

# The effect of laterite stone as filler on marshall stability hot mix asphalt AC-WC

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**Abstract.** The highway is the main transportation infrastructure in Indonesia. Most of the highway pavement construction in Indonesia is flexible pavement. The filler commonly used in hot mixture asphalt is Portland Cement. Along with the issue of sustainable development and utilization of local materials, fillers are often replaced with cheaper and easily available materials. One material that can be used as a filler, cheaper and easily available is Laterite.

The experiment was proposed to find out whether laterite could be used as filler material on Asphalt Concrete Wearing Course (AC-WC). The method and technical specification of experiment referred to Asphalt Pavement Specification, that published by Public Work Ministry of Indonesia. The experiment had another objective. The experiment would be examine whether laterite percentage variation on filler material that mixed with Portland Cement, would effect on Marshall Stability value. The filler material was a mixture of laterite and Portland Cement, which the proportion of each were 0:100, 50:50, and 100:0. Each proportion of filler material compacted with 75 and 400 blows. There were 3 samples of each combination of the proportions of the filler material. The total number of specimens were 18. Furthermore, the Marshall stability value of each specimen would be tested using ANOVA test. And ANOVA test used Software Minitab 16.

The experiment result showed, Marshall Stability was greater than 800 kilograms as asphalt concrete wearing course (AC-WC) specification requirement. Analysis of Variance (ANOVA) test results using Minitab 16 software showed no difference in Marshall stability value on all specimens. Because, P-value of Laterite and compaction combination were less than 0.05.

## 1 Introduction

The highway is the main transport infrastructure in Indonesia and the total road length is 523,974 kilometres. Three hundred one thousand and three hundred eighty five of 523,974 kilometres road length had paved. So, there are still more than 40 percent of road length in Indonesia had not paved.

There are two types of road pavement construction in Indonesia. It was flexible pavement and rigid pavement. The mostly used in Indonesia is the flexible pavement. Flexible pavement materials consist of coarse aggregate, fine aggregate, filler and bitumen as binder. The filler is a fine aggregate that pass sieve number 200. Filler material is usually used right now, is cement. But, not all regions in Indonesia are available cement material. So, it takes alternative material to replace cement as filler material. Such alternative materials are preferred in many areas where there are road construction projects.

The island of Borneo has large laterite material deposits. The Laterite Stone of Borneo is a hardened soil resembling a stone from the deposition of nickel and iron substances. Laterite stone is formed naturally in which many contain basic solutions. The organic material content is lost due to the weather and leaves the nickel and iron substances that form a layer of soil and harden like a stone.

In Borneo, laterite stones are used as subbase pavement layer because the material is easy to obtain and the quality is also strong. Based on the above background it is necessary to research about laterite stone as filler on asphalt mixture. Whether using laterite stone as filler can influence the value of Marshall test parameters better than using cement filler. It is hoped that with the results of this test the use of laterite stone can be used as an alternative to more expensive cement replacement.

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## 2 Literature Study

### 2.1 Hot Mix Asphalt

Hot mix asphalt consists of aggregate and bituminous, mixed by heating process on Asphalt Mixing Plant (AMP), spread out and compacted on the base course or subgrade. Several kinds of hot mix asphalt (HMA) are Sand Sheet, (SS), *Hot Rolled Sheet*, (HRS), and *Asphalt Concrete*, (AC).

Hot Mix Asphalt material consists of asphalt cement, coarse aggregate, fine aggregate and filler. The gradation of each aggregate size should be check before combined as mix aggregate that fulfilled the job specification of hot mix asphalt.

All hot mix asphalt types are designed by considering percentage of asphalt, air void, stability, flow, void filled with bitumen, and type of traffic.

### 2.2 Aggregate

Aggregate or granular material is grained and compacted materials. The term is including round aggregate, crush aggregate, stone ash and sand. The aggregate is main part in the highway flexible pavement. Because, their percentage is around 90% until 95% from total weight hot mix asphalt.

Based on material size, aggregate is consists of 2 kinds, are coarse aggregate and fine aggregate. Coarse aggregate is hard and compacted grained aggregate, including gravel, stone crushed, stone ash and sand. Fine aggregate consists of natural sand, artificial sand or slag sand or a combination of such materials. The fine aggregate must be clean, dry, strong, free of clumps of clay and other disturbing materials and composed of sharply corners and having a rough surface.

