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Mathematical Model of Penetration and Softening Pointchanges of Asphalt Pen 60/70 Due to Additional Viatop[66]

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ABSTRACT
Asphalt is an adhesive material that can bind aggregates in asphalt mixtures. During service period, asphalt quality is strongly influenced by temperature and traffic load. Various ways can be done to improve its performance. One of them is by giving additive material. The authors try to use additional ingredient in the form of viatop[66] which is one type of cellulose fiber. This material is assumed to affect the mechanical properties of asphalt, e.g. penetration values and asphalt softening points. The goal of this study is to determine the effect of asphalt and level of viatop[66] on penetration values and asphalt softening point values. In addition, to determine the mathematical model that is most appropriate to describe penetration and softening points changes of asphalt pen. 60/70 due to presence of viatop[66]. Penetration testing and softening point were carried out using the variation of each viatop[66] content of: 0%, 1%, 2%, 3%, 4% and 5% of the asphalt weight of 100 gr, 200 gr, 300 gr, 400 gr, and 500 gr. This study used SPSS software and F test statistical analysis method. Results show that the weight of asphalt did not affect penetration and softening point of asphalt. Viatop[66] in asphalt caused decrease of the penetration value and resulted in increase of softening point rate. The linear graph model in accordance with relationship between penetration values and viatop[66] levels has been known as an mathematical equation of y = -3,5773x + 67,421 with the largest R^2 of 0,99. On the other hand, the relationship between softening point values and viatop[66] levels obtained the highest R2 = 0,94 with the equation of y = 1,4737x + 49,832.
Keywords-Mathematical Model, Penetration, Soft Point, Viatop[66]

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I. INTRODUCTION

Asphalt is an adhesive material in flexible pavement because it can bindaggregates in asphalt mixtures.In the city of Palu, generally the type of asphalt used as a binder is asphalt of pen 60/70, due tothis area experienceshot weather and road conditions with medium or high traffic volumes.According to Sukirman (1999) low penetration asphalt is used in areas with hot weather and high traffic volumes, while high penetration asphalt is used for cold weather areas and low traffic volumes.Asphalt has a viscoelastic properties which are liquid at high temperatures and solid at low temperatures. So that asphalt is strongly influenced by temperature and traffic load.During the service period, asphalt concrete will be easily carried out asphalt from the aggregate (stripping), cracking, and bleeding.

Generally the mechanical characteristics of asphalt can affect the quality of flexible pavement mixtures such as durability, adhesion and cohesion, sensitivity to temperature, hardening and aging so it is necessary to do some testing of asphalt mechanical characteristics, namely penetration testing of bitumen materials and testing of asphalt softening points.

With these problems, various ways can be done to improve the performance of the asphalt mixture.One of them is by giving added ingredients in the form of viatop[66] which is a type of cellulose fiber. This added material, in the asphalt mixture is thought to affect the mechanical properties of asphalt (penetration value and asphalt softening point).In addition, there are several purposes for modified asphalt, which are to avoid the occurrence of damp asphalt and to be easily damaged due to the asphalt's natural properties that are less resistant to surrounding climate conditions, reduce the potential for cracking, reduce the potential for rutting on paved pavements, reduce viscosity at the spreading temperature so that the ease of execution of the laying and compaction can be achieved, it can increase the stability and strength of the asphalt mixture.

So far, many studies have used added ingredients in asphalt concrete mixtures.However, just looking at changes in the characteristics of the mixture as a whole without seeing how the

mechanical characteristics of the asphalt change when using added ingredients into it.

The author intends to analyze how the mathematical model of penetration changes and the softening point of asphalt due to the added ingredient of viatop[66].

