Laboratory Study On The Durability Characteristics (Moisture Damage Evaluation) Of Asphalt Concrete Wearing Course (AC-WC) Utilizing Bantak And Clereng As Aggregate (Using Marshall Methods)

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Abstract: The increasing of road material demand particularly on aggregate has been follow-up by finding the new alternative materials. Local materials such as Bantak and Clereng are potentially to substitute current need. Apparently Bantak is having high porosity and abrasion value more than 40%, on other hand Clereng is giving lower abrasion value (± 25%) than Bantak. Therefore, it is essential to study the performance and durability of these materials in AC-WC mixture. To find the durability index, the specimens are immersed around 0 (unconditioned) to 14 days at 60^{o}C and tested by using Marshall and ITS. From the Marshall test, the index values for aggregate variations I, II, and III are 35.01%, 28.11%, and 26.10% respectively, while from ITS test, the indexes are 33.70%, 27.97%, and 25.45% respectively. The best result is variation III as the lowest value because has less of Bantak, which means less porosity and water absorption.

Keywords: Durability, Bantak, Clereng,

1. INTRODUCTION

The most pavement design methods are focusing on the selection of pavement structure that will be resistant to traffic and environmental conditions; where one factor the pavement materials frequently inundated for long time periods are by water. However, this factor of safety in terms of skid resistance and durability in different weather conditions should be concerned, and also pavement durability related with its endurance to restrain deformation within its service time.

This research is to improve durability characteristics and asphalt stability of dense graded mixture Asphalt Concrete-Wearing Course (AC-WC) utilizing Bantak and Clereng aggregate. On the other hand, this research is the continuation of the similar study using dry compaction method which utilizes Bantak and Clereng aggregate to determine aggregate gradation to the pavement material. Where, this research using the data such as optimum asphalt content, aggregate gradation and variation based on previous study. Study on the influence of Bantak and Clereng aggregate products as the pavement material was performed by Eva Nur Rohmah (2008) by using aggregate variation 40% Bantak and 60% Clereng aggregate (a), Dini

Syafiyah (2008) by using aggregate variation 30% Bantak and 70% Clereng aggregate (b), and Prastono Sibuea (2008) by using aggregate variation 10% Bantak and 90% Clereng aggregate (c). This research is using boundary condition as mentioned below:

1. This research used Marshall Test.
2. This research is a study on the durability behavior of AC-WC mixture. Durability behaviors studied are Marshall Properties (Marshall Stability value and Retained Marshall Stability value).
3. This research using optimum asphalt content 6.2% for aggregate variation (a), 6.3% for aggregate variation (b), and 7% for aggregate variation (c).
5. This research using Bantak and Clereng are gravel materials from Merapi.
6. This research outcomes are observation result of pavement characteristic in Transportation Laboratory, Civil Engineering Department of Gadjah Mada University, Yogyakarta. Furthermore, will be studied agreed with the appropriate theory and will be compared with the specification from Ministry of Public Work 2005.

2. LITERATURE REVIEW

2.1 Asphalt Concrete-Wearing Course

Kerbs and Walker (1971) described that the surface course as the top layer is a relatively thin layer and designed to optimize as much as possible the desired properties of stability, durability, flexibility and skid resistance.

The purpose of designing Asphalt Concrete Wearing Course is to provide a stable mixture by means of a well graded aggregate with good mechanical interlock held together with a binder.

2.2 Durability Behavior

Durability of an asphalt mixture is defined as its resistance to weathering and the abrasive action of traffic. In terms of its application to asphalt paving materials, durability can be defined as the ability of the materials in the asphalt pavement structure to withstand the effects of environmental conditions, such as water, ageing and temperature variations without any significant deterioration for an extended period for a given amount of traffic loading (Scholtz and Brown, 1996 in Suparma, 2001).

.In assessing durability, a mixture is subjected to environmental conditioning, and a mixture property associated with load-related or environmental distress is measured before and after the conditioning process. Abrasion characteristics of the aggregate in the mixture must also be considered in the assessment of durability. The greater the protection by asphalt concrete, more durable the mix will be. The fewer air voids in the total mix, the slower will be the deterioration of the asphalt concrete itself.

3. THEORITICAL APPROACH

3.1 Marshall Test

The Marshall Test is applicable to hot mix asphalt paving mixtures using asphalt cement and containing dense or fine graded aggregates with a maximum size of 25 mm (1in), or less. It may be used for both laboratory design and field control of asphalt hot mix paving. The stability and flow of an asphalt concrete mix for optimum asphalt content determination are defined in terms of the empirical Marshall test. Croney and Croney (1998) described briefly that Marshall test is carried out on compacted samples of the mixture prepared in a steel mould 101.6 mm in diameter.