### 2.3 Filler

Filler material specification is:

- a. For filler material such as stone ash, fly ash, Portland cement or other nonplastic material, filler should be cleaned or free from disturbing material and should be check on wet condition.
- b. Filler should be dry and there is no lumps and if tested by sieve, the result must contains materials that pass sieve number 200 (aggregate size 0.075 mm) not less than 75% of total weight. (SNI 03-1968-1990)

### 2.4 Asphalt

Asphalt is defined as dark brown material, at room temperature is solid to slightly solid. If heated to a certain temperature the asphalt becomes soft or liquid so that it can wrap the aggregate particles at the time of making the hot mix asphalt or can penetrate the pores of aggregate when it sprays or mixed on macadam pavement or hot mix asphalt process. If the temperature starts to decrease, the asphalt will be hardening and bond in place (thermoplastic character). As one of the

flexible pavement construction materials, the use of asphalt is low, generally only 4% -10% of total weight or 10% -15% of total volume, but asphalt is an expensive material.

Based on how to obtain, type of asphalt is divided by 2:

- A. Natural deposits asphalt, consist of
  - a. Rock asphalt, such as asphalt from Buton
  - b. Lake asphalt, such as asphalt from Bermudes, Trinidad
- B. Processed asphalt, consist of:
  - a. Asphalt Cement, from natural oil processing
  - b. Ter, from coal processing. The material is not common used on the highway pavement. Because, the pavement is hardening quickly, and sensitive to temperature changes (Silvia Sukirman, 1995)

### 2.5 Bitumen Content Estimation

Bitumen content on the hot mix asphalt can be estimated by the following formulation:

$$PB = (0,035 \times \% CA) + (0,045 \times FA) + (0,18 \times FF) + Nk$$

Where:

- PB = Bitumen content.  
CA = Coarse Aggregate  
FA = Fine Aggregate  
FF = Filler  
Nk = Constant number, 0,5-1 (for hot mix asphalt AC-WC)

### 2.6 Laterite Stone

Based on the USDA classification, Laterite soils have the same name Oxisols. This soil is rich in mineral sochlyoid and has more weathering. The soil is poor in rotten minerals, highly resistant mineral content and Cation exchange capacity is very low (Soil Survey Staff, 1998).

This soil is characterized by the presence of horizon oxic at less than 1.5 m depth or has horizon candic that the amount of mineral easily decayed to meet the requirements of horizon oxic. This soil has special properties such as very low nutrient reserves, very low natural fertility, high interchangeable Al content, good permeability, and soil against erosion. However, some of these soils (Laterite/Oxisols), for example from the great group Eutrotrorox, have high base saturation throughout their profiles (Hardjowigeno, 1993).

The process of laterite soil formation is the development of further weathering of Latosol soil. High rainfall (wet or humid) plus high temperatures leads to faster and more intensive soil-development forces in the tropics due to heavy growth. High temperatures accelerate the process of mineralization of organic materials that can offset the process of humification, resulting in CO<sub>2</sub> and H<sub>2</sub>O. These substances accelerate the process of decomposition of rocks, and also silicate Al and Fe by dissolving alkaline ions such as K, Ca, Na,

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and Mg. The absence of a process of gleization enhances the intensity of the base dissolution.

From the description above, the process of Laterite is a further weathering process of Latosol soil where there is a process of removal/ leaching of silica and alkaline ions chemically from soil solum until the

concentration of Fe and Al is increased relative. Occurs in the tropics where rainfall and high temperatures so that Si and alkaline ions easily dissolve. Here laterit used in this research.



**Fig. 1.** Laterite Stone

## 2.7 Analysis of Variance

Analysis of variance (ANOVA) is a collection of statistical models and their associated procedures (such as "variation" among and between groups) used to analyze the differences between group means. ANOVA was developed by statistician and evolutionary biologist Ronald Fisher. In the ANOVA setting, the observed variance in a particular variable is partitioned into components attributable to different sources of variation. In its simplest form, ANOVA provides a statistical test of whether or not the means of several groups are equal, and therefore generalizes the *t*-test to more than two groups. ANOVAs are useful for comparing (testing) three or more means (groups or variables) for statistical significance. It is conceptually similar to multiple two-sample *t*-tests, but is more

conservative (results in less type I error) (Diez et al, 2017) and is therefore suited to a wide range of practical problems.