II. LITERATURE REVIEW

Definition of Asphalt

Asphalt is defined as a cementitious material, black or dark brown, with the main elements of bitumen.Asphalt can be obtained in nature or is a residue from petroleum refining. (Sukirman, 2003)

Asphalt is a material which at room temperature is solid to slightly dense, and is thermoplastic.So, the asphalt will melt if it is heated to a certain temperature, and again freezes if the temperature drops.Together with aggregates, asphalt is a form of pavement mixture. The amount of asphalt in the pavement mixture ranges from 4-10% based on mixed weight, or 10-15% based on mixed volume. (Sukirman, 2003)

Asphalt Testing

Asphalt is a product of natural materials, so the properties of asphalt must always be examined in the laboratory and asphalt that meets the stipulated conditions can be used as a flexible pavement binder.Examinations carried out for hard asphalt are as follows:

(1) Physical Test of Asphalt
a. Asphalt type weight checking
b. Check flash point and burn point
c. Examination of asphalt viscosity
d. Examination of oil and asphalt weight loss
(2) Asphalt Mechanical Testing

In this study, the authors are more specific to discuss asphalt mechanical inspection, namely penetration testing and examination of asphalt softening point.

a. Penetration testing

Asphalt penetration examination aims to check the level of asphalt hardness. Examination is done by inserting a penetration needle with a diameter of 1 mm using a load of 50 grams so that the motion load of 100 grams (needle weight + load) is obtained for 5 seconds at a temperature of 25ºC.

b. Testing the asphalt softening point

Softening point is the temperature at which a layer of asphalt in a ring placed horizontally in a solution of water or glycerine that is heated regularly becomes soft due to the load of a steel ball with a diameter of 9.53 mm weighing ± 3.5 grams placed on top so that the asphalt layer falls through a distance of 25.4 mm (1 inch). Asphalt softening points vary from 30ºC to 200ºC. Asphalt with a higher softening point is less sensitive to temperature changes and is better for pavement construction binders.

c. Ductility testing

(Sukirman, 1999)

Ingredients Add Viatop[66]

Viatop[66] is a cellulose fiber coated with bitumen in a special production process. This bitumem acts to help the granulation process.With the existence of this bitumen, it is possible to control the behavior of the granulation process that occurs on the fiber during the granulation process.At the same time this bitumen took over the function of the inter-fiber space filler needed for the process of dispersion of the fibers in the process of mixing asphalt.Viatop[66] consists of Arbocel with other added ingredients, which are packaged in cylindrical granules and blackish gray.Arbocel itself is a cellulose fiber which is also a hot asphalt mixture additive material (Tegalaksana, 1994). Tegalaksana, (1994) states that the specifications of Arbocel are as follows:

1. Cellulose content : 75 - 80%
2. Ph : 7.5 + 1 (wet)
3. Maximum fiber length : 5000 microns
4. Average fiber length : 1100 microns
5. Average fiber thickness : 45 microns
6. Solvent resistance :good under normal conditions
7. Heating resistance : good to 2500 C

Table 1 General Specifications of Viatop[66]

No.	General Specifications of Viatop	
1.	Percentage ofARBOCEL®ZZ 8 - 1	65 - 70%
2.	Average length	2 - 10 mm
3.	The average thickness	5 $\pm$ 1 mm
4.	Bulk Density	480 - 530 g/l
5.	Filter analysis, > 3,55 mm	Max. 5%

Sumber : J. Rettenmaier & Sohne GMBH + Co Kg, 200.http://www.jrs.de

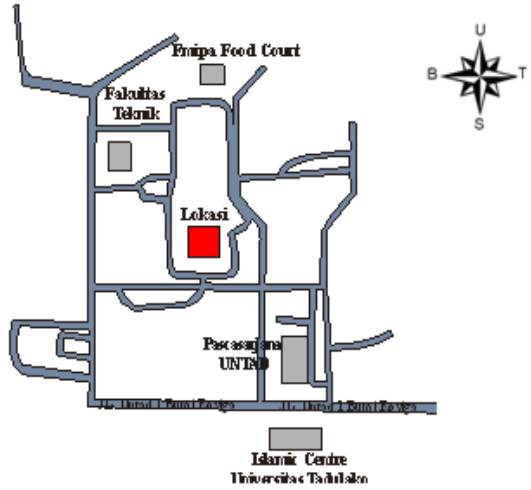
III. RESEARCH METHOD

Types of research

This research is scientific research by conducting experiments in the Laboratory, based on scientific rules with systematic procedures through scientific proof. This research is carried out through stages, both theoretical concept procedures and application procedures consisting of sampling in the field and examination of samples in the laboratory to sample testing to obtain results from research objectives

Research Sites

This research will be conducted at the Transportation and Highway Laboratory, Faculty of Engineering, University of Tadulako.



