039	Min. 1.0	-
Loss on Heating – LOH (163 °C, 5hrs)	0.015	Min. 0.8	% weight
Penetration after LOH (25°C, 100 gr, 5 secs)	85	Min 54	% origin
Softening Point after LOH	53	-	°C
Ductility after LOH (25°C, 5 cm/min)	> 140	Min. 50	Cm

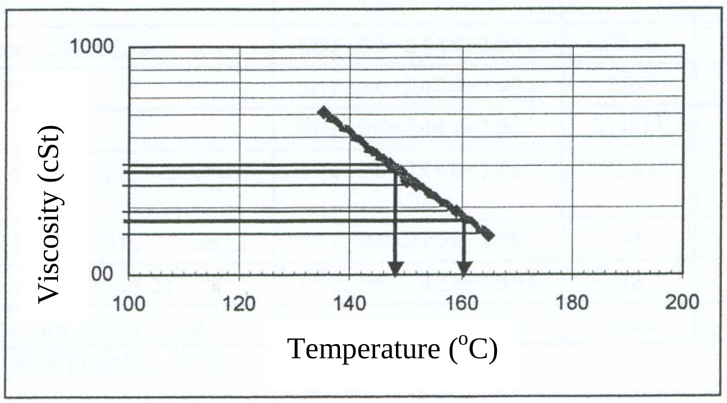

Figure 1. Temperature for Mixing and Compaction

3.3. Natural Asphalt from Lawele and Kabungka

Physical and chemical tests were done on the extraction results of Lawele and Kabungka natural asphalt as shown on Tabel 5 and Table 6.

Table 5. The Properties of Lawele and Kabungka Natural Asphalt Extraction Results

Properties	Lawele	Kabungka	Units
Asphalt Content (%)	30.8	20.0	
Penetration (25°C, 100 gr, 5 secs)	36	4	0.1 mm
Softening Point	59	101	°C
Ducility (25°C, 5 cm/min)	>140	<140	Cm
Solubility in C_2HCl_3	99.6	-	% weight
Flash Point, COC	198	-	°C
Specific Gravity	1.037	1.046	-
Loss on Heating – LOH (163 °C, 5hrs)	0.31	-	% weight
Penetration after LOH (25°C, 100 gr, 5 secs)	94	-	% origin
Softening Point after LOH	62	-	°C
Ductility after LOH (25°C, 5 cm/min)	>140	-	Cm

Table 6. Chemical Results of Lawele and Kabungka Asphalt

Chemical Components	Lawele	Kabungka
Nitrogen Bases (N), %	27.01	29.04
Acidaffins (A1), %	9.33	6.60
Acidaffins (A2), %	12.98	8.43
Paraffin (P), %	11.23	8.86
Maltene Parameter	1.50	2.06
Nitrogen/Paraffine, N/P	2.41	3.28
Asphaltene Content, %	39.45	46.92

3.4. Mineral of Lawele

The particle of natural asphalt is consisted of two material as asphalt itself and the rest is dominantly by aggregate as mineral. The gradation of particle and mineral and also the chemical composition of both type of natural asphalts are shown in Table 7 and Table 8. It can be seen that the mineral part of natural asphalt observed were mainly carbonate in the form of $CaCO_3$ (72.90% and 86.66% for Lawele and Kabungka, respectively).

Table 7. Gradation of Particle and Mineral from Lawele and Kabungka

Sieve Size		Percentage Passing		
		Lawele		Kabungka
inch	mm	Particle	Mineral	Mineral
No. 4	4.76	100	-	-
No. 8	2.38	40.9	100	-
No. 30	0.595	5.7	99.1	-
No. 50	0.297	1.4	89.1	100
No. 100	0.148	1.0	49.3	95.6
No. 200	0.074	0.2	32.2	4.5

Table 8. Chemical Composition of Mineral of Lawele and Kabungka

Composition	Values (%)	
	Lawele	Kabungka
$CaCO_3$	72.90	86.66
$MgCO_3$	1.28	1.43
$CaSO_4$	1.94	1.11
CaS	0.52	0.36
H_2O	2.94	0.99
SiO_2	17.06	5.64
$Al_2O_3 + Fe_2O_3$	2.31	1.52
LOI	1.05	0.96

Sieve analysis was also done to consider the gradation of natural asphalt before and after extraction.