## 3 The Method

The methodology flowchart that guided the experiment was showed as **Figure 2**.

## 4 Result

### 4.1 Material Testing

The result of aggregate material testing is showed on **Table 1**:

**Table 1.** The result of aggregate material testing

Test	Coarse Aggregate	Fine Aggregate	Laterite	Reference	Standard Value
Fineness Modulus		2,44%		SNI 03 - 2461	2,3% - 3,2%
Abrasion	14,86%			SNI 2417:2008	Max. 40%
Bulk specific Gravity	2,718	2,580	2,609		> 2,5 gr/cc
Effective Specific Gravity	2,741	2,611	2,653	SNI 1969:2008	-
Apparent Specific Gravity	2,783	2,663	2,728		-
Absorption	0,855%	1,215%	1,678%	SNI 1970:2008	≤ 3%
Atterberg Limit			Non Plastic	SNI 03-1966	-

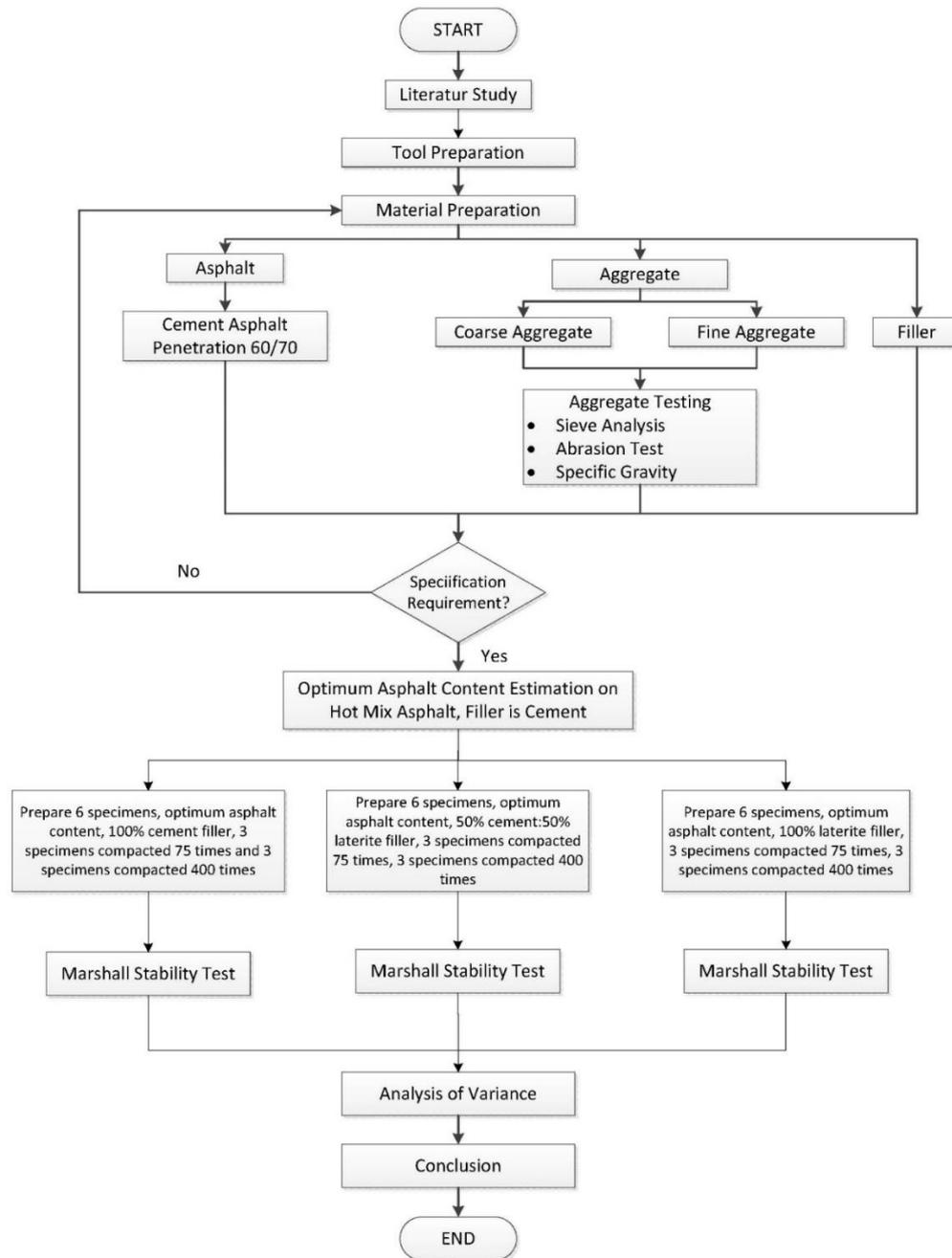
The result of asphalt testing is showed on **Table 2**:

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**Table 2.** The result of asphalt material testing

No	Testing	Testing Method	Test Result	Specification		Unit
				Min	Max	
1	Penetration at 25°C, 100 gram, 5 seconds	SNI 06-2456-1991	62	60	70	0,1mm
2	Softening point	SNI 06-2434-1991	53,5	48	58	°C
3	Ductility at 25°C, 5cm/minutes	SNI 06-2432-1991	128	100	-	cm <sup>3</sup>
4	Solubility Asphalt in C <sub>2</sub> HCL <sub>3</sub>	SNI-06-2438-1991	99,5	99	-	%
5	Flash Point (°C)	SNI 06-2433-1991	331	200	-	°C
6	Specific Gravity	SNI 06-2441-1991	1,030	1,0	-	gr/cc
7	Penetration after TFOT	SNI 06-2456-1991	52,3	54	-	%
8	Ductility after TFOT	SNI 06-2434-1991	83,0	50	-	Cm
9	Softening point after TFOT	SNI 06-2432-1991	53,5	-	-	°C
10	Mixing temperature	AASHTO-27-1990	150	-	-	°C
11	Compaction temperature	AASHTO-27-1990	145	-	-	°C
12	Paraffin content	SK-SNI M-09-1993-03	0,440	-	-	%
13	Ductility	ASTM D 113	150	Min 100	-	Cm
14	Fresh Point COC	ASTM D 92	347	Min 200	-	°C
15	Loss on Heating 5 Hrs at 163°C	ASTM D 5	0,01	-	Max 0,04	%
16	Penetration at 25°C	ASTM D 5	62	60 – 79	60 – 79	0,1mm
17	Penetration after loss on heating	ASTM D 5	93	Min 75	-	%
18	Softening point ring & ball	ASTM D 36	48,2	48	58	°C
19	Specific Gravity 25/25°C	ASTM D 70	1,0443	Min 1,0000	-	-