Picture 1 Research Sites
(Source : Google Map 2017)

Preparation of Research Materials

Preparation of materials used in this study are:

a. Asphalt used is asphalt ex. Pertamina pen 60/70 is available at the research site at the Transportation and Highway Laboratory, Faculty of Engineering, University of Tadulako. The prepared material is then examined at the Laboratory, to determine the feasibility of the material to be used.
b. Ingredients added to viatop66 used are available at the research site at the Transportation and Highway Laboratory, Faculty of Engineering, University of Tadulako.

Research Procedure

The stages of the procedure for carrying out this research are illustrated in a flowchart of research methods that will guide researchers to provide a directed process of conducting research.

Test Object Matrix

Data collection is carried out systematically by recording all data generated from a series of tests from the beginning to the end while taking into account the validity of the data collected. The following is a table for the total number of test items during the study.

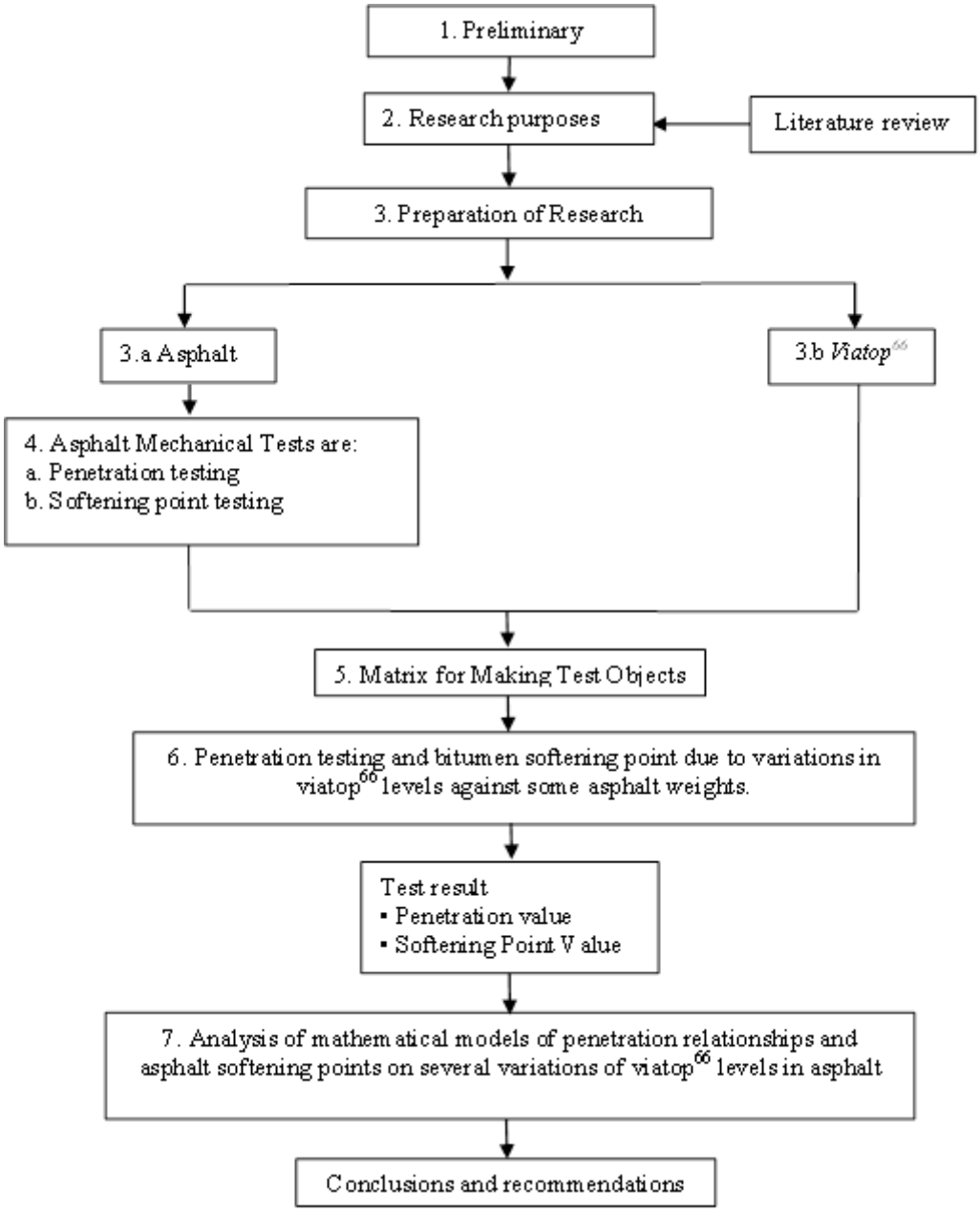
Table 2 Matrix for making test items for penetration testing

