CHARACTERISTICS OF MARSHALL ON AC-BC USE THE ANALOG AND DIGITAL TEST EQUIPMENT

Akhmad Taufik Aditama
Undergraduate in Civil Eng.
Civil Engineering Departement
Faculty of Engineering
University of Jember
Jl. Kalimantan 37 Jember
aditamataufik0@gmail.com

Sonya Sulistyono
Lecturer in the Department of
Civil Engineering
Faculty of Engineering
University of Jember
Jl. Kalimantan 37 Jember
Telp./Fax. (0331) 410241
sonya.sulistyono@yahoo.co.id

Ririn Endah B.
Lecturer in the Department of
Civil Engineering
Faculty of Engineering
University of Jember
Jl. Kalimantan 37 Jember
Telp./Fax. (0331) 410241
ririndidin@gmail.com

Abstract

The strength of the surface pavement can be seen from Marshall Characteristics using Marshall test equipment. Equipment type for Marshall Test can be analog and digital. Digital test equipment using the computer system, and minimize operator/ laboratory intervention for maximum efficiency. The reading of the data was done manually on analog test equipment, so it is very dependent on operator skill. This study examined a mixture of AC-BC using analog and digital Marshall Test equipment, to determine result of Marshall Characteristic. Methods of Marshall Test, material test, mix of bitumen and aggregate follow the guidelines in the Indonesian National Standard (SNI). Results of preliminary test obtained optimum bitumen content of 6,75%, and then the sample is made of 28 pieces (2 x 14). The analysis results of the average difference in the two shows there is no real difference in the Marshall Characteristics of the testing results using analog and digital test equipment. Estimation results of Marshall Characteristics using analog test equipment acquired: stability = $\pm$ 208,26 kg, Flow = $\pm$ 0,29 mm dan MQ = $\pm$ 40,07 kg/mm. Digital test equipment acquired: stability = $\pm$ 175,47 kg, Flow = $\pm$ 0,48 mm dan MQ = $\pm$ 60,93 kg/mm.

Keywords: *Mixture of AC-BC, Marshall Characteristics, analog and digital Marshall Test equipment*

Abstrak

Kekuatan lapis permukaan perkerasan jalan dapat diketahui dari hasil karakteristik Marshall menggunakan alat uji Marshall. Jenis alat uji untuk pengujian Marshall dapat berupa analog dan digital. Alat uji digital menggunakan sistem komputer, dan menghasilkan data yang meminimumkan intervensi operator/laboran untuk efisiensi maksimum. Sedangkan alat uji analog dengan pembacaan data secara manual sangat bergantung pada ketrampilan operator. Penelitian ini melakukan pengujian Marshall pada campuran AC-BC menggunakan alat uji Marshall analog dan digital, untuk mengetahui hasil karakteristik Marshall yang dihasilkan. Metode pengujian material, pencampuran aspal dan agregat serta pengujian Marshall mengikuti pedoman dalam Standar Nasional Indonesia (SNI). Hasil uji pendahuluan diperoleh kadar aspal optimum 6,75%, selanjutnya benda uji dibuat sebanyak 28 buah (2 x 14). Berdasar hasil analisa perbedaan dua rata-rata menunjukkan tidak terdapat perbedaan secara nyata karakteristik Marshall dari hasil pengujian menggunakan alat uji analog dan digital. Pendugaan hasil pengujian Marshall menggunakan alat uji analog diperoleh: stabilitas = $\pm$ 208,26 kg, *Flow* = $\pm$ 0,29 mm dan *MQ* = $\pm$ 40,07 kg/mm. Alat uji digital diperoleh: stabilitas = $\pm$ 175,47 kg, *Flow* = $\pm$ 0,48 mm dan *MQ* = $\pm$ 60,93 kg/mm.

Kata Kunci: *Campuran AC-BC, karakteristik Marshall, alat uji Marshall analog dan digital.*

INTRODUCTION

Marshall testing is performed to determine the characteristics of a pavement layer. One of the Marshall testing tools that are widely used in laboratory is Marshall analog test equipment. The test equipment in the dial readings of stability and flow values, are still using the precision and accuracy of human vision aided by a videotape. The video is used to recorrect, if we are not sure with direct dial readings. Impact that may occur is an error caused by human factors, namely negligence, fatigue and operator psychological conditions. The result can affect speed level and data accuracy generated.

