Empirical Evaluation of the Use of Oily Sludge as a Modifier of Buton Rock Asphalt in Hot Mix Asphalt Pavement

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ABSTRACT: Oily Sludge is a waste product from the activity of mining, transporting, storing, and refining of petroleum crude oil. It is categorized as hazardous waste; therefore its handling is expensive and should abide by the environmental regulation. The oily sludge consists of three main substances i.e. oil, water and mineral. In this study, the oily sludge is used as the softening agent for the bitumen of Buton-rock-asphalt which has penetration as low as 4 dmm. In order to dissipate the water and volatile fraction of oil, the oily sludge is preprocessed by heating up to 120^0 C. An amount of petroleum bitumen is added to fulfill the current specification of modifier for Buton-rock-asphalt. The mineral of the sludge is maintained and will be considered as part of the filler of the asphalt concrete mixture. The laboratory study indicates that characteristics of asphalt concrete which made of oily sludge modified Buton-rock-asphalt can be equivalent to the conventional asphalt concrete. This finding is confirmed by a two year observation of the full scale field trial.

KEY WORDS: Oily-sludge, buton, rock-asphalt.

1 INTRODUCTION

Oily sludge is a waste product from the activity of mining, transporting, storing, and refining of crude oil. Oily sludge is categorized as hazardous waste material; handling of such substance is costly and should tightly follow the environmental regulation (BAPEDAL, 1995). Oily sludge used in this study is obtained from the crust of crude oil piled up at the bottom of the container of oil tankers. The tankers should be cleaned up of this crust regularly and the sludge should be disposed somewhere. The oily sludge consists of three main substances; those are oil (light and heavy fraction oil), water and mineral substances. The three substances coalesce as a colloid system.

It is believed that the oily sludge can be utilized as a modifier for rock asphalt because the use of heavy oil as a recycling agent for aged bitumen of the reclaimed asphalt pavement is common. The existing water content can be controlled by heating the system or adding Portland cement or other hydration products; whilst the mineral can be used as part of filler of asphalt mixture.

Indonesia has a very potential source of rock asphalt that has not been exploited well. It is located in Buton Island and locally known as asbuton which carries the meaning: the rock asphalt of Buton Island. For a practical reason, this local term for the rock asphalt of Buton is used for the rest of this report. The deposit of asbuton is spread over a wide area of the island with total deposit is estimated about 700 million tons (Directorate General of Highway, 2006). Bitumen content of asbuton is varied from as low as 10 percent up to as high as 90 percent.

Nevertheless, deposit of such high bitumen content is limited and only those with bitumen content of 20 percent and above are considered as economically viable to be exploited.

Asbuton consists of bitumen, mineral, and, due to its nature as a naturally deposited material, some water. The bitumen is usually hard; the range of penetration of the bitumen between 2 to 10 dmm has been reported. The common mineral is lime stone. Asbuton is normally classified by penetration of its bitumen and bitumen content. For instance, asbuton 5/20 is asbuton with 5dmm penetration and 20 percent bitumen content.

Asbuton has been used as road pavement material for long. In the past it was used in the form of cold mix. In the last decade attempt has been made to use it as the binder for hot mix asphalt with a reasonable quality relatively compare to the conventional hot mix asphalt made of 100 percent petroleum bitumen. Bitumen modifier is required to mobilize and soften the bitumen of asbuton down to the proper range of road pavement material. However, the use of asbuton is limited because of the high cost of transport. As an illustration, to get one ton of equivalent petroleum bitumen at least five tons of raw asbuton of 20 percent bitumen content need to be transported. Another constraint is the cost of modifier. Bunker oil, flux oil and short residue have been used as asbuton as modifier; since all of these materials is commercial petroleum product these materials are also expensive (Hermadi, 2006). Therefore, an option to utilize waste material such as oily sludge as asbuton modifier is obviously attractive not only because it may reduce the cost but also because of its advantage to the environment.

This paper presents the result of a study on utilizing the oily sludge as asbuton modifier. It embarks the following objectives:

- To identify the properties of oily sludge.
- To improve the characteristics of oily sludge in complying the current specification for asbuton modifier.
- To assess the characteristics and performance of asphalt concrete with oily sludge modified asbuton.

