PROPERTIES OF REFINED NATURAL ASPHALT BUTON (ASBUTON) as PAVEMENT MATERIALS

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RINGKASAN

Ada dua tipe bitumen, yaitu yang terjadi dialam dan yang merupakan hasil refinery dari minyak bumi. Salah satu jenis aspal alam ialah" rock asphalt".

Di P.Buton, propinsi Sulawesi tenggara terdapat deposit aspal alam jenis " rock asphalt" yang sangat besar, mengandung kadar aspal antara 5% sampai 30% dengan rata rata sekitar 20% dan sisanya dalah mineral, yang umumnya batu kapur atau pasir.

Aspal alam jenis "rock aspal" ini dikenal dengan nama Asbuton merupakan singkatan dari Asphalt Batu dari P. Buton

Perkiraan jumlah deposit bervariasi dan diperkirakan mencapai 200 juta ton. Deposit tersebut merupakan sumber alam nasional yang sangat penting, yang berpotensi untuk meningkatkan sifat aspal minyak guna melayani volume serta beban lalu lintas di masa dating, mengurangi impor aspal dan meningkatkan pendapatan dari sisi ekspor. .

Untuk mendapatkan produk Asbuton yang lebih baik, penelitian dan pengembangan telah dan sedang dilakukan. Proses refinery telah dikembangkan. Proses refinery mengurangi kandungan mineral guna menghasilkan "Refined Asphalt Buton" yang mempunyai kandungan bitumenya sekitar 60% dan proses yang baru baru saja dikembangkan dimaksudkan untuk menghasilkan "Aspal buton murni hasil refinery" yang mempunyai kandungan aspal > 99%.

Penambahan Refiend Asphalt Buton menaikan "Titik Lembek" dan menurunkan "Penetrasi" dari aspal pen 60/70. Penambahan 20% Refined Asphalt Buton dan sekitar 54% " Asphalt Buton Murni hasil Refineryi" menaikkan titik lembek dari 48,5 C menjadi 55C; serta 58C dan 54C.

Campuran yang mengandung "Refined Asphalt Buton" tidak begitu terpengaruh oleh perubahan temperature sebagaimana ditunjukkan oleh naiknya nilai Penetrasi Indek (PI). Hal ini akan memperbaiki ketahanan dari campuran beraspal terhadap deformasi permanen khususnya di daerah beriklim tropis sebagaimana ditunjukkan dari hasil pengujian wheel tracking dan pengujian kuat tekan bebas.

Penambahan Refined Asbuton mempunyai pengaruh yang sangat berarti dalam peningkatan kekakuan campuran yang akan memperbaiki kemampuan penyebaran beban dari campuran beraspal tersebut sebagaimana ditunjukkan oleh kenaikkan dari modulus campuran tersebut. Kenaikan modulus mencapai 1,2 dan 2,7 kali untuk campuran yang mengandung 20% dan 54% "Refined Asphalt Buton" dalam campuran bitumennya. Hal ini dikarenakan kenaikan dari Titik Lembek dan penurunan dari nilai Penetrasi. Kenaikan kekakuan campuran menjadiakn campuran tersebut mampu menyebarkan beban lalu lintas ke lapisan bawah perkerasan yang lebih luas lagi. Ini akan menjadikan tegangan dan regangan pada perkerasan menjadi lebih rendah lagi dan selanjutnya menghasilkan perkerasan dengan umur pelayanan yang lebih lama.

SUMMARY

There are two main types of bitumen i.e. those which occur naturally and those which are by product of the fractional distillation of petroleum. One type of natural bitumen is natural rock asphalt.

There is a large reserve of natural rock asphalt in Buton Island-South East Sulawesi Province, Indonesia; containing a bitumen content of 5% to 30% with an average bitumen content of 20% and the remainder of the material is solid mineral matter, usually limestone or sandstone. The natural rock asphalt is known as Asbuton abbreviation of Asphalt Batu Buton i.e. Rock asphalt from Buton Island.

The size of deposit has been variously estimated at up to 200 million tonnes. The deposit is therefore an important national resource with the potential to improve the properties of petroleum bitumen to carry the current and ever increasing traffic and axle loads in the future, reduce need imported bitumen and generated export income.

To get a better quality Asbuton product, research and development has been ongoing. A viable refining process has been developed. The refining process reduces the mineral content to produce Refined Asphalt Buton that has a bitumen content around 60 % and new process has been recently developed produce a "pure Refined Asphalt Buton" has bitumen content > 99 %. These types possess high consistency and homogeneity and allow a uniform high quality asphalt to be produced.

The addition of Refined Asphalt Buton bitumen increases the "Softening Point" and lower the "Penetration" of petroleum bitumen 60/70 pen grade. The addition of 20% refined asphalt Buton and about 54 % pure refined Asphalt Buton bitumen P40/60 and P60/80 increases the softening point from 48,5°C to 55°C; 58°C and 54°C respectively. The penetration decreases from 61 dmm to 46 dmm and 47 dmm respectively.

Blends containing Refined Asphalt Buton are less temperature susceptible as indicated by increasing Penetration Index (PI) value. This will improve resistance of a mix to permanent deformation particularly in tropical climates as indicated from wheel tracking test and Unconfined Uniaxial loading test results.

The addition of Refined Asbuton has a significant effect in improving the mix stiffness which will improve the load spreading ability of the mix as indicated by increasing stiffness modulus. Increasing in the mix stiffness by 1.2; 2.7; times for the mixes containing 20 % and 54 % Refined Asbuton in the blend binder. This is due to increase in Softening Point and a reduction in Penetration. Increasing in the mix stiffness would be able to spread the traffic loads onto the under laying layers of the pavement over as wide an areas as possible. The latter would mean that the stresses and strains in the pavement would be kept to a minimum resulting in a longer life for the pavement.

I. INTRODUCTION

Indonesia currently consumes 1.2 million tonnes of bitumen annually for maintaining and constructing new roads. About 600,000 tonnes is locally produced and the rest is imported. The local product consist of 500,000 tonnes of petroleum bitumen and 100,000 tonnes of natural rock asphalt in granular form.