As the advances of technology Marshall test equipment has been developed innovative and commercially. One of them is Marshall digital test equipment. Different from analog test equipment, Marshall digital test equipment is able to control the test system with minimum operator intervention for maximum efficiency. The tool works by directly connected to software on a computer system. Then, the computer is used for inputing, controlling, implementing and processing Marshall Test results data digitally. So, it can reduce errors caused by human factors.

The use of analog and digital test equipment in the Marshall test will provide the speed and accuracy of data with in its capabilities. Therefor the evaluation of the characteristics using a Marshall analog and digital test equipment needs to be done. Evaluation conducted is comparing the result of testing of analog and digital test equipment is there a significant difference or not. Then, analyzing estimation results of the test by using a Marshall test analog and digital equipment.The study was conducted by carrying out Marshall test son the hot mix asphalt Asphalt Concrete-Binder Course (AC-BC).

RESEARCH METHODS

Marshall Test Equipment

Marshal equipment is aprober test specimens to determine the value of stability and flow. Press tool is equipped with aproving ring (ring testers) 22.2 KN capacity equivalents to 5000 lbf to measure the stability and flowmeter to measure the melting plastic or flow. Marshall Specimens are cylindrical with diameter of 4 inches or 10.2 cm and a height 2.5 inch or equal to 6.35 cm. (Sukirman, 2003).

Picture 1. Analog Marshall Test

Picture 2. Digital Marshall Test

Stages of Research Implementation

Implementation research is divided into preliminary testing, manufacture specimen and Marshall test, as well as the analysis of the test results with the following stages:

1. The preliminary test: testing of materials (coarse aggregate, fine aggregat, filler and asphalt pen60/70), planning the composition of the mixture, the specimen manufacture, Marshall Test, determination of OBC.
2. Determining the numberof samples needs to analog and digital test equipment.
3. Making test specimens according OBC and sample requirements.
4. Marshall Testing using analog and digital Marshall Test equipment.
5. Analysis comparation of two means (independent sample test).
6. Estimation results of the test.
7. Conclusions and suggestions.

Hypothesis

There is no significant difference in the test results using analog and digital Marshall test equipment ($\mu 1 = \mu 2$) on Asphalt Concrete – Binder Course(AC-BC).

Description:

$\mu 1$: Average test results using analog test equipment

$\mu 2$: Average test results using digital test equipment

Determination of Sample Size

Based on the statement (Roscoe 1975) for a simple experimental research with tight control of the experiment, a successful research is possible with small sample sizes between 10 to 20. So, defined population of 14 pieces by using an error rate of 5 %. The calculation shown inS lovin formula (in Riduwan, 2005:65) as follows:

$$n = \frac{N}{(1+Ne^2)} \quad (1)$$

$$n = \frac{14}{(1+0{,}05^2)} = 13{,}99 \approx 14 \ \ buah \text{ specimens}$$

Data Analysis

Marshall Characteristic value test results processed and analyzed using the t distribution. T distribution is used to test hypotheses and make predictions on thet test results of two populations maximum. Stages in analyzing the data using the t testis shown as follows:

Comparation of Two Means

Testing was conducted to test the truth or falsity zero hypothesis, whether there is a significant difference or not. To test the hypothesis can be done with the following steps (Supranto, 2009):