4. MIX DESIGN, TESTS AND ANALYSIS

4.1. Design of Asphalt Concrete

Gradation is one important factor influencing the properties of asphalt mixture such as stiffness, stability and also durability. In this investigation, gradations following the Fuller curve was chosen and to distinguish the type of mixture used, two alternative of gradations were selected, firstly is above the Fuller curve (GAL, GAK) and secondly across the Fuller curve in between the sieves of No. 4 – No. 8 (GBL, GBK). L represents the natural asphalt from Lawele and K from Kabungka. Asphalt Mixture design was based on the aggregate gradation and Lawele (L) and Kabungka (K) natural asphalt used; firstly, asphalt mixture uses the gradation above the Fuller Curve (GAL & GAK) and secondly, asphalt mixture uses the gradation across the Fuller Curve (GBL & GBK) with some aggregates replacement by particle from Lawele and Kabungka of 10% for each type. The substitution of Lawele and Kabungka particles will automatically replace the asphalt and filler used in the mixture.

Table 9. Gradation Requirement and Selected Gradations

	Sieve Sizes							
inch	¾”	½”	3/8”	#4	#8	#30	#50	#200
mm	19	12.7	9.5	4.75	2.36	0.6	0.3	0.075
	Percent passing							
Control Points								
Max	100.00	100.00	90.00		58.00			10.00
Min	100.00	90.00			28.00			4.00
Fuller Curve	100.00	82.20	73.20	53.60	39.10	21.10	15.50	8.30
Restricted Area								
Max					39.10	23.10	15.50	
Min					39.10	19.10	15.50	
Gradation above Fuller Curve (GAL)	100.0	92.0	81.0	60.0	45.0	27.0	19.0	6.5
Gradation across Fuller Curve (GAK)	100.0	92.0	81.0	57.5	35.0	17.0	12.0	6.0

Marshall design was used and five asphalt content were applied for each type of asphalt mixture, namely 6%, 6.5%, 7%, 7.5% and 8% from the total weight of mixture. The aggregates and asphalt was heated and mixed at the temperature of 160^{o}C and the compaction of 2 x 75 blows were applied at the temperature of 148^{o}C. The optimum asphalt content were obtained for each asphalt mixture of 6.7% and 7.2% for GAL and GBL mixtures respectively and 6.3% and 7.2% for GAK and GBK mixtures respectively. The properties of asphalt concrete mixture at their optimum asphalt content are shown in Table 10.

The Marshall stability values of mixture (for both Lawele and Kabungka) having gradation above the Fuller curve are higher than the mixture having gradation across the Fuller curve type. The reasons might be caused by the lower of Voids in Aggregate Mixture (VMA) and Voids in Mixture (VIM) values and higher densities in comparison with other mixture having gradation across the Fuller type.

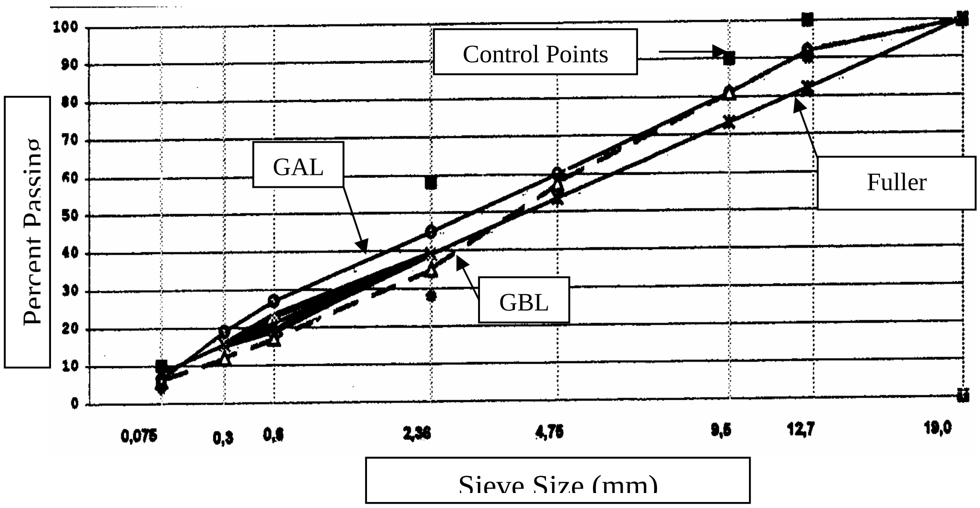

Figure 2. Mix Gradation Selected with Maximum Aggregate Size of 19.00 mm

Table 10. The Properties of Asphalt Concrete Mixture at Their Optimum Asphalt Content