No	**Levels of viatop[66] (%)**	**Asphalt Weight (gr)**					**Total**
		100	200	300	400	500	
		Number Of Specimens					
1	0	10	10	10	10	10	50
2	1	10	10	10	10	10	50
3	2	10	10	10	10	10	50
4	3	10	10	10	10	10	50
5	4	10	10	10	10	10	50
6	5	10	10	10	10	10	50
Total Test Specimen							**300**

Table 3 Matrix for making test items for softning point testing

No	**Levels of viatop[66] (%)**	**Asphalt Weight(gr)**					**Total**
		100	200	300	400	500	
		Number Of Specimens					
1	0	10	10	10	10	10	50
2	1	10	10	10	10	10	50
3	2	10	10	10	10	10	50
4	3	10	10	10	10	10	50
5	4	10	10	10	10	10	50
6	5	10	10	10	10	10	50
Total Test Specimen							**300**

Research Flow Chart



Picture 2 Research Flow Chart

IV. RESULTS AND DISCUSSION

Analysis of Effect of Viatop^{66} Levels on Penetration Value of Pen 60/70 Asphalt for 100 gr Asphalt Weight, 200 gr, 300 gr, 400 gr and 500 gr

a) Determine the hypothesis formulation:

(1) H_0 = there is no effect on the variation of asphalt weight on the penetration value.

H_1 = there is the effect of variations in the weight of bitumen on the value of penetration.

(2) H_0 = there is no effect of variation in viatop^{66} levels on penetration value.

H_1 = there is an effect of variations in viatop^{66} levels on penetration values.

b) Determine the real level (α) and the value of F table

Significant level(α) = 5% (0,05)

F table for rows

$v_1 = b - 1 = 5 - 1 = 4$

$v_2 = (k - 1)(b - 1) = (6 - 1)(5 - 1) = 20$

$F_{0,05\,(4,20)} = 2,87$ (see in table F)

F table for columns

$v_1 = b - 1 = 6 - 1 = 5$

$v_2 = (k - 1)(b - 1) = (5 - 1)(6 - 1) = 20$

$F_{0,05\,(5,20)} = 2,71$(see in table F)

c) Determine the testing criteria

(1) H_0 = accepted (H_1 rejected) if $F_0 \leq 2,87$

H_0 = rejected (H_1 accepted) if $F_0 > 2,87$

(2) H_0 = accepted (H_1 rejected) if $F_0 \leq 2,71$
H_0 = rejected (H_1 accepted) if $F_0 > 2,71$

d) Determining the value of the statistical test (value F_0) The statistical test value can be determined based on the total test value of penetration of asphalt pen 60/70 on several variations of viatop[66] levels for asphalt weight 100gr, 200gr, 300gr, 400gr, and 500gr can be seen in table 4

Table 4 The total test value for penetration of asphalt pen is 60/70 for asphalt weight of 100gr, 200gr, 300gr, 400gr and 500gr

Asphalt Weight (gram)	Penetration Value (div) Levels ofViatop[66] (%)						Total
	0	1	2	3	4	5	
100	68,0	62,8	59,4	55,2	54,0	50,8	350,2
200	68,0	63,5	60,2	56,1	52,9	50,1	350,9
300	68,0	64,5	60,6	55,3	53,5	51,2	353,1
400	68,0	63,4	58,6	56,2	53,1	50,4	349,7
500	68,0	61,9	59,4	57,2	53,3	51,0	350,7
Total	339,9	316,1	298,2	280,0	266,8	253,5	**1754,6**