1. Calculate the average value of the sample studied

$$X = \frac{1}{n} \sum Xi = \frac{1}{n} (X1 + X2 + \cdots Xn) \quad (2)$$

2. Calculate the standard deviation value

$$s = \sqrt{\frac{1\ (\Sigma(Xi - X)^2)}{n-1}} \quad (3)$$

$$S_x = \sqrt{\frac{S}{\sqrt{n}}} \quad (4)$$

3. Formulating a hypothesis

   H0 : $\mu 1 - \mu 2 = 0$ ($\mu 1 = \mu 2$), the hypothesis H0 is accepted

   H1 : $\mu 1 - \mu 2 \neq 0$ ($\mu 1 \neq \mu 2$), the hypothesis H0 is accepted

4. Testing hypotheses with a compare of two means (n ≤ 30)

$$t_{\alpha/2} = \frac{X-\mu 0}{S/\sqrt{n}} \quad (5)$$

5. If the value of t $_{calculate}$ ≥ t $_{table}$ then H0 is rejected, means there is a significant difference from the results of testing using test analog and digital test equipment. If t $_{calculate}$ ≤ t $_{table}$ then H0 is accepted, meaning that there is no significant difference from the results of testing using analog test equipment with digital test equipment.

Estimation Results of Testing

Testing is done to look for a value prediction in form of interval bounded by two values, those are value of the lower limit and upper limit. To test the prediction results of the test can be done with the following steps (Supranto, 2009):

1. Determinethe average sample

$$\mathrm{X} = \frac{1}{n}\sum Xi = \frac{1}{n}\,(\mathrm{X1} + \mathrm{X2} + \cdots \mathrm{Xn}) \quad (6)$$

2. Determine the error rate of 5% or 95% probability.
3. Determine the deviation standard

$$s = \sqrt{\frac{1\,(\Sigma(Xi-X)^2)}{n-1}} \quad (7)$$

$$s = \sqrt{\frac{S}{\sqrt{n}}} \quad (8)$$

4. Calculate the value estimation test results

$$\mathrm{X} - t_{\alpha/2}\frac{s}{\sqrt{n}} < \mu < X + t_{\alpha/2}\frac{s}{\sqrt{n}} \quad (9)$$

RESULTS AND DISCUSSION

Asphalt concrete-Binder Course (AC-BC)

AC-BC is the layer that lies between the binder layers and foundation layers. AC-BC layer composed of coarse aggregate, fine aggregate and filler. This layer has a thickness of 5 cm and serves to distribute the load of the wear layer to layer foundation deformation due to traffic loads.)

There are seven characteristics that must be possessed by a mixture of asphalt concrete. These characteristics are stability, durability, durability, flexibility, resistance to fatigue, resilience sliding, water-resistant and ease of implementation. (Sukirman, 2003). So to get the seven characteristics Marshall be required mix design. Mix design should be according to the requirements and specifications as shown in Table 1.

Table 1. Requirements of Properties and Gradation AC-BC

Properties Requirements AC-BC *)		
Parameter	Requirements	
The number of compaction per field		75
The voids in the mix (%)	min	3,5
	max	5,5

Gradation Requirements AC-BC **)		
Sieve Size		% Weight Passes
ASTM	mm	
1 1/2"	37,5	100
1"	25	100
3/4"	19	90 – 100

Properties Requirements AC-BC *)		
The voids in the aggregate (VMA) (%)	min	14
Voids filled with asphalt (%)	min	63
Marshall stability (kg)	min	800
	max	-
Flow (mm)	min	3
Marshall Quotient (kg/mm)		250
Residual of Marshall stability (%)after soaking for 24 hour, 60°C	min	80
The voids in the mix (%) on density	min	2,5

Gradation Requirements AC-BC **)		
1/2"	12,5	71 – 90
3/8"	9,5	58 – 80
4	4,75	37 – 56
8	2,36	23 - 34,6
16	1,18	15 - 22,3
30	0,600	10 - 16,7
50	0,300	7 - 13,7
100	0,150	5 – 11
200	0,075	4 – 8
Prohibition Zone		
No. 8	1,36	34,6
No. 16	1,18	22,3 - 28,3
No. 30	0,6	16,7 - 20,7
No. 50	0,3	13,7

*) Source: Departemen Pekerjaan Umum, 2010.