The natural rock asphalt is known as Asbuton abbreviation of Asphalt Batu Buton i.e. Rock asphalt from Buton Island, Southeast Sulawesi Province, Indonesia. In Indonesia, the Asbuton deposits are found on South Buton Island in southeast Sulawesi. They occur in a roughly linear belt that stretches from just north of Sampolawa Bay in the south to Lawele Bay in the north (Figure 1). This is a distance of approximately 50 km. At its widest in the Winto – Kabungka area the deposit are about 10 km wide.

There is a large reserve of natural rock asphalt in Indonesia containing a bitumen content of 5% to 30% with an average bitumen content of 20%. The Size of deposit has been variously estimated at up to 200 million tonnes. The deposit is therefore an important national resource with the potential to :

- Reduce the need of imported bitumen
- Improve the properties of petroleum bitumen to carry the current and ever increasing traffic and axle loads in the future.
- Generated export income

They have been mined commercially since 1926 for road applications. The deposits were discovered in the early 1920's and exploration began in the mid 1920's.

Production from this area in 1926 was 670 tonnes. Peak production of Asbuton was reached in 1983 with the total production of 533,189 tonnes. In 1987 it was 84,888 tonnes . The cumulative production from 1929 to 1987 has been 3,894,220 tonnes. In road paving or industrial application there typically only minor usage of these natural asphalt (O'Flaherty, 1988; Whiteoak, 1990) In Indonesia the amount of road paved with Asbuton is very small. Hoff and overgaard (1992) in their report "Indonesia Highways Statistic" as staded by Akoto(1996) that the length of national road network in Indonesia was 258.854 km. This comprises National and Provincial roads (51.738 Km), Kabupaten roads (181.266 km); Municipal roads (35.431 km) and Toll roads 9373 km)

; 90% of the National and Provincial road networks are paved. Only 3.8% (1,951 km) of this paved with Asbuton. Nearly 63% of National and Provincial roads paved with Asbuton are found in Sulawesi Island.

As shown in Figure 1, the deposit occurs in at least twenty four areas on Buton island, south east Sulawesi Province and is commonly known as Asbuton.

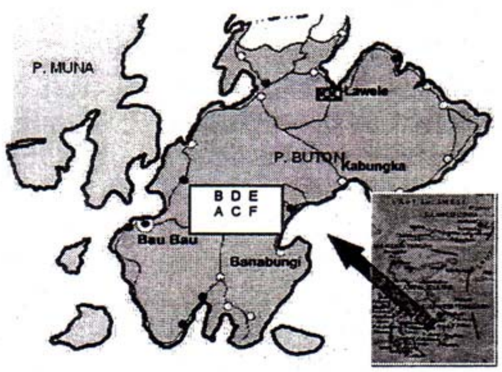

Figure 1. Location of map for Buton Island deposits

The best known of the Asbuton deposits are those of the Kabungka area. These are collectively known as the Kabungka deposits.

The company who produce Asbuton product has identified 3.8 million tonnes of remaining mine able Asbuton reserves in the Kabungka area. In the Lawele area it has been established that there is 87.7 million tonnes of Asbuton with > 5% bitumen content and an average saturation of 18.1 % by weight (Kreamers, 1989)

II. PHYSICALAND CHEMICAL CHARACTERISTICS OF ASBUTON

The Asbuton deposits on Buton Island have a wide range of bitumen properties. Considering only those areas which have mineable reserves to support commercial development, the bitumen from Kabungka Pit F would need to be hardened to meet the road–grade specification. Kabungka Pit B is either slightly to hard or just meets the specification, Kabungka Pit E bitumen needs to be softened to be used for road paving. There is a large range of bitumen properties with penetration values reported as low as 0 dmm at 25 °C and 100 g load for 5 sec, to as high as 10 dmm under the same conditions (Wallace, 1989)

Lawele bitumen either tends to be soft or just meet road grade specifications. Within the Lawele deposits, there is a large range of bitumen properties with penetration values reported as low as 60 dmm at 25 °C and 100 g load for 5 sec, to as high as 210 dmm under the same conditions (Wallace, 1989).

Bitumen from Pit B and some a reas of Lawele area are approximately of the correct rheology for pavement application. Bitumen from Pit F and other areas of Lawele would require hardening either by blending with a harder Asbuton bitumen or propane asphaltenes, or by striping the light components in a distillation unit. Chemical cómposition of Asbuton mineral content is shown in Table 1.

Table 1
Chemical composition of Asbuton mineral content (Dairi, 1992)

Chemical	Buton ASP Batavia	Institute of Geology Research	RDCRB	Unit
SiO_2	6.95 – 10.20	11.4	8.80 – 10.20	%
Al_2O_3	2.15 – 2.84	3.54	0.78 – 2.61	%
Fe_2O_3	-	2.18	2.09 – 2.42	%
FeO	-	0.00	-	%
CaO	-	33.51	39.09 – 46.72	%
MgO	-	2.61	0.44 – 3.50	%
Na_2O	-	0.23	0.50 – 0.80	%
K_2O	-	0.39	0.30 – 0.39	%
TiO_2	-	0.18	-	%
MnO	-	0.00	-	%
P_2O_5	-	0.20	-	%
H_2O -	-	2.07	-	%
H_2O+	-	0.78	-	%
SO_3	-	-	0.5 – 0.9	%
CO_2	-	-	-	%
$CaCO_3$	81.62 – 85.27	-	-	%
$MgCO_3$	1.98 – 2.25	-	-	%
$CaSO_4$	1.25 – 1.70	-	-	%
CaS	0.17 – 0.33	-	-	%
CO_2	-	-	37.5 – 39.5	%
Loss on burning	-	42.89	-	%

RDCRB : Research and Depelopment centre for Road and Bridge

The fact that a range of bitumen treatment options are required to produce a consistent product is a major consideration in the overall refining strategy and economics of these deposits.