Mix Properties	Lawele		Kabungka		Requirements
	GAL	GBL	GAK	GBK	
Optimum Asphalt Content (%)	6.7	7.2	6.3	7.2	-
Asphalt Absorption (%)	0.7	0.3	0.8	0.5	max. 1.2
Density (gr/cm^3)	2.30	2.24	2.28	2.26	-
Voids in Mixture (%)	4.5	5.4	5.0	5.2	4 - 6
Voids in Mineral Aggregate (%)	18.0	20.4	17.2	20.0	min. 15
Voids Filled with Asphalt (%)	72.0	74.0	70.0	73.0	min. 65
Marshall Stability (kg)	1390	975	1525	1360	min. 800
Flow (mm)	2.9	3.1	3.3	3.5	min. 2
Marshall Quotient (kg/mm)	495	315	470	380	min. 200
Voids in the Mixture at its Absolute Density (%)	3.5	3.0	3.4	3.2	min. 2.5

4.2. Marshall Immersion

The purpose of this test was to measure the resistant of mixtures against the water and temperature. The results are shown in the Table 11.

Table 11. the Results of Marshall Immersion Test

Mixtures containing	Type of Mixtures	Stability after Immersion (kg)		Index of Retained Stability (%)
		at 30 minutes	at 24 hours	
Lawele	GAL	1146	980	85.50
	GBL	146	998	87.10
Kabungka	GAK	1319	1069	81.10
	GBL	NA	NA	NA

For the mixture having similar gradation which is above the Fuller curve (GAL and GAK), mixtures containing Lawele natural asphalt seems to have a higher value of index of retained stability and satisfy the requirements. Lawele asphalt is softer than the Kabungka and it is therefore able to soften easily when it is mixed with petroleum asphalt and together fill the voids in mixture resulted in low values of VIM. Mixture having low value of VIM will stands better and more resistant against water.

4.3. Wheel Tracking Tests

Wheel tracking test is simulation test using moving wheel load forward and backward on the specimens of asphalt mixture of 30cm x 30cm x 5cm in size. The aim is to evaluate the resistant of asphalt mixture against permanent deformation in the form of rutting. Test was done in the laboratory with temperature adjustment depending of the pavement temperature in the service and the results show the relation between times and deformations. Dynamic Stability (DS) and Rate of Deformation (RD) can be obtained from the curve as shown in the following Figure 3.