**) Source: Spesifikasi Umum Bina Marga, 2010.

Preliminary Test

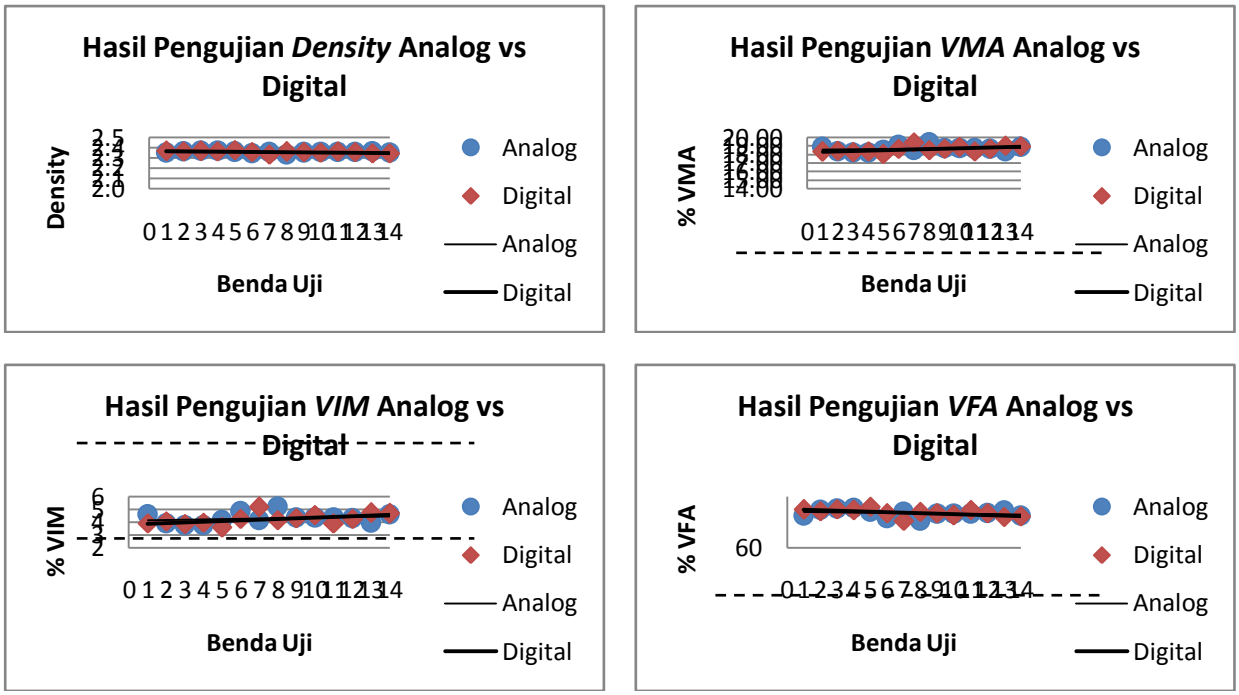
Preliminary test carried out to obtain the value Optimum Bitumen Content (OBC). The first step to getting the OBC is to test the feasibility material of asphalt concrete mixture, which is coarse aggregate, fine aggregate, filler and bitumen pen 60/70. Then planning of the proportion aggregate and ideal asphalt content according AC-BC. Furthermore, make 18 specimens with 6 variations bitumen content, which is 4.5%; 5%; 5.5%; 6%; 6.5%; 7%. After testing the Marshall obtained OBC value of 6.75%.