2 MATERIALS AND METHODS

The asbuton used in this study is asbuton 5/20. Its characteristics are shown in Table 1. Table 2 presents the characteristics of the raw oily sludge.

Table 1: Characteristics of asbuton

Characteristics	Test Results	Requirement*
Water content (%)	4.0	Max 2%
Bitumen content (%)	18.3	20±2%
Penetration of bitumen at 25 ^{0}C, 100 g, 5 sec (dmm)	4	2-8
Wax content (%)	0.278	-
Softening point of bitumen (^{0}C)	78.0	-
Specific gravity	1.635	-

* *Technical Guidelines of Hot Mix Asbuton PD T-07-2004-B* (Public Work Department, 2004)

Table 2 indicates that the raw oily sludge cannot directly use as modifier because of high water content and, for the safety reason, low flash point. The later is because of the existence of volatile light oil fraction. Nevertheless, these problems can be solving straightforwardly by heating the sludge up to 120^0 C. Then, some petroleum bitumen was added to improve its characteristics further to be complying with the requirement of asbuton modifier. Three types of asbuton modifier are specified in the present construction guideline for asbuton hot mix.

The specification is shown in Table 3. Characteristics of oily sludge after the treatment will be presented in the next section. Table 4 presents the characteristics of petroleum bitumen.

Table 2: Characteristics of the raw oily sludge

Characteristics	Test Results
Water content (%)	9.5
Mineral content (%)	57.9
Oil:	
• Oil content (%)	32.6
• Saybolt furol viscosity at 60 ^{0}C (sec)	78
• Lost on heating after thin film oven test (TFOT) (%)	6.04
• Saybolt furol viscosity after TFOT at 60 ^{0}C (sec)	86
• Wax content (%)	0.42
Specific gravity	1.130
Flash point (^{0}C)	198

Table 3: Specification of asbuton modifier

Characteristics	Type 1*	Type 2*	Type 3*
Penetration at 25 ^{0}C, 100 g, 5 sec (dmm)	N/A	400 ±50	300 ± 45
Saybolt Furol Viscosity at 60 ^{0}C (cSt)	3000 - 4000	N/A	N/A
Softening point (^{0}C)	N/A	Min. 30	Min. 30
Ductility at 25 ^{0}C, 5 cm/min (cm)	N/A	Min. 100	Min. 100
Solubility in trichloroethylene (%)	Min. 99,5	Min. 99,5	Min. 99,5
Flash point (Cleveland Open Cup) (^{0}C)	Min. 200	Min. 200	Min. 200
Specific Gravity	Min. 0,95	Min. 1	Min. 1
Loss in heating after TFOT (%)	Max. 1	Max. 1	Max. 1
Paraffin content (%)	Max. 2	Max. 2	Max. 2

* *Technical Guidelines of Hot Mix Asbuton PD T-07-2004-B* (Public Work Department, 2004)

Table 4: Characteristics of the petroleum bitumen

Characteristics	Test Results
Water content (%)	0
Solubility in trichloroethylene (%)	99.7
Penetration at 25 ^{o}C, 100 g, 5 sec (dmm)	76
Ductility at 25 ^{o}C, 5cm/minute (cm)	>140
Loss on heating after TFOT (%)	0.018
Penetration after TFOT (%) of original	72.4
Wax content (%)	0.278
Specific gravity	1.034
Flash point (Cleveland Open Cup) (^{0}C)	335

Hot mix asbuton with three different types of modifier were prepared for evaluation. The mixtures were designed based on the standard Marshall mix-design procedure (Asphalt Institute 1989, Public Work Department 2004). The estimated optimum proportion of each type of modifier and asbuton in hot mix asbuton are shown in Table 5. These proportions aimed to produce asbuton mixture with total bitumen content (the bitumen of asbuton plus modifier) around 6.5% and to yield equivalent bitumen penetration grade 60/70 (Hermadi and Syandanulirwan, 2003). The actual optimum proportion of modifier was determined by varying the modifier content around the estimated optimum proportion, while the proportion of asbuton in the mix was kept constant.