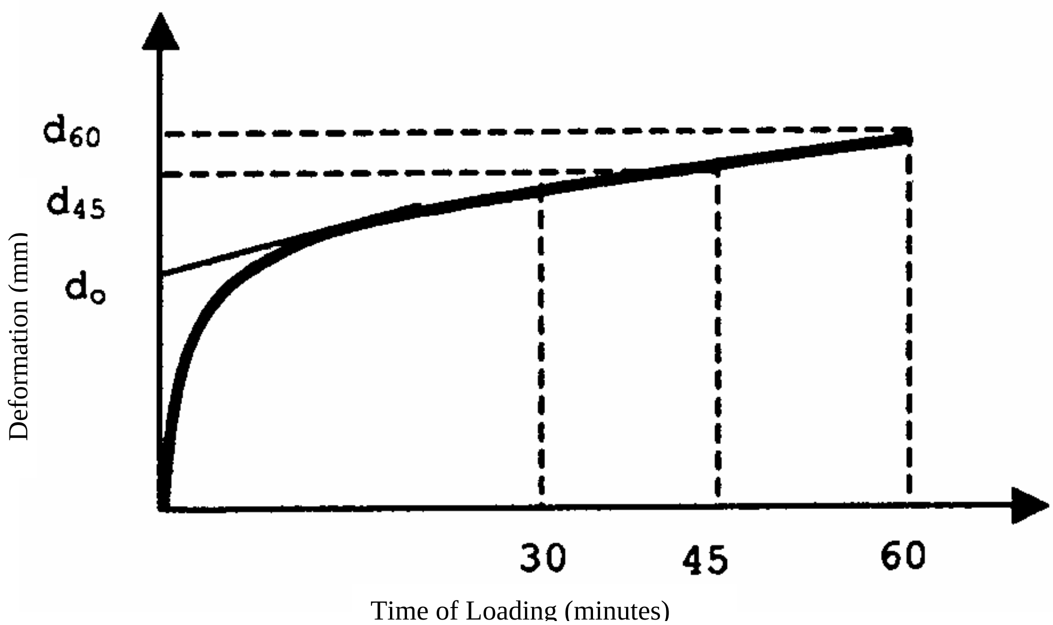

Figure 3. The Relation between Time of Loading and Deformation

Specimens were prepared at their optimum asphalt content and the wheel tracking test was carried out at the temperature of 60°C. Results are shown in the Table 12 and Figure 3.

$$DS = 44x\frac{(t2-t1)}{(d2-d1)} \quad \ldots (1)$$

$$RD = \frac{(d2-d1)}{(t2-t1)} \quad \ldots (2)$$

where :

DS = Dynamic Stability (passes/mm)
RD = Rate of Deformation (mm/minute)
d1 = deformation after 45 minutes (mm)
d2 = deformation after 60 minutes (mm)
t1 = 45 minutes
t2 = 60 minutes

The value of permanent deformation is depended on the mixture composition and its component materials such as gradation and asphalt properties. From two type of gradation and two type of natural asphalt used in the mixtures, the average rate of deformation seems to be similar for all variations, whish is higher in the beginning of test and lowering after 630 wheel passes. The influence of gradation on the resistance of the mixtures is quite significant, mixtures having gradation above the Fuller curve (GAL and GAK) has smaller permanent deformation values (GAL = 1.07 mm and GAK = 1.47 mm) in comparison with the mixtures having gradation across the Fuller curve (GBL = 1.95 mm and GBK = 1.61 mm).

Table 12. Wheel Tracking Test Results at Temperature of 60^{o}C

Time of Loading (minutes)	Amount of Passing	Mixtures Containing Natural Asphalt from			
		Lawele		Kabungka	
		GAL	GBL	GAK	GBK
0	0	0	0	0	0
1	21	0.37	1.00	0.67	0.70
5	105	0.65	1.52	1.07	1.15
10	210	0.85	1.79	1.28	1.39
15	315	0.95	1.97	1.40	1.55
30	630	1.14	2.29	1.61	1.87
45	945	1.27	2.52	1.74	2.12
60	1260	1.35	2.71	1.83	2.29
Rate of Deformation (mm/minute)		0.005	0.013	0.006	0.011
Dynamic Stability (passes/mm)		7875	3315	7000	3705
Permanent Deformation (mm)		1.07	1.95	1.47	1.61

The low average permanent deformation values of GAL and GAK mixtures show that the resistance of that mixtures are higher caused by the dense gradation as seen by low value of VMA. Mixtures having Lawele asphalt has lower permanent deformation values since those mixtures are stiffer as seen by high value of MQ and it means that the mixture containing Lawele asphalt will be more resistant to traffic loading

