Proceedings of International Conference : Problem, Solution and Development of Coastal and Delta Areas
Semarang, Indonesia – September 26th, 2017
Paper No.C-23

Bitumen Modification Using Buton Natural Rock Asphalt

Ayu Fitrianti[1)], Rizal Palefi Hidayat[1)], Gatot Rusbintardjo[2)], Abdul Rochim[2)]
[1)]Student of Civil Engineering Department, Engineering Faculty of UNISSULA
[2)]Lecturer of Civil Engineering Department , Engineering Faculty of UNISSULA
Sultan Agung Islamic University, Department of Civil Engineering
Jl. Raya Kaligawe Km.04, Semarang, Jawa Tengah, Indonesia
ayufitrianti34@gmail.com

Abstract- In Buton Island, an island located in South-East Sulawesi Island in Indonesia is found about 700 million tons natural rock asphalt (NRA) which have not been maximally utilized yet. Buton-NRA contains 20 to 30% of bitumen. This paper reported the experimental study on utilizing of Buton-NRA as additive of bitumen binder in hot mix asphalt (HMA) mixtures. Amount of 5, 10, 15, 20, 25% of very fine of Buton-NRA was added into the bitumen, resulted Buton-NRA-Bitumen's binder. Penetration and softening point test were conducted to get penetration index (PI) value, an index to determine the temperature susceptibility of the binder. The results show that the Buton-NRA-Bitumen's binder has low temperature susceptibility. Used as binder in HMA mixtures also shown that the Buton-NRA-Bitumen's binder can improve the performance of the mixtures. Marshall Stability and stiffness of the mixtures are higher compared to that of base bitumen binder, especially Buton-NRA-Bitumen's binder with 15% of Buton-NRA, Marshall Stability reaches 1620kg and stiffness 142kg/mm, while HMA mixtures with base bitumen (0% Buton-NRA) only has 1068kg of Marshall stability and 110kg/mm of stiffness.

Keywords: *Buton-Natural Rock Asphalt, Binder, Improve, Performance, HMA mixtures.*

1. Introduction

1.1 Background

From the beginning of mankind, transport, especially road transport has become a major aspect of human life. Communication and commerce would not be possible without it. To this end, thousands of kilometers of roads have been built all over the world. Indonesia, a country with a land area of 1.922.570 square kilometers and a population of 258 million people (2016 estimate), based on the authority level, Indonesia has 523 974 km long road which consists of 47 017 km of State roads, provincial roads and 55 416 km 421 541 km of road district / city.

Started from the pavements built on Crete during the Minoian period (2600 – 1150 B.C.) mankind continuously develop the construction of road. The famous ancient road construction was built by the Romans. It should be noted that these pavements were remarkably well designed. From those early days of the Roman Empire to the interstate highway system in the United States, roadway networks as well as roadway construction have been developed. The materials used for roadway construction have progressed with time.

In the development, pavements can be broadly classified into two types, flexible and rigid pavement. From the two types of roadway pavement, flexible pavement is the most used in the world at the moment. In Indonesia, for instance, from 91,620 kms length of road, 508,620 km or 95.64% are flexible pavement roads, and roads constructed with rigid pavement are only 343 kms or 0.37%, while the rest of 3.99% are earth/gravel roads. In the United States as of 2001 there were about 2.5 million miles of paved roads of which 94% were bituminous surfaced. Figure 1.1 shows basic flexible pavement structure

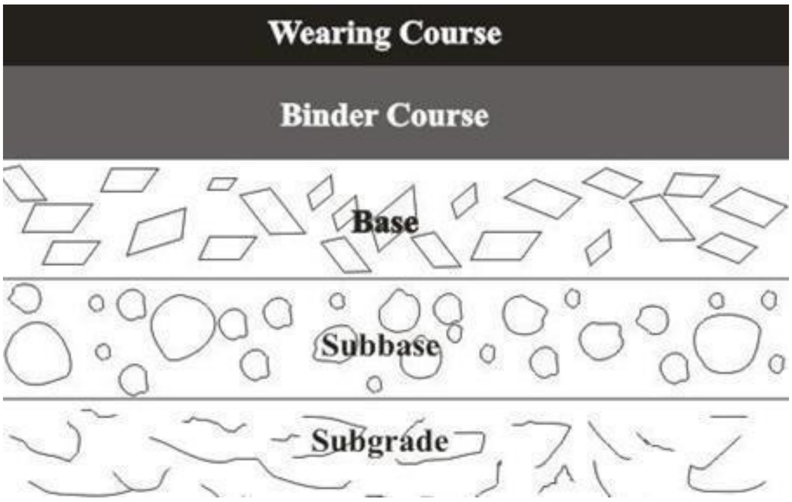

Figure 1: Basic flexible pavement structure

In most asphalt pavement, stiffness of each layer or lift is greater than in the lower layers and less than that in the upper layer. It can be understood from the distribution of the load (Figure 2) in which the stress in the surface layer is higher than the bottom layer.