Table 5: Estimated proportions of asbuton and modifier in hot mix asbuton

Estimated proportions in total mix	Modifier		
	Type-1	Type-2	Type-3
Modifier (%)	4.5	5.0	5.5
Asbuton type 5/20 (%)	12.0	8.4	5.0

Assessment was made based on the laboratory performance of the mixture in term of Marshall Stability, resilient modulus and dynamic stability. Mixture with relatively best performance was selected for further evaluation in a full scale trial test. In both, laboratory and field test, hot mix asphalt with ordinary petroleum bitumen was used as the control.

3 RESULTS AND DISCUSSION

3.1 Hazardous of the oily sludge

Hazardous level of the oily sludge was assessed and the results are shown in Table 6. It indicates that all of heavy metals content the oily sludge is well below the maximum allowable limit.

Table 6: Toxicity characteristic of oily sludge

Heavy Metals	Oily Sludge (mg/L)	Upper limit* (mg/L)	Method
Arsenic	0.002	5.0	EPA SW 846-7061
Barium	0.02	100.0	EPA SW 846-7080
Boron	0.13	500.0	EPA-2123
Cadmium	< 0.005	1.0	EPA SW 846-7130
Chromium	< 0.05	5.0	EPA SW 846-7190
Copper	< 0.03	10.0	EPA SW 846-7210
Free Cyanide	< 0.01	20.0	EPA SW 3352
Flouride	0.10	150.0	4500 F- D
L e a d	< 0.001	5.0	EPA SW 846-7420
Mercury	< 0.001	0.2	EPA SW 846-7470
Nitrate+Nitrite	< 0.11	1000.0	4500 NO_3-F
Nitrite	< 0.03	100.0	4500 NO_2-B
Selenium	< 0.007	1.0	EPA SW 846-7740
Silver	< 0.003	5.0	EPA SW 846-7760
Zinc	0.13	50.0	EPA SW 846-7950

**Technical Requirement of Processing Hazardous Materials* (BAPEDAL, 1995)

3.2 Preprocessing of the oily sludge

As was mentioned previously, the oily sludge was heated and stirred up to 120 ^{0}C. Then, the petroleum bitumen was added to produce modifiers that comply with the current specification of asbuton modifier types 1 to 3. After a number of trials in the laboratory, the oily sludge to petroleum bitumen ratio that yield the suitable modifiers are as shown in Table 7.

Table 7: Oily sludge to bitumen ratio and characteristics of oily sludge asbuton modifier

Characteristics	Asbuton Modifier		
	Type-1	Type-2	Type-3
Oily sludge to petroleum bitumen ratio	1 : 0.533	1 : 1.314	1 : 1.527
Water content (%)	0.0	0.0	0.0
Mineral content (%)	41.8	27.7	25.3
Oil content (%)	58.2	72.3	74.7
• Saybolt furol viscosity of oil at 82.2 ^{0}C (sec)	309	N/A	N/A
• Penetration of oil at 100g, 5sec, 25^{0}C; dmm	N/A	412	305
• Softening point of oil (^{0}C)	N/A	32	38
• Ductility at 5 cm/min, 25^{o}C; cm	N/A	> 140	>140
• Loss on heating after TFOT at 163^{0}C, 5 hr (%)	0.95	0,86	0,73
• Viscosity at 82.2 ^{0}C after TFOT (sec)	512	N/A	N/A
• Penetration after TFOT (% of original)	N/A	74.0	64.6
• Wax content (%)	0.323	0.302	0.299
• Flash point (Cleveland Oven test) ^{0}C	216	324	328

3.3 Gradation of the mixtures

The gradation of the mixtures used in the study is shown in Figure 1. The gradation was managed to be identical for all mixture.