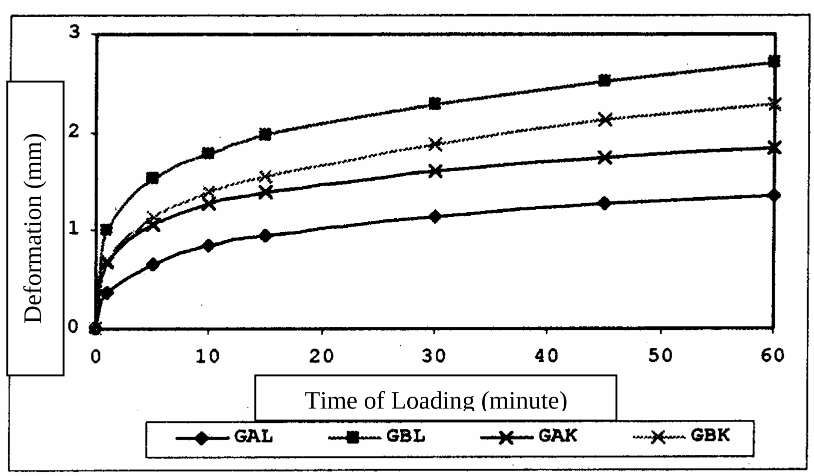

Figure 4. The Relationship of Deformation and Time of Loading

4.4. Resilient Modulus of Asphalt Concrete Mixture

Resilient Modulus is an important parameter to determine the performance of pavement, to analysis the pavement response to traffic loading. The test was done by measuring the indirect tensile strength in repeated loading using Universal Material Testing Apparatus (UMATTA). Specimens at their optimum bitumen content were made and loaded by diametrical force in pulse loading. This apparatus consists of Control and Data Acquisition System (CDAS), personal computer and related integrated software. The test follows the ASTM Designation D 4123-82. Data inputted were condition pulse count = 5, condition pulse period = 3000 ms, test pulse period = 2000 ms, rise time = 50 ms, peak loading force = 1000 N and estimated poisons ratio = 0.35 (Kusnianti, 2003).

Some parameters were obtained directly by the automatic computer calculation, e.g. resilient modulus, rise time peak, time of loading, tensile stress, peak force and total recoverable strain. The temperature of test was selected as room temperature of 25^{o}C, 35^{o}C and 45^{o}C.

The formula of resilient modulus calculation is :

$$E = Fx\frac{(\mu + 0.27)}{(LxH)} \quad \text{..... ….. ….. ….. ….. ….. ….. ….. ….. ...} \quad (3)$$

where :
E = resilient modulus (MPa)
F = maximum applied load (N)
μ = poisson ratio
L = length of specimen
H = total horizontal deformation (mm)

The resilient modulus of asphalt mixture is an important parameter in determining the pavement performance and as a basic properties to analysis the pavement response against the traffic loading. The resilient modulus of the asphalt mixture is important parameter to see the pavement response to traffic loading. Measurement was done using UMATTA apparatus and the results are shown in the following Table 13.

Table 13. The Values of Mixture Resilient Modulus

Temperature	Type of Mixtures (MPa)			
	GAL	GAK	GBL	GBK
25^{o}C	5596	5378	4729	4575
35^{o}C	2987	2812	2432	2274
45^{o}C	1645	1523	1332	1215

As expected that temperature influence much the values of asphalt mixture since asphalt is a material of viscoelastic influenced by temperature and time of loading. The values of resilient modulus are higher for mixture having gradation above the Fuller curve than the mixture having gradation across the Fuller type for both Kabungka and Lawele mixtures. The reasons are mixtures containing Lawele asphalt have a low values of voids and high value of density than the mixture containing Kabungka asphalt and it is therefore mixture containing Lawele asphalt is expected to have slightly higher resistant against traffic load than the Kabungka one.

Results and discussions represent that Lawele natural asphalt gives an indication for having better characteristics to be used as road making materials than the Kabungka natural asphalt.

5. CONCLUSIONS

Some conclusions can be drawn from the discussions

a. Lawele natural asphalt has a good physical properties as with penetration value is higher than the Kabungka and in the mixture can therefore be mixed with soft petroleum asphalt. Chemical composition also supports better durability with high asphaltene content
b. The Marshall properties of asphalt concrete mixture also show that the asphalt concrete mixture with gradation above the Fuller curve (GAL and GAK) has a better properties in comparison with asphalt concrete mixture with gradation across the Fuller curve.
c. All mixtures with 10% substitution of Lawele asphalt satisfy the specification required and even has a better values especially in the influence of water against the mixture
d. The resistant against deformation permanent, mixture containing Lawele asphalt sow a better result than the mixtures containing Kabungka asphalt.
e. The values of resilient modulus of mixture containing Lawele asphalt with gradation above Fuller type is higher than the mixture with gradation across Fuller type for all temperature measurements.

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