III. DEVELOPMENT OF INDONESIA NATURAL ROCK ASPHALT PRODUCT

There are two main types of bitumen i.e. those which occur naturally and those which are by product of the fractional distillation of petroleum, as shown in Figure 2. One type of natural bitumen is natural rock asphalt. Asbuton as Natural rock asphalt consists of a granular material usually limestone or sandstone. In it natural state its contains bitumen intimately dispersed throughout its mass. The bitumen content of natural rock asphalt generally varies from 5 % to 30 %. The remainder of the material is solid mineral matter.

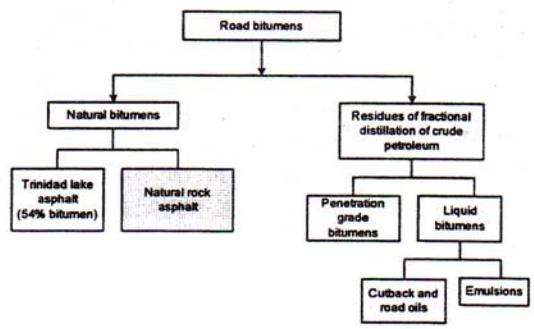

Figure 2 Bitumen categories (O'Flaherty, 1988)

The Dutch first opened an Asbuton mine at the southern tip of the deposit belt around Sampolawa Bay

(Kabungka). This was later continued by P.T Sarana Karya.

Deposits at the northern tip of the belt (Lawele Bay) that have a much higher bitumen content have not yet been exploited. This has been due to the unavailability of appropriate technology to process the natural rock asphalt of the Lawele type. In general the rock asphalt from Kabungka area is relatively hard and therefore easier to crush prior to use for paving low quality roads (Kadarsin, 1998).

In the past, only granular types of Asbuton product are available in the market. These product are produced by crushing and the size varies from 12.5 mm (conventional Asbuton) down to less than 0.6 mm (Mikro Asbuton). The product can be applied either in a cold mix by fluxing the Asbuton with a suitable rejuvenating flux oil or in a hot mix system through the formation of a hot mastic (Kadarsin et.al, 1998; James, 1996)

To get a better quality Asbuton product, research and development has been ongoing. A viable refining process has been developed. This technology can process the both types of rock asphalt i.e. the Kabungka as well as the Lawele type. The refining process reduces the mineral content to produce Refined Asphalt Buton that has a bitumen content 60% and nearly 100%.

Unlike the granular products, these new type such as Refined Asphalt Buton possess high consistency and homogeneity and allow a uniform high quality asphalt to be produced (Kadarsin et.al, 1998).Asbuton has been used with varying degrees of success both as an overlay and as a surfacing material for new construction. Both structural and non structural overlays have been attempted. Asbuton was applied either in a cold mix by fluxing with a suitable rejuvenating flux oil or in a hot mix system through the formation of hot mastic. Both these used granular types of Asbuton (Purwadi et,al., 1998; Kadarsin et.al., 1998)

The factors responsible for poor field performance of Asbuton in some projects include an inherent variability in moisture content, bitumen content, the maximum particle size, type of modifier used, contamination during transportation and curing, inability of the modifier to penetrate into the Asbuton particles and finally the quality control on – size (Purwadi et.al., 1998). The performance of most of the roads constructed with Fine Asbuton (granular type, particle size less than 2,36 mm), Asbuton mikro and Butonite Mastic (liquid binder, granular size of 0,6 mm) tended to better than those constructed with conventional Asbuton (Purwadi et.al., 1998).

3.1 Asbuton product and applications

Type of Asbuton product

In conventional Asbuton there are certain problems with its quality. The producers of granular Asbuton categories their product by bitumen content. For example B 16 and B20 grades means bitumen contents of 16% and 20% respectively. The main types of Asbuton product is shown in Table 2.

Table 2
The main types of Asbuton product (James, 1996)

Type of Asbuton product	Characteristics product	Application	Available since
Granular type			
Conventional Asbuton	Original product Grading to less than 12.7 mm	Cold mix	1929
Fine Asbuton	Grading to less than 6 mm	Cold mix	1993
Asbuton Mikro and Asbuton Mikro plus	Grading to less than 0.6 mm	Cold, Warm and Hot mixes	1993 and 1996
Butonite Mastic (liquid binder)	Grading to less than 0.6 mm	Hot mix	1995
Buton Granular Asphalt (BGA)	Grading to less than 1.16 mm	Hot mix, Cold mix	
Refined product type Refined Asbuton Bitumen	Extracted from Asbuton	Hot mix	1997; 2003

The aggregate grading was found to be extremely variable. The main problem in terms of performance is the material passing the No 200 (75 micron) sieve. This varied between 12% and 60%, and that variability is extremely difficult to account for in a mix design procedure.

Another problem of conventional Asbuton is contamination and segregation as the materials is exported from Buton without being put in a bag. Another problem is the inability of modifiers to penetrate into the larger Asbuton particles to release the bitumen and go permanently soften it.

Asbuton halus (Fine Asbuton)

As the result of this problems with conventional Asbuton, the company who produces Asbuton product (PT Sarana Karya) now produce an Asbuton Halus (Fine Asbuton) with a maximum particle size less than 6.3 mm with between 35% to 100 % passing a 2.36 mm sieve size. The moisture content is 6% and it is suplied in bags. These changes eliminate most of the problems for conventional Asbuton.

Asbuton Mikro and Asbuton Mikro plus

Asbuton Mikro and Asbuton Mikro Plus is similar to Fine Asbuton. However, the maximum particle size is 2.36 mm with 85% to 100% passing a 0.6 mm sieve. This homogenised, finely ground contributes to better field performance. It was developed not to lump together.

Buton Granular Asphalt (BGA)

Buton Granular Asphalt (BGA) is similar to Asbuton Mikro, the maximum particle size is 1.16 mm. This homogenised, finely ground and limitation of water content, contributes to better field performance. BGA consist of two types, first is "5/20 BGA" with penetration bitumen < 10 dmm and bitumen content between 18–22 %, meanwhile the second one is "20/25 BGA" where its penetration bitumen between 19–22 dmm and bitumen content 23 to 27 %.