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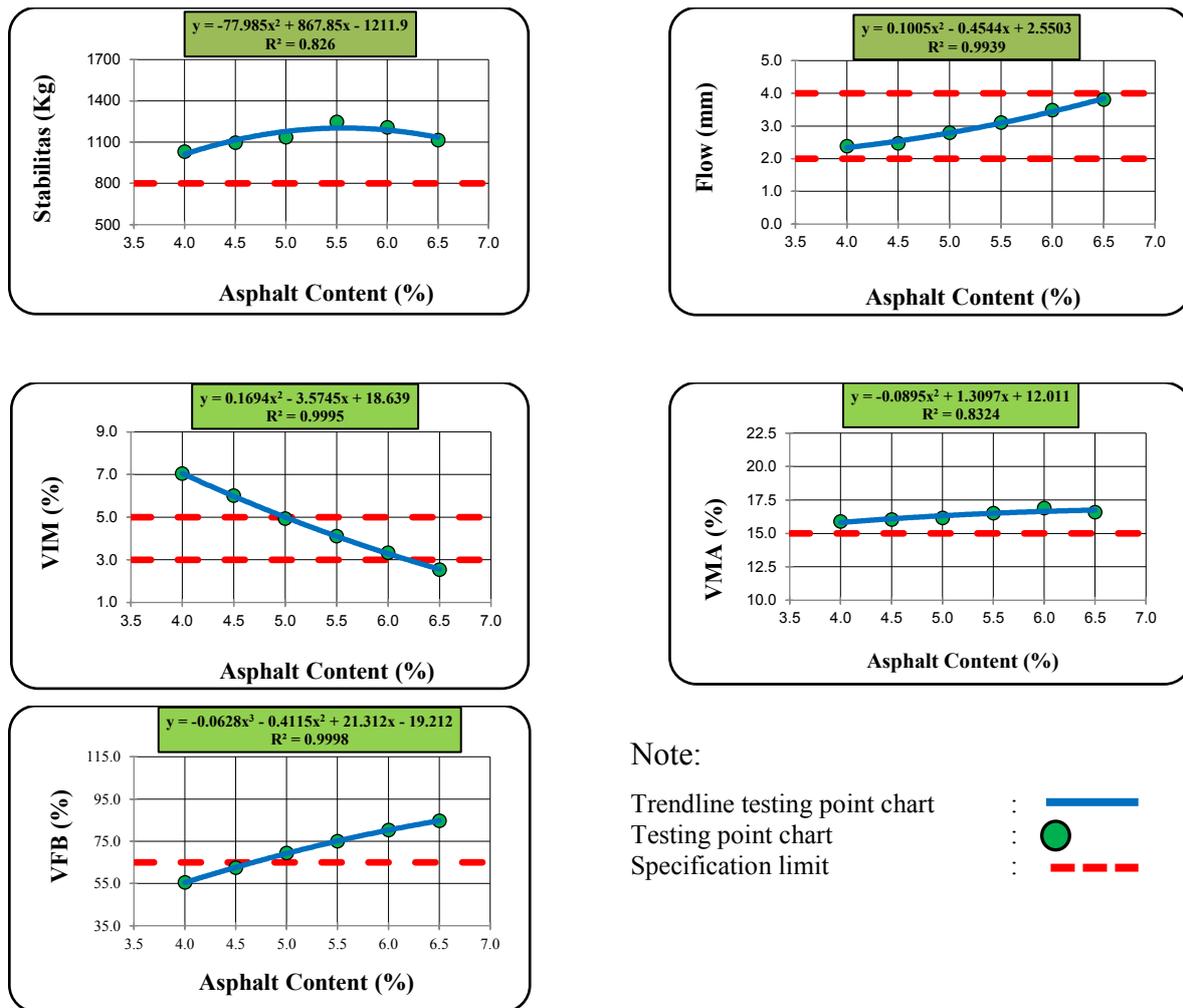
**Fig. 2.** Methodology Flow Chart

## 4.2 Optimum Asphalt Content

First experiment was done to decide the optimum asphalt content. The optimum asphalt content was obtained by Marshall Stability testing on hot mix asphalt specimen. Hot mix asphalt specimen was made with variation percentage of asphalt content level to total weight specimen. There were six specimens with different variations of asphalt content, i.e. 4.0%, 4.5%, 5.0%, 5.5%, 6.0%, 6.5%. Each specimen was tested by

Marshall Test Equipment. The test results were shown by correlation chart between asphalt content with stability, flow, void in mixture (VIM), void filled with bitumen (VFB), and void in mineral aggregate (VMA). Correlation charts between asphalt content with stability, flow, void in mixture (VIM), void filled with bitumen (VFB), and void in mineral aggregate (VMA) can show on **Figure 3**.

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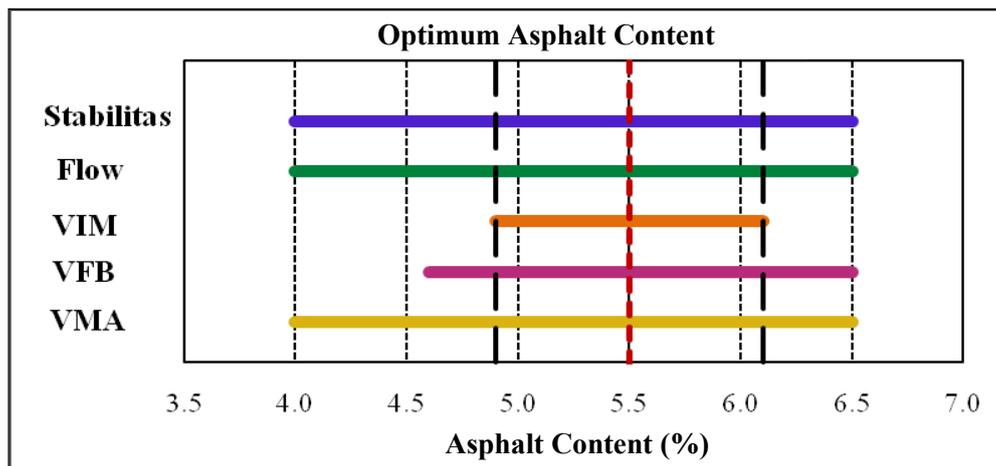