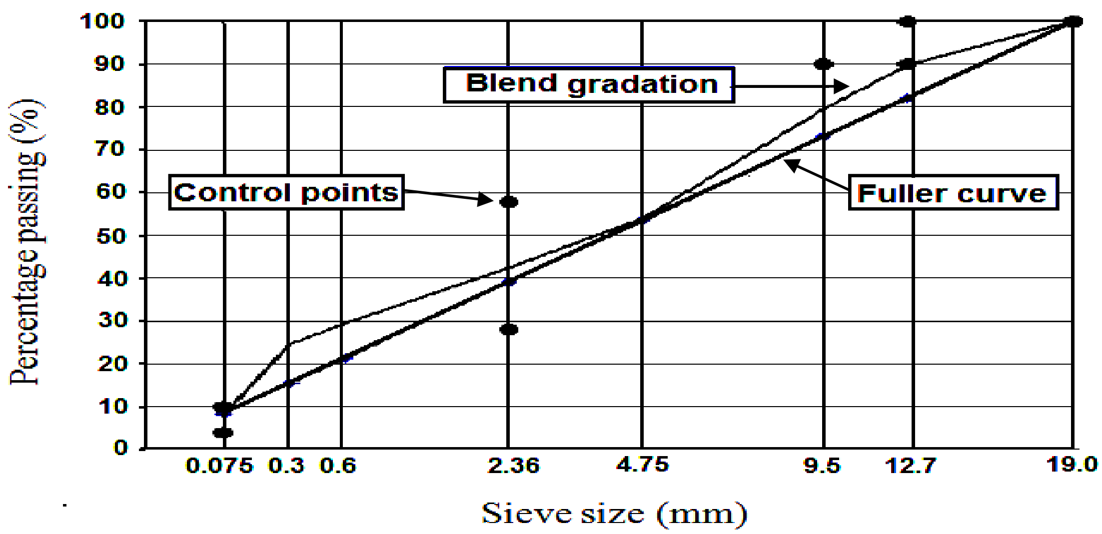

Figure 1: Gradation of the Mixtures

3.4 Characteristics of the mixtures

The characteristics of the mixtures at optimum proportion of modifier or bitumen content are shown in Table 8.

Table 8: Mixture characteristics of asbuton hot mix and conventional hot mix asphalt

Mixture Characteristics	Conventional Hot Mix	Asbuton Hot Mix		
		Type-1	Type-2	Type-3
Optimum bitumen content* (%)	6.45	7.1	6.84	6.58
Density (g/ml)	2.284	2.280	2.253	2.279
Void in mix (%)	4.72	4.63	4.33	4.73
Void in mix at refusal density (%)	3.01	2.57	2.60	2.70
Void filled bitumen (%)	73.99	74.10	75.21	76.64
Void in mix aggregate (%)	18.02	21.65	21.35	20.09
Marshall stability (kg)	1419	1000	1114	1080
Flow (mm)	3.65	2.94	3.51	3.47
Residual stability after 24 hours water immersion at 60^{o}C (%)	83.6	76.5	75.5	59.8
Marshall quotient (kg/mm)	389	340	317	311
Dynamic stability at 60^{o}C (track/mm)	1658	3706	4846	1703
Resilient modulus at:				
• 35 ^{0}C (MPa)	1012.6	1402.2	1569.4	1133.4
• 45 ^{0}C (MPa)	404.6	592.3	627.2	453.0
• 55 ^{0}C (MPa)	221.5	233.5	247.3	220.6

* For hot mix asbuton means percent of asbuton's bitumen plus modifier

Based on the finding as shown in Table 8 the following can be deduced:

[1] Mixture with higher asbuton content tends to yield higher optimum bitumen content. This is probably due to higher oil absorption of the asbuton mineral.

[2] Volumetric properties, as well as the flow of the mixes are relatively similar.

[3] Dynamic stability and resilient modulus of asbuton hot mix are higher than conventional hot mix.

[4] Asbuton hot mix made of modifier type-2 shows the highest dynamic stability and resilient modulus.

3.4 Field Performance

After the completion of the laboratory works, a full scale trial section was constructed at Km 73 of Bandung-Cirebon road of West Java Indonesia. It is a two-lane-two-direction road. Asbuton hot mix made of Type-2 modifier was selected for this trial with conventional hot mix asphalt as the control. The total length of trial section is 100 m or 50 m for each type of mixture as illustrated in Figure 2.