Refined type Asbuton Product

Refined Asphalt extracted from Asbuton behaves differently to other granular Asbuton products. The refining process reduces the mineral content to produce a Refined Asbuton Bitumen with a bitumen content between 60% and 100 % (Pure Refined Asbuton) The grades of refined Asbuton are shown in Table 3.

Table 3

Refined Asbuton product range

Product	Composition		Applications
	Bitumen Content	Filler Content	
Refine Asphalt Buton 60	Min 60 %	40 %	Multipurpose mastic asphalt grade for road construction e.g. Base Course, Stone Mastic Asphalt (SMA), Hot Rolled Asphalt (HRA)
Blend of Pure Refined Asphalt Buton; SP = 54 °C Pen= 47,2 dmm	> 99 %	Less than 1%.	Multipurpose mastic asphalt grade for road construction e.g. Base Course, Stone Mastic Asphalt (SMA), Hot Rolled Asphalt (HRA)
Blend of Pure Refined Asphalt Buton; SP = 57,6 °C Pen = 47 dmm	> 99 %	Less than 1%	Multipurpose mastic asphalt grade for road construction e.g. Base Course, Stone Mastic Asphalt (SMA), Hot Rolled Asphalt (HRA)

IV. THE RHEOLOGICAL PROPERTIES OF BITUMEN BASED ON EXPERIMENTAL LABORATORY TEST

Bitumen is only a minor component of bituminous mixes. But it has a crucial part to play in providing visco–elasticity and acting a durable binder. Essentially, the performance of a binder is achieved if certain properties are controlled, namely rheology, cohesion, adhesion and durability. The primary or routine rheological properties are penetration, softening point and viscosity.

The penetration can be considered as a consistency parameter for the service range of bitumen temperatures. The viscosity is a consistency parameter for bitumen in the liquid phase and thus important for the application temperature range. The softening point is a transition temperature between a more solid and a more liquid consistency. The temperature susceptibility is usual described as the change of primary or routine rheological properties of bitumen with temperature.

Pleiffer and Van Dormaal defined the temperature susceptibility of bitumen as the Penetration Index (Whiteoak, 1990; Bats and Gooswilligen, 1989).

$$PI = \frac{1952 - 500\log Pen - 20(SP)}{50\log Pen - (SP) - 120}$$

Where: pen = penetration
SP = Softening Point

The value of PI ranges from-3 for highly temperature susceptible bitumens to about + 7 for highly blown low temperature susceptible (high PI) bitumen. The penetration Index may also be used as an indicator of other rheological properties and is a guide to chemical composition as shown in Table 4.

Table 4.
Penetration Index (PI), Chemical composition and Rheological properties of bitumen binders (Lees, 1982).

Chemical composition	PI	Rheological Properties
About 15% aromatic	> +2	" Rubbery " gel. Type of colloid thicotropic and with elastoplastic flow characteristics, low temperature susceptibility.
About 25% aromatic	+2 to – 2	"Normal" gel. Type of Colloid, visco elastic. Medium temperature susceptibility.
About 50% aromatic	< -2	"Brittle" true solution exhibiting Newtonian behaviour, i.e. viscous flow. High temperature susceptibility.

The physical properties of blend Refined Asphalt Buton (contain 40 % mineral in its original and pure Refined Asphalt Buton) are shown in Table 5.

Table 5
Rheology properties of Refined Asbuton Product

Property	Blend of Refined	Blend of Pure Refined Asbuton		Pure Petroleum bitumen	Unit
		P 60/80	P 40/60		
Composition of blend bitumen (BRA: Petroleum bitumen 60/70 pen grade)	20 : 80	54 : 46	35:65	-	-
Penetration at 25 C	44	47.2	47	61	0.1 mm
Softening Point (R& B)	55	53.9	57.6	48.5	°C
Ductility	81.2	> 40	>140	>140	Cm
Solubility in C_2HCL_3	93.3	-	-	99.8	%
Flash Point	328	-	-	335	°C
Unit Weight	1.069	-	-	1.046	-
Loss on Heating	0.010	-	-	0.014	%
Penetration after loss on heating	88.2	-	-	90.2	0.1 mm
Softening Point after loss on heating	58.3	-	-	49.5	°C

This Table showed that the addition of Refined Asbuton Bitumen increases the Softening Point and lowers the penetration of petroleum bitumen 60/70 pen grade. The addition of 20% Refined Asbuton and 35% to 54% Pure Refined Asbuton bitumen increases the Softening Point from 48.5 °C to 55 °C and 54 to 57.6 °C respectively. The penetration decreases from 61 dmm to 44 dmm and 47 dmm respectively.

Based on the data in Table 5, the Penetration Index (PI) of pure petroleum bitumen is -1.3, mean while the Penetration Index of Refined Asbuton Bitumen (40% mineral), pure Refined Asbuton Bitumen (P 60/80), and pure Refined Asbuton Bitumen (P 40/60) are -0.33, -0.41, 0.32 respectively.

It can be seen from Table 6 that the addition of Refined Asbuton Bitumen increased the Penetration Index value of the binder. If the data compared to Table 4, it can be concluded that all of bitumen have medium temperature susceptibility. However the PI of pure Refined Asbuton Bitumen and Refined Asbuton Bitumen are less temperature susceptible as the penetration Index increase. The results show that the pure Refined Asbuton Bitumen is less temperature susceptible than the Refined Asbuton Bitumen contain 40% mineral.

During mixing the pure bitumen requires less energy to raise its temperature to the required mixing temperature than for the Asbuton blends. However it will be less stiff in service when the temperature of the structure is quite high.

A high temperature susceptible bitumen will not only be less resistant to permanent deformation but also will not be able to spread traffic loads as efficiently onto the underlying layers. Bitumen with a higher PI (Penetration Index) is stiffer at high temperatures and longer loading time, i.e. it is less temperature susceptible.

It was concluded that the addition of Refined Asbuton Bitumen will improve the Penetration Index (PI) values.

The addition of Refined Asbuton Bitumen to pure petroleum bitumen 60/70 pen grade will improve resistance of mixes to permanent deformation and increase the spreading of traffic loads to the under laying layers in the pavement.