Source : Test result 2018

$$JKT = \sum_{i=1}^{b}\sum_{j=1}^{k} x_{ij}^2 - \frac{T^2}{bk} \ldots$$
$$= 68^2 + 62,8^2 + ... + 53,3^2 + 51^2 - \frac{1754,6^2}{5 \times 6}$$
$$= 103662,9 - 102618,8$$
$$= 1044,1$$
$$JKB = \sum_{i=1}^{b} \frac{T_i^2}{k} - \frac{T^2}{bk}$$
$$= \frac{350,2^2 + 350,9^2 + 353,1^2 + 349,7^2 + 350,7^2}{6} - \frac{1754,6^2}{5 \times 6}$$
$$= 102619,8 - 102618,8$$
$$= 1$$
$$JKK = \sum_{j=1}^{k} \frac{T_j^2}{k} - \frac{T^2}{bk}$$
$$= \frac{339,9^2 + 316,1^2 + 298,2^2 + 280^2 + 266,8^2 + 253,5^2}{5} - \frac{1754,6^2}{5 \times 6}$$
$$= 103652,7 - 102618,8$$
$$= 1033,9$$

$$JKE = JKT - JKB - JKK$$
$$= 1044,1 - 1 - 1033,9$$
$$= 9,2$$

Table5 The results of the statistical test value (value F_0) Penetration for Asphalt Weight 100 gr, 200 gr, 300 gr, 400 gr, and 500 gr

Source of Variance	Number of squares	Free degree	Average Squares	F_0
Line average	1	4	0,250	$F_1 = 0,543$
Average column	1033,9	5	206,780	$F_2 = 449,522$
Error	9,2	20	0,460	
Total	1044,1	29		

Source : Test Result 2018

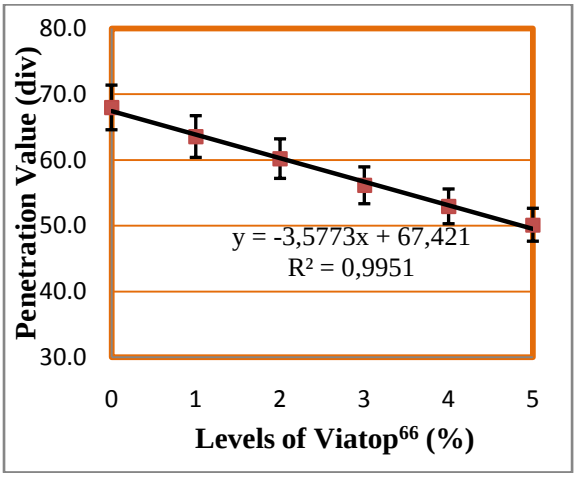
e) Analysis Results
(1) Because F_0 = 0,543 <$F_{0,05\ (4,20)}$ = 2.87 then H_0 is accepted. So, there is no effect on the variation of asphalt weight on the value of penetration.
(2) Because F_0 = 449,522> $F_{0,05\ (5,20)}$ = 2,71 then H_0 is rejected. So, there is the effect of variations in viatop^{66} levels on penetration values.

Analysis of the Relationship between Penetration Value and Viatop^{66} Levels in 200 gr Asphalt Weight

Table6The results of the average test value for penetration of asphalt pen 60/70 for asphalt weight of 200 gr

Levels of viatop^{66} (%)	0	1	2	3	4	5
Penetration value (div)	68	63,5	60,2	56,1	52,9	50,1

Source : Test Result 2018



Pictures 3 Relationship between Penetration Value and Viatop^{66} Level for 200 gr Asphalt Weight
Source : Test Result 2018

From the graph of the relationship of penetration value and viatop^{66} levels in some asphalt weights, the addition of variations in viatop^{66} levels greatly affected the asphalt penetration value.Asphalt penetration value decreases along with the addition of variations in viatop^{66} levels. As the penetration value decreases, the asphalt properties will get harder.In addition, based on the previous F test analysis regarding the effect of viatop^{66} levels on penetration values in asphalt weight of 100 gr, 200 gr, 400 gr, and 500 gr it was concluded that there was no effect of asphalt weight on penetration values.So that from the linear graph model the relationship between the value of penetration and the level of viatop^{66} is used the coefficient of determination or R^2 is greatest, R^2 = 0.9951.