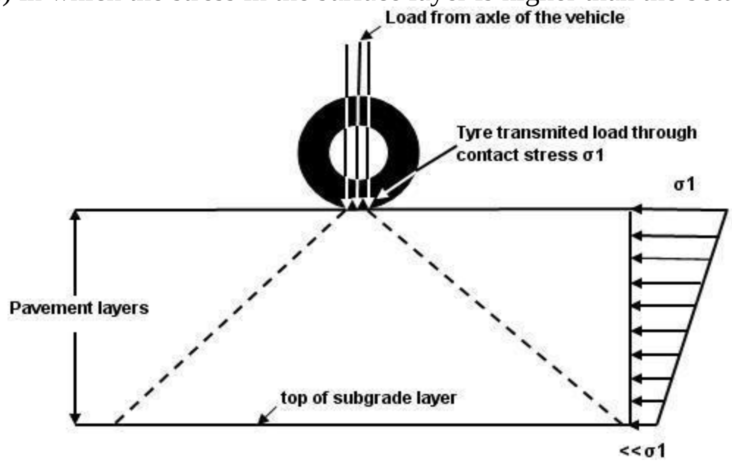

Figure 2. Load distribution on flexible pavements

Base course layer is the layer directly placed under the surface layer. Since the surface layer relatively thin, the tire load that have to be supported by base course layer stilll significantly high. Therefore, to be able support the traffic load and also the surface layer, base course layer have to have enough strength and also a high stiffness as well. To fulfill those strength and stiffness base course layer should be made from the good material.

1.2 The Objectives of the Research

From the description above it is clear that the material of base course layer should be treated to improve it strength and stiffness. Therefore, this study has the following objectives:

a. To investigate the feasibility of using Buton Natural Rock Asphalt (BNRA) to improve the strength of base course material.

b. To formulate the mix between Buton Natural Rock Asphalt and bitumen that will result in a new binder with better physical and mechanical properties.
c. To evaluate the use of Buton Natural Rock Asphalt – Modified Bitumen as a binder in hot mix asphalt (HMA).

2. Testing Program

2.1 Dense Graded Asphaltic Concreate

Premature rutting of heavy duty asphalt pavements has been a significant problem in recent years. Thid rutting problem has primarily resulted form higher pressure truck tires and increased wheel loads. The design of HMA (hot mix asphlat) mixures, which served reasonably well in the past, needs to be reexamined to withstand in the increased stresses. Various asphalt additives are being promoted to increase the stability of HMA pavements at high temperatures. However , most asphalt technologists believe that fundamental properties of the aggregat component of the HMA (such as size, shape, texture and gradation) are most important to ensure that a rut resistant mixture is obtained. There is general agreement that the use of large size stone in the binder and base courses will minimize or eliminate the rutting of heavy duty asphalt pavements. Marshal mix design procedures are used by 76 percent of the states in the United States according to a survey conducted in 1984 [1]. The equipment specified in the Marshall procedure (ASTM D1559) consist of a 4 – inch (100 mm) diameter compaction mold, which is inteneded for mixtures containing aggregate up to 1 – inch (25 mm) maximum size only. This has also inhibited the use of HMA containing aggregate larger than one inch because this mixture cannot be tastef by the standard Marshall mix design procedures. There are other test procedures, such as gyratory compaction, TRLL refusal test, and the Minnesota DOT vibrating hammer, which use 6 – inch (150 mm) diameter molds accomodating $1^1/_2$ to 2 – inch (38 to 51 mm) maximum aggregate size [2]. equipment and/or methodology (such as Marshall test) with some modifications. NCHRP's AAMAS (Asphalt – Aggregate Mix Analysis system) research study showed that a laboratory gyratory compactor better simulates the aggregate particle orientation obtianed in the field compared to that obtained with an impact compactor used in the Marshall procedure [3]. The term "large stone" is a relative one. For the purpose of this section, large stone is defined as an aggregate with a maximum size of more than one inch (25 mm) which cannot be used in preparing standart 4 – inch (100 mm) diameter Marshall specimens. The gradation limits of combined aggregate for Dense Graded Asphaltic Concreate Mixtures was given in Table 2.1.