Table 6

Stiffness modulus of bitumen

Type of bitumen	Penetration Index (PI)
Pure petroleum bitumen 60/70 pen grade	-1.3
Blend of Refined Asphalt Buton (40% mineral)	-0.33
Pure Refined Asphalt Buton P 60/80	-0.41
Pure Refined Asphalt Buton P 40/60	0.32

V. PROPERTIES OF BITUMINOUS MIXTURES USING PURE REFINED ASPHALT BUTON

The type of bituminous mixes was selected is Asphaltic Concrete (AC), because Asphaltic Concrete mixes has perform well in America and is commonly used in Indonesia. Asphaltic Concrete mixes are continuously graded mixtures of aggregate, filler and bituminous binder.

They were originally developed in the USA to meet the need for stiff and strong pavements to carry heavy loads and high tyre pressures of aircraft tyres. The interlocking aggregate structure is the major contribution to the strength and stability of AC.

The bitumen content for a particular blend or gradation is determined using the Marshall method. A series of test specimens is prepared for a range of bitumen contents so that the test data curves show well defined relationships. Three test specimens are prepared for each bitumen content. The aggregate grading for Indonesia Asphalt Concrete is shown in Table 7 and Figure 3.

Table 7
Aggregate grading for Indonesia Asphaltic Concrete and grading of the mixes

Sieve size (mm)	Percent mass passing		
	Specification grading		Grading of the mixes
	Wearing course	Binder course	
25	-	100	-
19	100	90 – 100	100
12.5	90 – 100	Max 100	90.3
9.5	Max 90	-	79.5
4.75	-	-	54.9
2.36	28 – 58	23 – 49	37.7
1.18	-	-	25.6
0.600	-	-	18.2
0.075	4 – 10	4 – 8	8.1
Restricted zone			
4.75	-	-	
2.36	39.1	34.6	
1.18	25.6 – 31.6	22.3- 28.3	
0.600	19.1- 23.1	16.7 –20.6	
0.300	15.5	13.7	

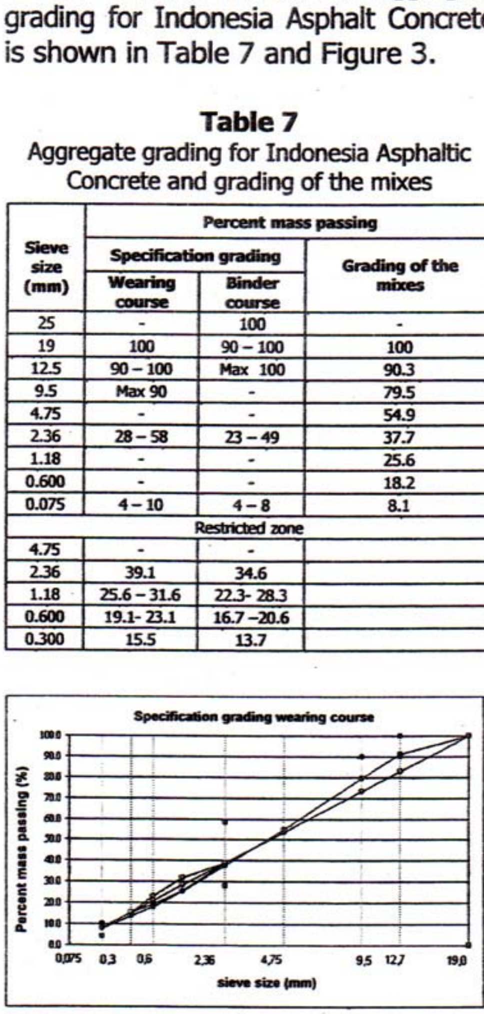

Figure 3 Chart of specification grading for Indonesia asphalt Concrete and grading of the mixes

The design bitumen content is selected by considering all of the data properties of the mix. The calculated and measured mix properties at this bitumen content can be evaluated by comparing them to the mix design criteria shown in Table 8. The design bitumen content is a compromise selected to balance all of the mix properties and can be adjusted within the range to achieve properties that will satisfy a requirement for a specific project.

Table 8
Mix Design Criteria of Indonesia Asphaltic Concrete

Mix Criteria		Asphaltic Concrete	
		WC	BC
Number of compaction blows	-	2 x 75	
Bitumen absorbed (%)	max	1.7	
Void in Mix (VIM) (%)	min	3.5	
	max	5.5	
Void in Mineral Aggregate (VMA) (%)	min	15	14
Void Filled Bitumen (%)	min	65	63
Marshall Stability (kg)	min	1000	
Flow (mm)	min	3	
Marshall Quotient (kg/mm)	min	300	
Retain Marshall Stability (%)	min	75	
VIM (%) at refusal density	min	2.5	
Dynamic Stability (pass/mm)	min	2500	

5.1. The Stiffness Modulus of Bituminous mixes

The stiffness Modulus of a bituminous mix is the ratio between stress and strain. It is perhaps the most important fundamental mix property as it provides information on how the material will deform under the action of a given load. This is related to

fatigue cracking, permanent deformation and load spreading ability.
The higher the stiffness of pavement the better the load spreading onto the sub grade. The load spreading principle in a pavement is illustrated in Figure 4.
The Stiffness Modulus of a bituminous mixture (S_m) is dependent on both temperature and on the speed with which the stress is applied. At high temperatures and long duration of loading, stiffness is low. At low temperatures and short of periods of loading, stiffness is high. The stiffness of the mixture will vary as the stiffness modulus of the bitumen changes (Nottingham Asphalt Tester Manual, 1994 : Fordyce, D and O'Donnel, E., 1994)

Increasing the voids in a mix will reduce its stiffness. Increasing the bitumen content reduces the voids and stiffness will be increased. If the mix already has negligible voids further addition of binder will reduce the stiffness (Pell, 1973)

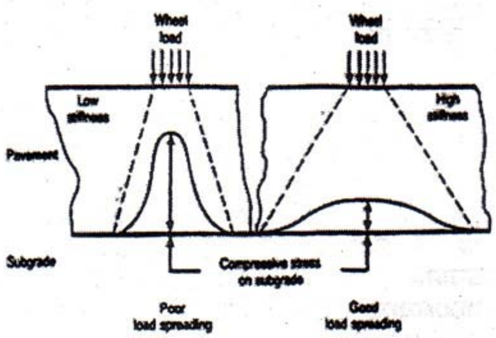

Figure 4 Spread loading in a road pavement (Brown, 1994)

5.1.1 Measurement of Stiffness Modulus of Bituminous Mixes

The test specimens for this test was prepared in the laboratory as for the Marshall test, each had diameter of 100 mm and thickness of 62.5 mm.