Marshall Characteristics of Analog and Digital Test Result

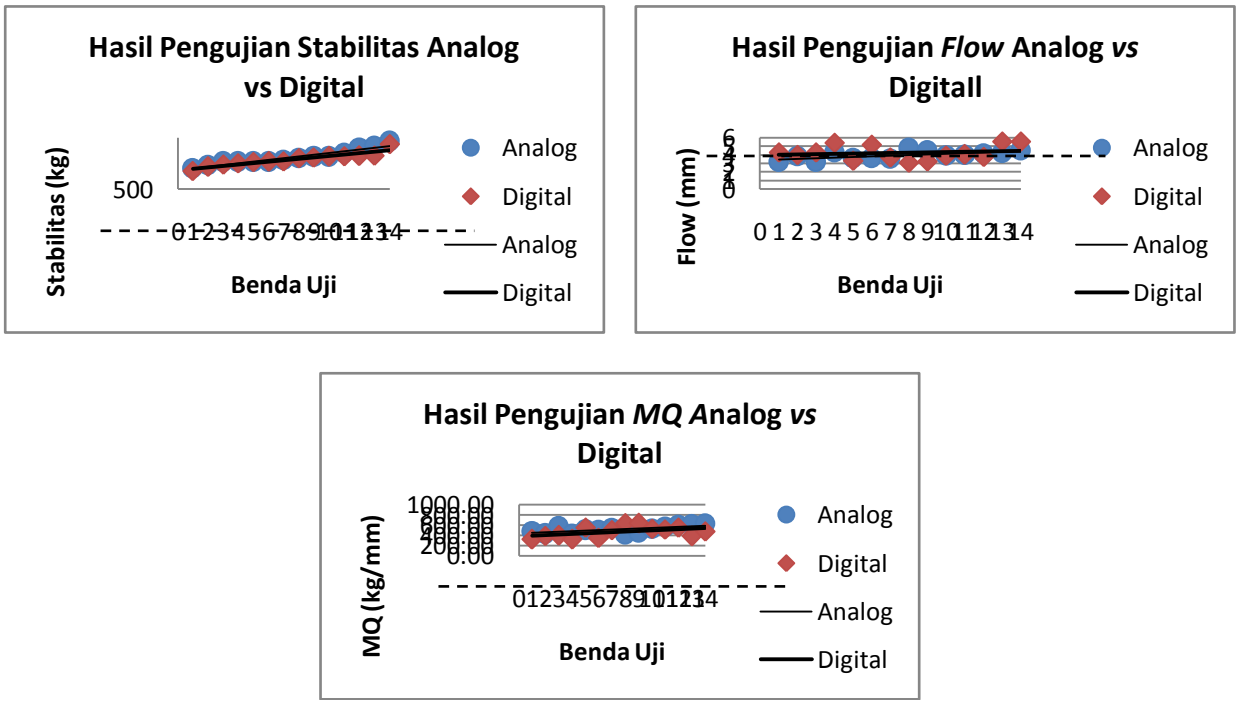
Characteristic Marshall is properties of dense asphalt concrete mixtures. There are seven characteristics in the mixture should have in asphalt concrete, that is stability, flow, MQ, VIM, VMA, VFA and Density. Of the fourteen test results specimen using analog and digital test equipment, then get value comparison Marshall characteristics such as in the Picture 3 and Picture 4.

Base on Picture 3, average value density specimens will be tested using analog and digital instruments 2,36 kg/m3. This shows density the solid asphalt concrete mixtures will be tested use analog test equipment equally with digital test equipment. Average value VMA that will be tested using analog test equipment amount 18,69%. This value is higher than digital test equipment (18,63%). This indicates pore voids between aggregate grains in the dense asphalt concrete will be tested using analog test equipment is greater than the digital test equipment. Average value VIM that will be tested using analog test equipment amount 4,32%. This value is higher than digital test equipment (4,25%). This indicates process oxidation, aging and decrease durability of asphalt concrete will be tested using test equipment faster than analog digital test equipment. Average value VFA that will be tested using analog test equipment amount 76,94%. This value is lower than digital test

equipment (77,22%). This indicates that surrounds asphalt aggregate grains in the dense asphalt concrete that will be tested use analog test equipment is lower than digital test equipment.



Picture 3. Comparison Density, VMA, VIM and VFA



Picture 4. Comparison Stability, Flow, dan MQ Analog and Digital Test Equipment

The average value stability using analog test equipment amount 2060,39 kg. This value is higher than using a digital test equipment amount 1939,86 kg. While the average value flow showed different results. Value flow analog test equipment (3,96 mm) lower than

digital test equipment (4,25 mm). Melting plastic deformation because the dense asphalt concrete and asphalt concrete's ability to receive reps loads without cracking show the results the testing analog test equipment is lower compared to use digital test equipment. The average value MQ results the stability analysis of flow using analog test equipment acquired amount 520,96 kg / mm. This value is higher than average value of MQ that tested using digital test equipment (471,43 kg / mm). Stiffness in the dense asphalt concrete that has been tested use the analog test equipment is higher than using digital test equipment.