Table 1. Gradation limits of combined aggregates for DG-AC

ASTM sieve size (mm)	Percentage by weight Passing Sieve	
	Wearing Coarse	Binder Coarse
25.0	100	100
19.0	85 – 95	80 – 100
12.5	75 – 100	-
9.5	60 – 85	60 – 80
4.75	38 – 55	48 – 65
2.36	27 – 40	35 – 50
0.600	14 – 24	19 – 30
0.300	9 – 18	12 – 23
0.150	5 – 12	7 – 15
0.075	2 – 8	1 – 8

2.2 Buton Natural Rock Asphalt (BNRA)

Buton Natural Rock Asphalt (BNRA) is the natural asphalt which found in Buton island in South-East of Sulawesi main island. The areas in Buton island which contain much rock asphalt is Lawele, Kabungka, Waisiu, Wariti, and Epe. From those five areas, Lawele and Kabungka have much deposit of rock asphalt.

BNRA was found firstly in the year 1926 by Hetzel, a Dutch Geologist. Estimate the deposit of rock asphalt which can be measured is 650 million ton from an amount two billion ton based on the result of survey conducted by Ministry of Energy and Mineral Resources Republic of Indonesia. Bitumen content consist in the rock asphalt varis between 20 to 30%. Deposit of BNRA can be found only in the depth of 1 to 1.5 meter from the land surface.

From the beginning explore up today, volume BNRA which have been explored was only 3.4 million ton. The gradation and properties of BNRA was given in Table 2.2.

Table 2. Gradation and Properties of Buton-NRA

NO.	TEST	TEST METHOD	RESULTS	SPECIFICATION	UNIT
1	Gradation	ASTM C 136			
	Sieve no. 16		100		% passing
	Sieve no. 30		54.02		% passing
	Sieve no. 50		16.97		% passing
	Sieve no. 100		3.75		% passing
	Sieve no. 200		1.82		% passinh
2	Bitumen content	ASTM D1856	22.52	18 - 22	%
3	Solubility in C_2HCL_3	ASTM D2042	18.72	Minimum 18	%
4	Specific Gravity	ASTM D854	1.976	1.70 – 1.90	-
5	Flash Point	ASTM D9272	232	Minimum 230	°C
6	Water Content	ASTM D1461	0.81	Maximum 1	%
7	Volatile Content by Distillation	ASTM D402	0.20	-	%

Source:Buton Asphalt Indonesia

2.3 Storage Stability test

The test procedure was conducted in accordance with ASTM D5892 [4]. The test procedure was as follows: immediately after the mixing finished, BNRA-MB was poured into 25.4 mm by 139.7 mm aluminum tube and was heated to 165°C for 1 and 3 days in the oven. The selection of storage days was based on estimation of road construction delay. At the end of the test period, samples were placed in the freezer at -10°C for 4 hours to solidify the BNRA-MB. Upon removing the tube from the freezer, samples were cut into three equal length portions with the spatula and hammer. Temperature of Softening point ($T_{r\&b}$) test was performed to the top and bottom of the samples. The difference of $T_{r\&b}$ between top and bottom part was used to evaluate BNRA-MB's stability and should be controlled within 2°C if the different of temperature lower then 2°C mean that BNRA was properly mixed in the bitumen, as practiced by researchers of highway engineering in Taiwan.

2.4 Softening point test

Softening point is the temperature when certain weighing steel ball pressing down the layer of bitumen which retained in ring. This test use to determining the melting point of bitumen content.

2.5 Penetration test

Penetration is the entry of needle penetration of a certain size, a certain load, and a certain time into the asphalt at a certain temperature. This test use to determining the penetration index of bitumen content

2.6 Specific Gravity test

Specific gravity is the ratio between the specific gravity of solid bitumen and heavy distilled water with the same content at a temperature of 25^{o}C or 15,6^{o}C. This test use to determining specific gravity of solid bitumen.

2.7 Marshall stability and flow test

The Marshall Test was most widely used test to measure the strength of bitumen mixtures that was developed by the Corps of Engineers U.S. in the 1940s. Test was conducted in accordance with ASTM D1559 [5]. The basic principle of the method is the examination of Marshall stability and melting (flow), as well as analysis and pore density of solid mix formed. In this case the test specimen or sample is formed of dense bitumen concrete mix aggregate gradation was obtained from stone mastic asphalt according mix specifications. Testing Marshall to gains stability and melting (flow) following the procedure SNI 06-2489-1991 or AASHTO T245-90. Then all samples grading stone mastic asphalt immersed in a water bath for 40 minutes at 60^{0}C. This test is intended to determine the durability and damage caused by water. Once the testing is done by Marshall Test.