**Fig. 3.** Correlation Charts between Asphalt Content with Stability, Flow, Void in Mixture (VIM), Void Filled with Bitumen (VFB), and Void in Mineral Aggregate (VMA)

On **Figure 3**, dashed line showed specification limit, that had to be fulfilled for standard of Asphalt Concrete Wearing Course (AC-WC) mixture. So, recapitulation value from correlation charts between asphalt content with stability, flow, void in mixture (VIM), void filled with bitumen (VFB), and void in mineral aggregate (VMA) that fulfilled for standard of

Asphalt Concrete Wearing Course (AC-WC) mixture is showed on **Figure 4**.

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**Fig. 4.** The Chart of Optimum Asphalt Content Procedure

Note:

Optimum Asphalt Content value : ■■■■■■ VIM value : ————  
 Stability value : ———— VFB value : ————  
 Flow value : ———— VMA value : ————  
 Optimum Asphalt Content limit : - - - - -

On **Figure 4**, optimum asphalt content value is 5.5% to total weight hot mix asphalt specimen.

### 4.3 Analysis of Variance (ANOVA)

Analysis of Variance (ANOVA) was used to analysis the effect of laterite on Marshall Stability value. The experimental applied 2 factors, laterite content on filler and number of compaction on hot mixture asphalt.

Laterite content on filler was made 3 level, 0% laterite:100% cement, 50% laterite:50% cement, and 100% laterite:0% cement. Number of compaction on hot mixture asphalt was made 2 level, 2x75 times and 2x400 times. Total experiment factors combination were 6. Number of specimen was 3 of each experiment factors combination. Total specimen were 18. Marshall stability values on 2 factors combination of experiment is showed on **Table 3**.

**Table 3.** the Effect of Laterite as Filler on Marshall Stability Specimen

No.	Laterite Level	Compacted 2 x75 times		Compacted 2 x 400 times		Specification (kg)
		Stability (kg)	Stability Average (kg)	Stability (kg)	Stability Average (kg)	
1	Cement Filler 100%	1.248	<b>1.231</b>	1.098	<b>1.140</b>	Min 800
		1.223		1.198		
		1.223		1.123		
2	Cement Filler 50% and Laterite Filler 50%	1.071	<b>1.107</b>	1.000	<b>1.041</b>	Min 800
		1.155		1.024		
		1.095		1.098		
3	Laterite Filler 100%	1.024	<b>1.056</b>	1.024	<b>1.012</b>	Min 800
		1.048		976		

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On table above, Laterite can be used as filler on asphalt concrete wearing course (AC-WC). Because, Marshall Stability value was greater than 800 kilograms as specification requirement.

There was a hypothesis that should be tested. The

tested hypothesis ( $h_0$ ) was, no difference of any Marshall Stability value on 18 hot mix asphalt specimen. The hypothesis was tested by using Minitab Software. The output minitab as result of tested hypothesis is shown below:

### General Factorial Regression: Response versus Laterite; Compaction

#### Factor Information

Factor	Levels	Values
Laterite	3	0; 50; 100
Compaction	2	75; 400

#### Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	5	96209	19241.8	11.89	0.000
Linear	3	94479	31493.1	19.46	0.000
Laterite	2	74144	37072.2	22.91	0.000
Compaction	1	20335	20334.7	12.56	0.004
2-Way Interactions	2	1730	864.9	0.53	0.599
Laterite*Compaction	2	1730	864.9	0.53	0.599
Error	12	19421	1618.4		
Total	17	115630			

In Minitab output, The result was no difference of any Marshall Stability value based on Laterite and compaction combination. P-value was less than 0.05.

### 5 Conclusion

Conclusion of the experiment were:

- Optimum asphalt content that used on asphalt concrete wearing course (AC-WC) was 5.5%.
- On table above, Laterite can be used as filler on asphalt concrete wearing course (AC-WC). Because, Marshall Stability value was greater than 800 kilograms as specification requirement.
- Marshall Stability value did not depend on percentage Laterite content and compaction energy.

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