Analysis of the Effect of Viatop^{66} Level
a) Determine the hypothesis formulation:
(1) H_0 = there is no effect on the variation of asphalt weight on the value of the asphalt softening point.
H_1 = there is an influence of variations in asphalt weight on the value of the asphalt softening point
(2) H_0 = there is no effect of variation in viatop^{66} levels on the value of the asphalt softening point.
H_1 = there is an effect of variation in viatop^{66} levels on the value of the asphalt softening point.
b) Determine the real level (α) and the value of F table
(1) Significant level(α) = 5% (0,05)
(2) F table for rows
$v_1 = b - 1 = 5 - 1 = 4$
$v_2 = (k - 1)(b - 1) = (6 - 1)(5 - 1) = 20$
$F_{0,05\ (4,20)}$ = 2,87 (see in table F)
(3) F table for columns
$v_1 = b - 1 = 6 - 1 = 5$
$v_2 = (k - 1)(b - 1) = (5 - 1)(6 - 1) = 20$
$F_{0,05\ (5,20)}$ = 2,71 (see in table F)
c) Determine the testing criteria
(1) H_0 = accepted (H_1rejected) if $F_0 \leq 2,87$
H_0 = rejected (H_1accepted) if $F_0 > 2,87$
(2) H_0 = accepted (H_1rejected) if $F_0 \leq 2,71$
H_0 = rejected (H_1 accepted) if $F_0 > 2,71$
d) Determine the statistical test value (value F_0)
Statistical test values can be determined based on the results of statistical test scores and the total value of testing the penetration of asphalt pen 60/70 on several variations of viatop^{66} levels for asphalt weight 100gr, 200gr, 300gr, 400gr, and 500gr can be seen in table 7

Table 7 The total test value of 60/70 asphalt pen softening point for asphalt weight of 100gr, 200gr, 300gr, 400gr and 500gr

Asphalt Weight (gram)	**Softening Point Value(°C)**						**Total**
	Levels of Viatop^{66} (%)						
	0	**1**	**2**	**3**	**4**	**5**	
100	48,9	51,8	53,8	54,3	55,7	56,8	321,1
200	48,9	52,2	53,6	54,3	55,6	56,9	321,6
300	48,9	52,3	53,8	54,1	55,3	56,8	321,2
400	48,9	52,5	53,9	54,4	55,3	56,8	321,7
500	48,9	52,8	53,9	54,5	55,4	56,7	322,2
Total	244,4	261,5	268,9	271,6	277,4	283,9	**1607,7**

Source : Test Result 2018

$JKT = \sum_{i=1}^{b}\sum_{j=1}^{k} x_{ij}^2 - \frac{T^2}{bk}$ ...
$= 48,9^2 + 51,8^2 + ... + 55,4^2 + 56,7^2 - \frac{1607,7^2}{5 \times 6}$
$= 86346,122 - 86154,499$
$= 191,622$
$JKB = \sum_{i=1}^{b} \frac{T_i^2}{k} - \frac{T^2}{bk}$

$= \frac{321,1^2+321,6^2+321,2^2+321,7^2+322,2^2}{6} - \frac{1607,7^2}{5 \times 6}$
= 86154,617 – 86154,499
= 0,117

$JKK = \sum_{j=1}^{k} \frac{T_j^2}{k} - \frac{T^2}{bk}$
$= \frac{244,4^2+261,5^2+268,9^2+271,6^2+277,4^2+283,9^2}{5} - \frac{1607,7^2}{5 \times 6}$
= 86345,305 – 86154,499
= 190,806
JKE = JKT – JKB – JKK
= 191,622– 0,117- 190,806
= 0,699

Table8The results of the statistical test value (value F_0) Softening Point for Asphalt Weight 100 gr, 200 gr, 300 gr, 400 gr, and 500 gr