3. Test Result and Discussion

3.1 Mixing bitumen with BNRA

To the mixtures of bitumen and BNRA, which have in after called BNRA-MB, then some test are performed. Those test are penetration test at 25°C, softening point ($T_{r\&b}$), specific gravity and storage stability. The result of penetration and softening point test are used to determine PI. The test results including the PI values are shown in Tables 3.

Statistical analysis using student t distribution and simple regression model are used to analyze the results all of the above tests. Detail of statistical analysis forall tests and described PI value are given in the following sub sections.

Table 3. Results of the consistency test of base bitumen and BNRA-MB

BNRA content (%)	Penetration at 25°C av. 2 x 5 reading (dmm)	S.P	S.G	PI
1	2	3	4	5
0	83	43	1,03	-2
5	76,5	45	1,05	-1,5
10	74,2	47	1,06	-0,7
15	70,5	48,5	1,08	-0,55
20	66,8	49	1,10	-0,6
25	52,8	49,5	1,12	-1,1

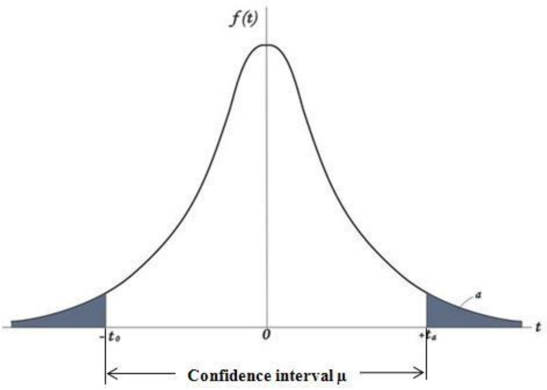

Figure 3 Student t distribution

3.2 Penetration Test Result

Penetration value of the bitumen will decrease with the increasing of BNRA content. This hypothesis is tested by using student t distribution and simple regression model. Statistical analysis for all of BNRA-MB is shows in Table 4 and Figure 4 simple regression model for penetration test data all of BNRA-MB. Test data have a confidence interval of 95% for all BNRA-MB. This shows that all penetration value is true and fit to the hypothesis. Meanwhile, coefficient of correlationis 0,951 as well as coefficient of determinationis 0,905 show very significant figure of penetration of BNRA-MB.

Table 4. Penetration test

Mean of Penetration (dmm)	Standard Deviation (σ)	Coefficient of Confident (%)	Confidence Interval (μ)	Coefficient of Correlation R	Coefficient of Determination R-square
70,63	23,0825	95	$48 < \mu < 94$	0,951	0,905

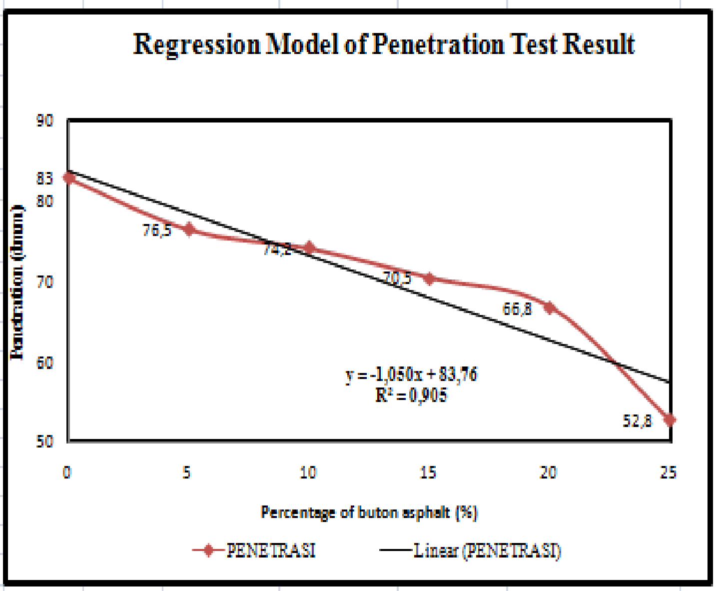

Figure 4. Regression model of penetration test results of BNRA-MB

3.3 Softening point test Result

There was inverse relation between the penetrations and the temperature of softening point of the bitumen. The lower penetration value of the bitumen or the harder the bitumen is the higher the temperature of softening point is. Statistical analysis using student t distribution and simple regression model to those test results indicate that all softening point test data of all of BNRA-MB have a confidence interval 95%.This shows that all softening point value are true and fit to the hypothesis. Meanwhile, coefficient of correlation is 0,964 as well as coefficient of determination is 0,930 show very significant figure of softening point of BNRA-MB. Detail result of statistical analysis for softening point test are given in Table 5, and the simple regression model of the test results of softening point of all BNRA-MB are given in Figure 5.