The method used was the Indirect Tensile Stiffness Modulus using the Universal Machine Testing Apparatus equipment. The stiffness test was used at the standard test temperature 25 °C; 35 °C; 45 °C and 55 °C with an axial stress of 200 kPa. The specimens were conditioned at the test temperature for one night. The test was carried out in a cabinet with forced air circulation. The principle of the test, which is shown in Figure 5, is that a cylindrical specimens is subjected to a compressive load pulse along one diameter which results in an indirect tensile stress along the diameter lying at right angles to the direction of the load. The transient deformation due to indirect tensile strain is measured. Elastic stiffness is a function of the measured compressive load and transient tensile deformation.
A sequence of five conditioning load pulses are applied to the specimen followed by five loading pulses. The conditioning pulses are to ensure that the loading platens are seated onto the specimen so that the consistent results may be obtained. A typical output from the load and deformation transducers is shown in Figure 6.
Prior to testing the specimens are left in a chamber at the prescribed testing

temperature for 24 hours. The rise time, measured from when the load pulse commences, is the time taken for the applied load to increase from zero to a maximum value.

The Indirect Tensile Stiffness Modulus test was performed at a temperature of 25 °C; 35 °C; 45 °C and 55 °C. The test is repeated and a mean stiffness modulus calculated.

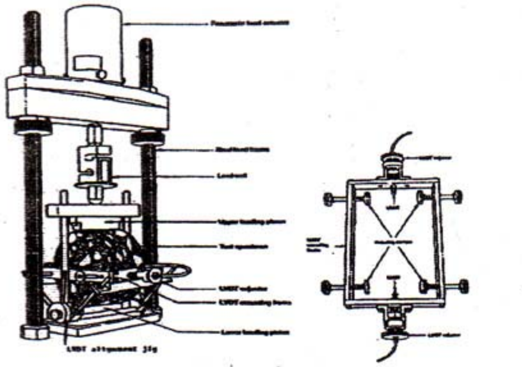

Figure 5 The principle of the stiffness modulus test

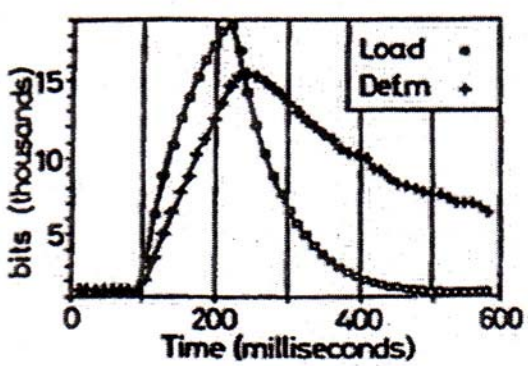

Figure 6 Typical output from UMATA load and deformation transducers.

5.1.2 Stiffness Modulus of Asphaltic Concrete Mixes

The mean value of Stiffness Modulus for each blend of 60/70 pen grade, Blend of Refined Asbuton Bitumen and Pure blend of Refined Asbuton Bitumen is shown in Table 9 and plotted in Figure 7. In all cases the stiffness modulus for AC mixes decreased as the temperature of test increased as shown in Figure 7. The stiffness modulus with pure 60/70 pen grade was 1625 MPa. This decrease by 552 MPa, 213 MPa, and 101 MPa times for the mixes tested at 35 °C; 45 °C and 55 °C respectively.

The stiffness modulus for the Refined Asbuton Bitumen blends was 2210 MPa and decreased by 736 MPa, 253 MPa, and 125 MPa respectively, also the stiffness modulus for the pure Refined Asbuton Bitumen blends with P 60/80 and P 40/60 were 2655 MPa and 2312 MPa decreased by 1112 MPa, 463 MPa, 268 MPa, and by 1014 MPa, 424 MPa, 174 MPa, respectively.

In Figure 7. it can be seen that the Stiffness Modulus of mixes using Pure Refined Asbuton Bitumen had the greatest Stiffness Modulus and were followed by the same mix using Refined Asbuton Bitumen and pure petroleum bitumen 60/70 pen grade mixes for any test temperature.

Table 9

Stiffness Modulus of mixes using pure petroleum bitumen 60/70 pen grade, Refined Asbuton Bitumen, Pure Refined Asbuton Bitumen.

Test Temperature (°C)	Stiffness (MPa)				Stiffness Ratio to Pure PB 60/70 pen grade		
	Pure petroleum Bitumen 60/70 pen grade	RAB (mineral 40%)	Pure RAB P 60/80	Pure RAB P 40/60	RAB (mineral 40%)	Pure RAB P 60/80	Pure RAB P 40/60
25	1625	2210	2656	2312	1.36	1.63	1.42
35	552	736	1112	1014	1.33	2.01	1.84
45	213	253	463	424	1.19	2.17	1.99
55	101	125	268	174	1.24	2.65	1.99

The stiffness ratio of RAB (mineral 40%), pure RAB to pure PB 60/70 pen grade about 1.19–1.36, 1.63–2.65, and 1.42–1.99 times for the mixes tested at temperature 25 °C, 35 °C, 45 °C and 55 °C respectively. This shows that the addition of Refined Asbuton Bitumen has a great effect to stiffness of the mixes.

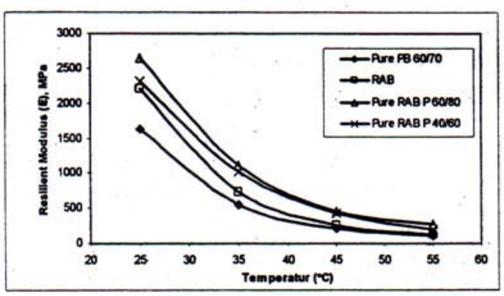

Figure 7. Plot of Stiffness Modulus and test temperature for pure Petroleum Bitumen, Refined Asbuton Bitumen and Pure Refined Asbuton Bitumen mixes.