Source of Variance	Number of squares	Free degree	Average Squares	F_0
Line average	0,117	4	0,029	F_1=0,829
Average column	190,806	5	38,161	F_2=1090,314
Error	0,699	20	0,035	
Total	191,622	29		

Source : Test Result 2018

e) Analysis Results

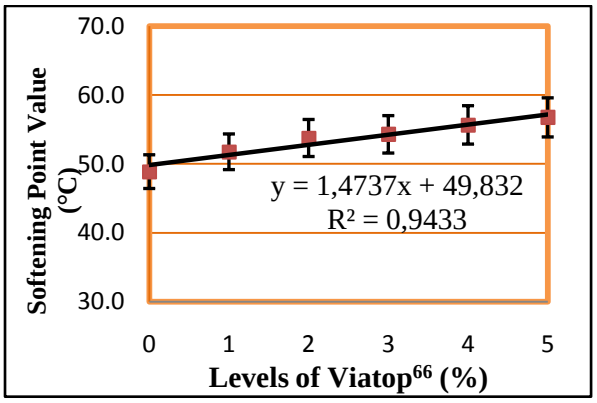
(1) Because F_0 = 0.829 <$F_{0.05\ (4.20)}$ = 2.87 then H_0 is accepted. So, there is no effect on the asphalt weight variation on the asphalt softening value.
(2) Because F_0 = 1090,314> $F_{0.05\ (5,20)}$ = 2,71 then H_0 is rejected. So, there is the effect of the variation of asphalt weight on the value of the asphalt softening point.

Analysis of the Relationship between Softening Point Value and Viatop[66] Level in 100 gr Asphalt Weight

Table 9 The results of the average value of testing the60/70 asphalt pen softening point for 100 gr asphalt weight

Levels of Viatop[66] (%)	0	1	2	3	4	5
Softening Point Value (°C)	48,9	51,8	53,8	54,3	55,7	56,8

Source : Test Result 2018



Picture 4 Relationship between Softening Point Value and Viatop[66] Level for 100 gr Asphalt Weight
Source : Test Result 2018

From the graph the relationship between the softening point value and the viatop[66] level in several asphalt weight variations shows that the addition of viatop[66] levels greatly affects the asphalt softening value.The bitumen softening point value is higher along with the addition of variations in viatop[66] levels.With the increase in the value of the asphalt softening point, the asphalt properties will be able to withstand the temperature that occurs to not soften so that it can reduce adhesion.In addition, based on the previous F test analysis of the effect of viatop[66] levels on softening point values in the weight of 100 gr asphalt, 200 gr, 300 gr, 400 gr, and 500 gr it was concluded that there was no effect of asphalt weight on the softening point value.So that from the linear graph model the relationship between the softening point value and the viatop[66] level is used the largest coefficient of determination or R^2 is R^2 = 0.9433.

V. CONCLUSIONS AND SUGGESTIONS

Conclusions

1. From the results of laboratory tests which are reinforced by the F test analysis (ANOVA) it is known that the asphalt weight does not affect the penetration and softening point of the asphalt.
2. That it turns out that the level of viatop[66] causes a change in the value of penetration. Asphalt penetration value decreases along with the addition of variations in viatop[66] levels. As with penetration, the level of viatop[66] influences the softening point value.Addition of variations in viatop[66] levels can increase the softening point value, so the asphalt properties will be able to withstand the temperature that occurs.
3. From the five mathematical models obtained from the analysis, it is known that on the weight of 200 gr asphalt produces a mathematical equation y = -3,5773x + 67,421 with the largest R^2 which is 0,99.
4. As the mathematical model obtained on the relationship between the level of viatop[66] with the

value of the asphalt softening point above, R^2 = 0.94 is obtained in the mathematical equation y = 1.4737x + 49.832 when the asphalt weight is 100 gr on the relationship between the viatop[66] level and the asphalt softening value .

Suggestions

Based on the results of the research obtained, the following research suggestions can be given as follows:

1. For research on the mechanical characteristics of asphalt using viatop[66] further research is suggested with other mechanistic properties, ductility.
2. In order for the results of the study to be more accurate without having to do repeated experiments, it is recommended to use a tool with heating temperatures that can be controlled evenly.
3. In the use of added ingredients must use the percentage of asphalt weight.

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