Table 5. Statistical analysis of softening point test results of BNRA-MB

Mean of Soft. Point (°C)	Standard Deviation (σ)	Coefficient of Confident (%)	Confidence Interval (μ)	Coefficient of Correlation R	Coefficient of Determination R-square
47	5,701	95	$41 < \mu < 53$	0,964	0,93

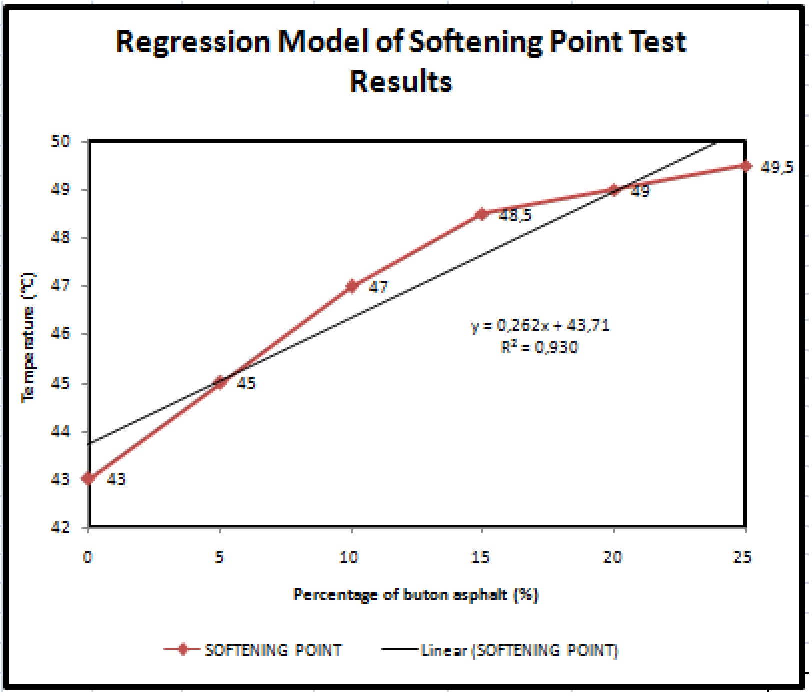

Figure 5. Regression model of softening point test results of BNRA-MB

3.4 Storage stability result

The other test to indicate whether or not BNRA has the possibilities to be used as bitumen modifier is by using storage stability test. The difference of softening point temperature of top and bottom of the each same samples test storage. The sample with different softening point temperature below 2°C was categorized stable and these samples were considered to have compatibility between BNRA and bitumen are shown in column

4 of Table 6 Those results are because BNRA are not dissolving to the bitumen and because most of BNRA have higher specific gravity than specific gravity of the bitumen.

Table 6. Result of Storage stability test of BNRA-MB

SAMPLE (%)	SOFTENING POINT (°C)		DIFFERENT
	UPPER	BUTTOM	
1	2	3	4
5	47,50	47,75	0,25
10	47,00	48,50	1,50
15	47,75	48,85	1,10
20	48,00	49,00	1,00
25	48,50	49,50	1,00