Comparation of Two Means Test

Testing was conducted to determine whether there are significant differences in the results Marshall Characteristics using analog and digital test equipment. The results of analysis compare means characteristics of Marshall using SPSS (independent sample test) are shown in Table 2.

Table 2. Compaire of Two Means Test Using Analog and Digital Marshall Equipment

No.	Marshall Characteristis	Number of Test Specimens	Average		Alfa	Sig	$T_{calc.}$	T_{table}	Hypotesa
			Analog Test Equipment	Digital Test Equipment					
1	Stability	14	2060,39	1939,86	0,05	0,364	0,924	2,0555	Accepted
2	*Flow*	14	3,96	4,25	0,05	0,296	1,066	2,0555	Accepted
3	*MQ*	14	496,38	471,43	0,05	0,168	1,418	2,0555	Accepted

Base on Table 2, for the decision rule is $t_{calculate} > t_{table}$ then there is a significant difference, if $t_{calculate} < t_{table}$ then there is no significant difference. From the calculation, the value $t_{calculate} < t_{table}$. From the analysis of 14 tests with a 5% error level indicates $t_{calculate}$ value for each Marshall test results is smaller than t table (2,0555). So there is no significant difference in the test specimen will be tested using a Marshall analog and digital.

Estimation Results of Testing

Estimation results tests conducted to obtain value of the parameter. The resulting value is estimate upper value and lower value or intervals. So that parameter value can be located at intervals estimated from results analysis. Prediction Marshall test results characteristics are shown in Table 3 and Table 4.

Table 3. Estimation Results of Testing Volumetric Specimen

No.	Marshall Characteristis	Number of Test Specimens	Average		Average SD		Estimation Results of Test	
			Analog Test Equipment	Digital Test Equipment	Analog Test Equipment	Digital Test Equipment	Test Specimens Analog Test Equipment	Test Specimens Analog Test Equipment
1	Density	14	2,36	2,36	0,00	0,00	± 0,006	± 0,006
2	VMA	14	18,69	18,63	0,09	0,10	± 0,20	± 0,21
3	VIM	14	4,32	4,25	0,11	0,11	± 0,24	± 0,25
4	VFA	14	76,94	77,22	0,47	0,49	± 1,01	± 1,05

Estimation result volumetric test specimen obtained through data analysis fourteen specimen. Table above shows, in general estimation result value the test specimen will be

tested using analog test equipment is smaller than digital test equipment. But value volumetric concrete pavement to be tested using analog and digital instruments show the same value.

Table 4. Estimation Result of Testing Marshall Using Analog and Digital Test Equipment

No.	Marshall Characteristis	Number of Test Specimens	Average		Average SD		Estimation Results of Test	
			Analog Test Equipment	Digital Test Equipment	Analog Test Equipment	Digital Test Equipment	Test Specimens Analog Test Equipment	Test Specimens Analog Test Equipment
1	Stabilitas	14	2060,39	1939,86	96,40	81,22	± 208,26	± 175,47
2	Flow	14	3,96	4,25	0,13	0,22	± 0,29	± 0,48
3	MQ	14	520,96	471,43	18,55	28,20	± 40,07	± 60,93

Estimation Marshall test results obtained through analysis Data as much as fourteen specimen. Estimation result testing using analog test equipment on the stability value = $\pm$ 208,26 kg, Flow = $\pm$ 0,29 mm and MQ = $\pm$ 40,07 kg / mm. While the estimation result the test using digital test equipment to the value stability = $\pm$ 175,47 kg, Flow = $\pm$ 0,48 mm and MQ = $\pm$ 60,93 kg / mm.

CLOSURE

Based on the Marshall test showed that the analog test equipment generates stability 2060,39 kg, Flow 3,96 mm, and MQ 520,96 kg / mm and the digital test equipment stability 1939,86 kg, Flow 4.25 mm, and MQ 471,43 kg / mm. From the analysis using a statistical test showed no significant differences in the Marshall test results in a test using analog and digital test equipment. Condition that needs attention is the dial reading of Marshall test equipment must use the analog video recording support. It is intended to reduce errors that can arise when direct visual readout directly at the time of testing.

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