5.2 Permanent Deformation of Bituminous Materials

When a bituminous mixture is subjected to a brief application of load the material will deform. When the load is removed a large part of this deformation is recoverable. However, there will be small irrecoverable permanent deformation. If the bituminous mixture is subjected to a series of load applications there will be an accumulation of permanent deformation as shown in Figure 8.

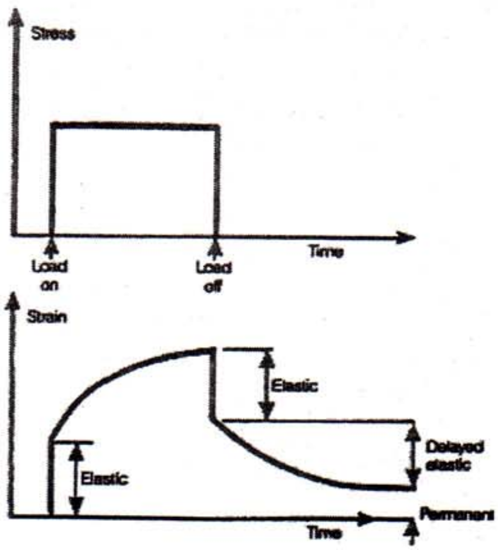

Figure 8 Effect of a single load Application

The deformation behaviour of a mix depends on temperature. The higher the temperature the greater the deformation for the same loading time. The influence of temperature change affects bitumen stiffness and so changes stiffness of the mix. The higher the bitumen stiffness the greater the mix stiffness value.

5.2.1 Method of Assessing Resistance of Bituminous Materials to Permanent Deformation

There are number of methods that are used for assessing the permanent deformation of bituminous mixes. These can be classified into two groups i.e. fundamental and simulative. An example of fundamental test is the unconfined uniaxial loading (creep) test. In this test a dynamic axial stress is applied to a specimen for a period of time and certain temperature. During the test, axial deformation is measured and recorded as a function of time. The stiffness modulus can be determined as follows, (BS 598-11, 1995; Whiteoak,1990; Nottingham Asphalt Tester Manual, 1994):

$$S_{m(t,T)} = \frac{\sigma}{\varepsilon_{m(t,T)}}$$

Where :

$S_{m(t,T)}$ Creep stiffness of the mix at a loading time t (in second) and a loading temperature T (in °C)

σ applied stress

$\varepsilon_{m(t,T)}$ compressive strain cause to the specimen during the loading time t (in second) at temperature T (in °C)

Calculating the deformation on a road is very complex. Account has to be taken of varying wheel load spectra, varying contact areas and pressure, lateral distribution of the wheel loads and varying ambient temperatures and temperature gradients within the asphalt layers.

A simulative test for evaluating the resistance to permanent deformation is the wheel tracking test. This test has been used to compare the performance of different materials rather than predict in situ performance.

In a laboratory wheel tracking test the specimen is subjected to a test load. The sample is confined in a rigid mould and a wheel with a specified load or specified contact pressure is driven backward and forward at a specified number of cycles per minute. The depth of tracking is recorded at themed point of its length. The quantity of deformation is measured at the end of a specified time interval.

The parameters obtained from the wheel tracking test are the Rate of Deformation and Dynamic Stability :

$$DS = 42\frac{(t_2 - t_1)}{(d_2 - d_1)}$$

$$RD = \frac{(d_2 - d_1)}{(t_2 - t_1)}$$

Where

DS = Dynamic Stability (number of passes/mm)

RD = Rate of Deformation (mm/min)

d_1 = value of deformation at time t_1 time deformation graph

d_2 = value of deformation at time t_2 time deformation graph

Normally t_1 and t_2 are at 30 and 45 minutes or 45 and 60 minutes of deformation graph for the test duration of 45 and 60 minutes respectively.

5.2.2. Resistance to permanent deformation using the wheel tracking test and the unconfined uniaxial loading test

The resistance to permanent deformation was assessed using the wheel tracking test as a simulative test and the Unconfined Uniaxial loading (creep) test which is more fundamental.

a. Wheel tracking test

This test is used to investigate the resistance of bituminous mixes to permanent deformation and is a simulation of trafficking. The specimens tested were in a slab form having dimension of 300 x 300 mm and thickness 50 mm. They were compacted in a rigid mould using a special steel roller compactor design to simulate the action site compaction. The wheel tracking apparatus was located within a constant temperature room.

The mounted test specimens were conditioned for 10 hours at the specified test temperature prior to testing. During wheel tracking test, the specimen was confined in the rigid mould and a loaded wheel with the contact pressure of 6.4 ± 0.15 kg/cm2 driven backward and forward at 21 ± 0.2 cycles per minute.

The depth of tracking is recorded at the mid point of the sample length. The test continued for 60 minutes. The temperature of testing of the samples was 60 °C.

Plot of wheel track deformation against number of loading cycles typically showed an initial rapid increase in deformation as the sample consolidates. This is follow by period when the wheel track deformation increases almost linearly with applied load cycles.

The deformation obtained for the mixes with pure petroleum bitumen 60/70 pen grade, RAB 40 mineral, pure RAB are shown in Figure 9. From Figure 9 it may be seen that the wheel track deformation of pure RAB (P 40/60) is the smallest followed by RAB (P 60/80), RAB (40% mineral) and pure petroleum bitumen 60/70 pen grade. This indicates the superiority, in terms of the resistance to permanent deformation, of mixes using RAB blends as a binder.

The Dynamic Stability for each of the mixes is shown in Table 10 and plotted in Figure 10a and Figure 10b.