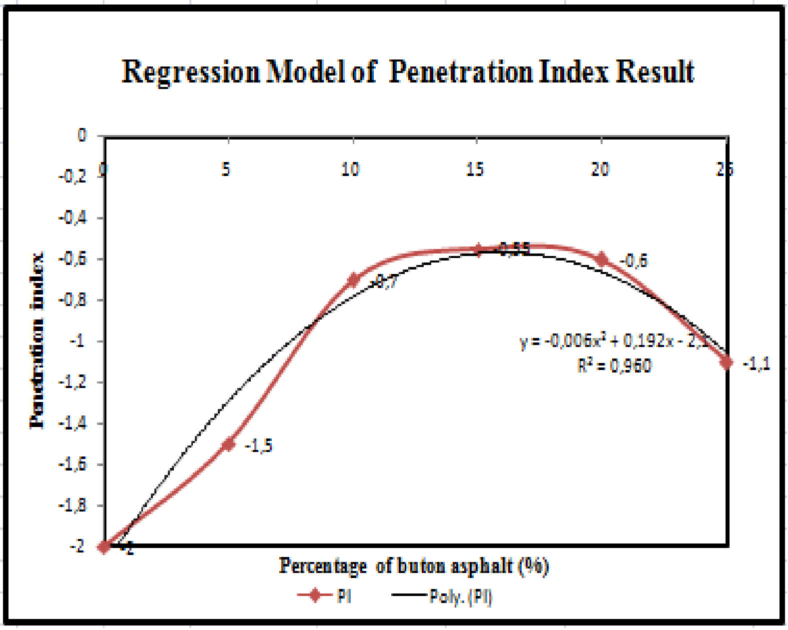

Figure 6 Regression model of Penetration Index velue

3.5 Marshall test Result

The result of Marshall are shown in Table 4.6. Specific gravity of the specimens is range from 2.28 up to 2.73 with average 2.55. Minimum requirement of Marshall stability according to [6] is 632,65 Kg. The results show that all BNRA-MB have Marshall stability above the minimum specification requirement, and above Marshall stability for base bitumen.

Table 7. The Result of Marshall Test

Binder of The Mixture	Spesific Gravity	Marshall Stability (Kg)	Marshall Flow (mm)	Stiffness (kg/mm)
1	2	3	4	5
Starbit binder	2,28	1015,47	11,17	90,94
0 % BNRA	2,73	1067,80	9,70	110,65
5 % BNRA	2,63	1349,13	10,26	132,00
10 % BNRA	2,56	1524,40	10,71	143,10
15 % BNRA	2,55	1620,14	11,40	142,08
20 % BNRA	2,51	1527,28	11,70	130,54
25 % BNRA	2,60	1441,61	11,84	121,69

4. Conclusions

From the results obtained in this study, the following two conclusions can be drawn as follows:

1) From the PI results, adding BNRA to the bitumen has improved the resistance of bitumen to temperature changes by 95%.
2) For the softening point test on samples from storage stability experiments, BNRA-MB samples have less than 2°C temperature difference. This means that results of BNRA are not dissolving to the bitumen and because most of BNRA have higher specific gravity than specific gravity of the bitumen.
3) Compare to the HMA mixture using binder starbit (a bitumen modified with polymer), HMA mixture using BNRA-MB have higher marshall stability.
4) Based on static immersion test, BNRA–MB exhibits have good adhesion to aggregate.

Acknowledgements

Alhamdulillah, in preparing this report, I was in contact with many people, researchers, academicians, and practitioners. They have contributed towards my understanding and thoughts. In particular, I wish to express my sincere appreciation to my main research and thesis supervisor, Ir. Gatot Rusbintardjo, M.R.Eng.Sc., Ph.D., for his encourages, guidance, criticism, and friendship. I am also very thankful to my co-supervisor Dr. Abdul Rochim,ST., MT for his guidance, advice and motivation. Very special thanks are given to our beloved parents, Imam Wahyu Sutrisno, Nurul Kistianti and Septia Putri Trisnianti, their patience, prayers and understanding during this study were always a blessing.

References

Huang Y.H. University of Kentuckty (2004). 2nd Edition. Pavement Analysis and Design. Published by pearson Prentice.

Benedict, C.R Slurry Seal Systems for Pavement Conservation. Paper presented to Toledo Secition, ASCE/ University of Toledo Seminar, April 12 (1982). Paper avalable form: International Slurry Seal Association Washington, D.C.

Design Technical Bulletin. International Slurry Seal Association.1978.

American Society for Testing and Materials (ASTM) (1987). ASTM D3625 – 1996 (Rep- approved 2005): *Standard Practice for Effect of Water on Bituminous Coated Aggergate Using Boiling Water*. Philadelphia U.S.: ASTM International.

American Society for Testing and Materials (ASTM) (1996). ASTM D5892 – 2009: *Standard Specification for Type IV Polymer – Modified Asphalt Cement for Use in Pavement Construction*. Philadelphia U.S.: ASTM International.
American Society for Testing and Materials (ASTM) (2006). ASTM C1559 – 2006: *Standard Test Method for Resistance to Plastic Flow of Bituminious Mixtures Using Marshall Apparatus*. Philadelphia U.S.: ASTM International.
Direktorat Bina Teknik. (1995). *Second Highway Sector Investment Project.* General Specification. Volume Three