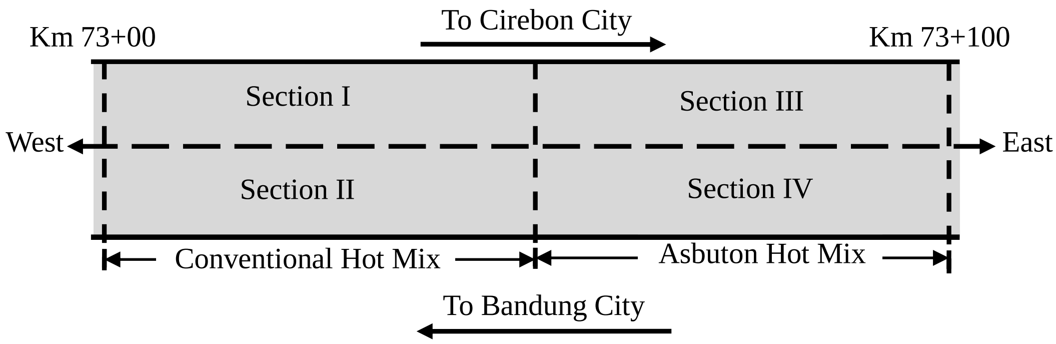

Figure 2: Full scale trial section

The performance of the trial section was assessed based on the visual observation, the maximum surface deflection and the International Rougness Index. The deflection was measured by the Falling Waight Deflectometer (FWD). The result is shown in Table 9. In general, it may conclude that after 24 month both mixture performance equally well.

Table 9: Deflection test results

Observation	Deflection Test Results (mm)				
	Conventional Hot Mix		Asbuton Hot Mix		
	Section I	Section II	Section III	Section IV	
Before overlay	0,306	0,318	0,346	0,338	Maximum
	0,181	0,153	0,212	0,246	Minimum
	0,237	0,249	0,283	0,275	Average
1 month	0,287	0,265	0,311	0,281	Maximum
	0,183	0,134	0,180	0,134	Minimum
	0,244	0,200	0,234	0,187	Average
24 month	0,507	0,345	0,461	0,288	Maximum
	0,207	0,164	0,210	0,161	Minimum
	0,378	0,231	0,335	0,240	Average

The roughness of trial section after 24 month was measured by using NAASRA Roughometer at the speed of 33 km per hour. As shown in Table 10, the measurement reveals that both mixtures yield the similar IRI (International Roughness Index) of less than 2.4 m/km which means, based on the FHA classification, roughness of both mixtures is good.

Table 10: Roughness of the trial section

Pavement Age	International Roughness Index (m/Km)				
	Conventional Hot Mix		Asbuton Hot Mix		
	Section I	Section II	Section III	Section IV	
24 months	2.22	2.22	2.12	2.22	Maximum
	2.01	1.91	2.01	2.01	Minimum
	2.07	2.03	2.03	2.14	Average

4 CONCLUSIONS

The possibility of utilizing oily sludge as modifier for rock asphalt has been discussed. Toxicity Characteristic Leaching Procedure (TCLP) reveals that the oily sludge is a non toxic material and, therefore, is safe for use in road construction. With a minimum treatment, the oily sludge can be used to produce all three types of asbuton modifier for asbuton hot mix. Laboratory investigation indicates that the asbuton hot mix with the oily sludge as modifier can fulfil the current specification of asbuton mixture. After 24 month of observation, the trial section reveals that asbuton hot mix made of the oily sludge as modifier performed equally well with conventional hot mix with petroleum bitumen as the binder.

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REFERENCES

Asphalt Institute, 1989. *The Asphalt handbook*, Manual Series No. 4 (MS-4), Asphalt Lexington, USA.

BAPEDAL, 1995, *Technical Requirement of Processing Hazardous Materials No: Kep-03/BAPEDAL/09/1995*, BAPEDAL, Jakarta, Indonesia.

Directorate General of Highway, 2006, *Technical Guidelines of Utilization of Asbuton Book 1 General No. 001-01/BM/2006*, Pubilc Work Department, Jakarta, Indonesia.

Hermadi, M., 2006. *Utilization of Oily Sludge as a Modifier of Buton Rock Asphalt in Asphaltic Pavement*, Proceedings of the 9th Road Regional Conference, Makasar, Indonesia.

Hermadi, M., Syahdanulirwan, M., (2003), *Hot Mix Asbuton Characteristics with Several Modifier and Mixture Gradation*, Institute of Road Engineering Journal, Public Work Department, Bandung, Indonesia.

Public Work Department, 2004. *Technical Guidelines of Hot Mix Asbuton PD T-07-2004-B*, Pubilc Work Department, Jakarta, Indonesia.