Table 10
The Dynamic Stability of the mixes

Dynamic Stability of the mixes (passing / mm)	
Type of mixes	**Dynamic Stability (DS)**
Pure petroleum bitumen 60/70 pen grade	1953
Refined Asbuton Bitumen (40% mineral)	3500
Pure Refined Asbuton Bitumen P 60/80	6300
Pure Refined Asbuton Bitumen P 40/60	5250

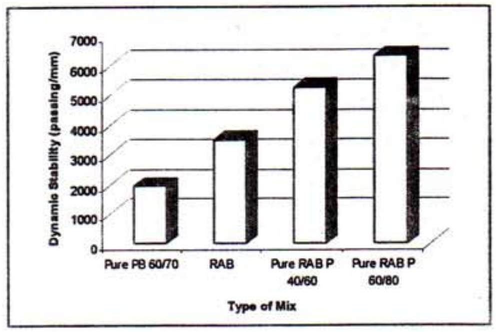

Figure 10a The Dynamic Stability of mixes

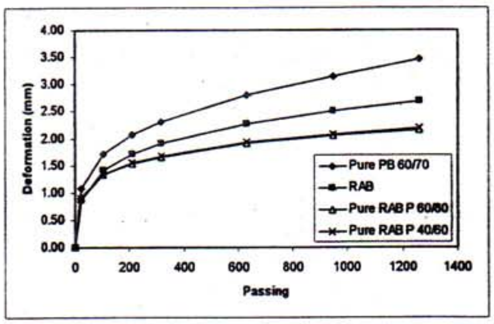

Figure 10b Plot of wheel track Deformation

b. Unconfined Uniaxial Loading (Creep) test

This is fundamental test for assessing the resistance of bituminous materials to permanent deformation. The sample were prepared in laboratory as for the Marshall test. Each had, a diameter of 100 mm and thickness of 62.5 mm. The unconfined uniaxial loading test was used at the standard test temperature 25°C and 45°C with an axial stress of 200 kPa. The specimens were conditioned at the test temperature for one night. The test was carried out in a cabinet with forced air circulation.

The Unconfined Uniaxial Loading test data for the asphaltic concrete mixes using 60/70 pen grade, RAB contain 40% mineral, pure RAB at different test temperature are shown in Figure 11.a and Figure 11.b.

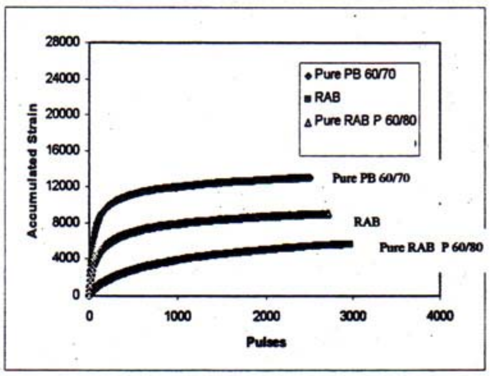

Figure 11a Unconfined Uniaxial Loading deformation for different mixes at 25 °C test temperature.

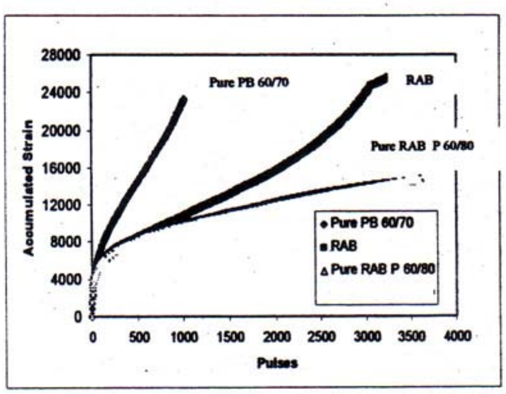

Figure 11.b Unconfined Uniaxial Loading deformation for different mixes at 45 °C test temperature.

For any test temperature, shows that Unconfined Uniaxial Loading deformations values for mix with 60/70 pen grade was the highest followed by Refined Asbuton Bitumen (give lower deformation and more resistant to deformation). From Figure 11.a and Figure 11.b it can be concluded that mixes using Refined Asphalt Buton Bitumen will be more resistant to permanent deformation.

VI. CONCLUSION

From those explanation about natural rock asphalt products from Buton island Indonesia, it can be concluded, that :

- Bitumen is only a minor component of bituminous mixes, but it has a crucial part to play in providing visco – elasticity and acting as a durable binder.
- To get a better quality Asbuton product, research and development has been ongoing. A viable refining process has recently been developed. This technology can process both type of rocks asphalt i.e. the Kabungka as well the Lawele type. The refining process reduces the mineral content to produce Refined Asphalt Buton that has a bitumen content between 60 % and >99 %.

- These new type possess high consistency and homogeneity and allow a uniform high quality asphalt to be produced.
- Refined Asphalt Buton as multi purpose mastic asphalt grade for road construction e.g. Base course, binder course, wearing course, Stone Mastic Asphalt etc.
- The addition of Refined Asbuton effects the rheological properties of penetration grade bitumen. The properties effected include:
  - Penetration – decrease
  - Softening point (R&B) – increase
  - Viscosity – increase
  - Penetration Index – increase
- The presence of Refined Asphalt Buton has a significant effect on resistance to permanent deformation of bituminous mixes. This relates to a corresponding increase in Penetration Index of binder which make it reducing in permanent deformation.
- The addition of Refined Asphalt Buton causes the mix to be less temperature susceptible to deformation and more appropriate for countries with a hot climate. This relates to the penetration Index of the binder.
- Increasing the amount of Refined Asphalt Buton improves the resistance to deformation for the bituminous mixes, as indicated from wheel tracking test and Unconfined Uniaxial loading test results.
- The addition of Refined Asphalt Buton has a significant effect in improving the mix stiffness which is related to the amount added. This is due to increase in softening point and a reduction in penetration.
- The optimum proportion of Refined Asbuton should be a compromise selected to balance all of the mix properties requirement of a specific project. It is dependent on traffic load, type of petroleum bitumen and climate conditions.
- The laboratory result prove that the addition of Refine Asbuton improve the performance of binder and also bituminous mixes.
- The deposits from Asbuton Island are a major source of bitumen that can improve the petroleum bitumen.
- Development of Refined Asbuton will enhance Indonesian ability to self – supply the domestic bitumen demand.

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