3.2 Marshall Stability

Marshall Stability is calculated from the following equation

$$So = o \times R \times T \quad \text{.....(1)}$$

Where,

o = stability timepiece reading on marshall test (lbs)
So = stability numeral (kg)
R = Proving ring calibration (kg)
T = the matter test correction factor

The primary use of Marshall Stability is in evaluating the change in stability with increasing asphalt content to aid in selection of the optimum asphalt content.

3.3 Retained Marshall Stability (RMS)

The Retained Marshall Stability is expressed as a percentage and is defined in terms of the Marshall Stability of the composition after an immersion process under set conditions (as defined later) as a percentage of the initial (absolute) Marshall Stability of the composition. The RMS values were determined as follows:

$$RMS = \frac{Si}{So} \times 100\% \quad \text{.....(2)}$$

Where:

RMS = *Retained Marshall Stability* (%)
Si = *maximum stability* in *conditioned set* based on times series
So = *maximum stability* in *unconditioned set* (0 days)

3.4 Durability Index (DI)

In this research, the formula in used to calculate durability index is adopted from durability index formula when Marshall Test. Durability index as calculated from the following equation:

$$DI = \left(\frac{1}{2tn}\right)\sum_{t=0}^{n-1}\left(S_i - S_{i+1}\right) \times \left[2tn - \left(t_{i+1} - t\right)\right] \quad \text{.....(3)}$$

Where:

S_{i+1} = percent retained strength at time t_{i+1}
S_i = percent retained strength at time t_i
t_i , t_{i+1} = immersion time (calculate from beginning of test)

Durability Index was defined as the average strength loss area enclosed between the durability curve (see Figure 1)

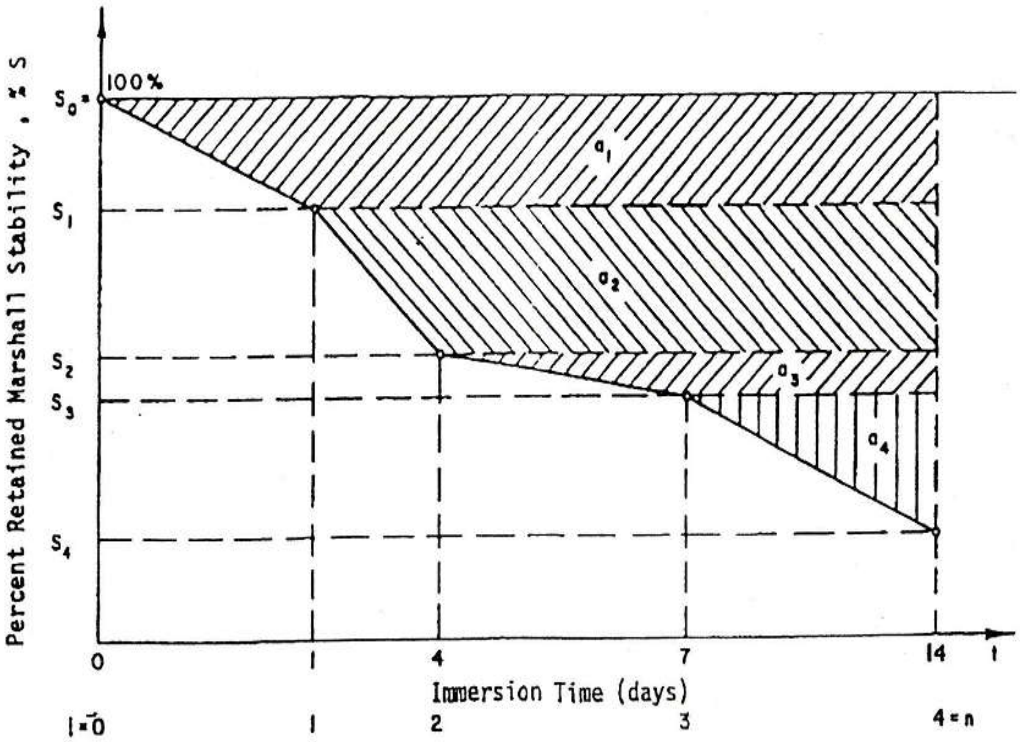


Figure.1. Schematic description of durability curve

3.5 Bantak and Clereng Aggregate

Bantak is gravel materials from Merapi explosion. This resource is potentially to be used based on its natural volume. The characteristic of this material is having high porosity and have value of abrasion more than 40% (± 40%), but the material can not be used directly as coarse aggregate in pavement construction. Bantak Aggregates are shown in Figure 2

Figure.2. Bantak aggregate

Clereng aggregate is one parameter to improve the porosity characteristic of Bantak, because these materials have denser porosity than Bantak. As same as Bantak, Clereng has potentials resources to be used. If these materials will be used in as hot mix asphalt composition, this should be determined each of its composition. Clereng Aggregates are shown in Figure 3

Figure.3. Clereng aggregate

4. RESEARCH METHODOLOGY

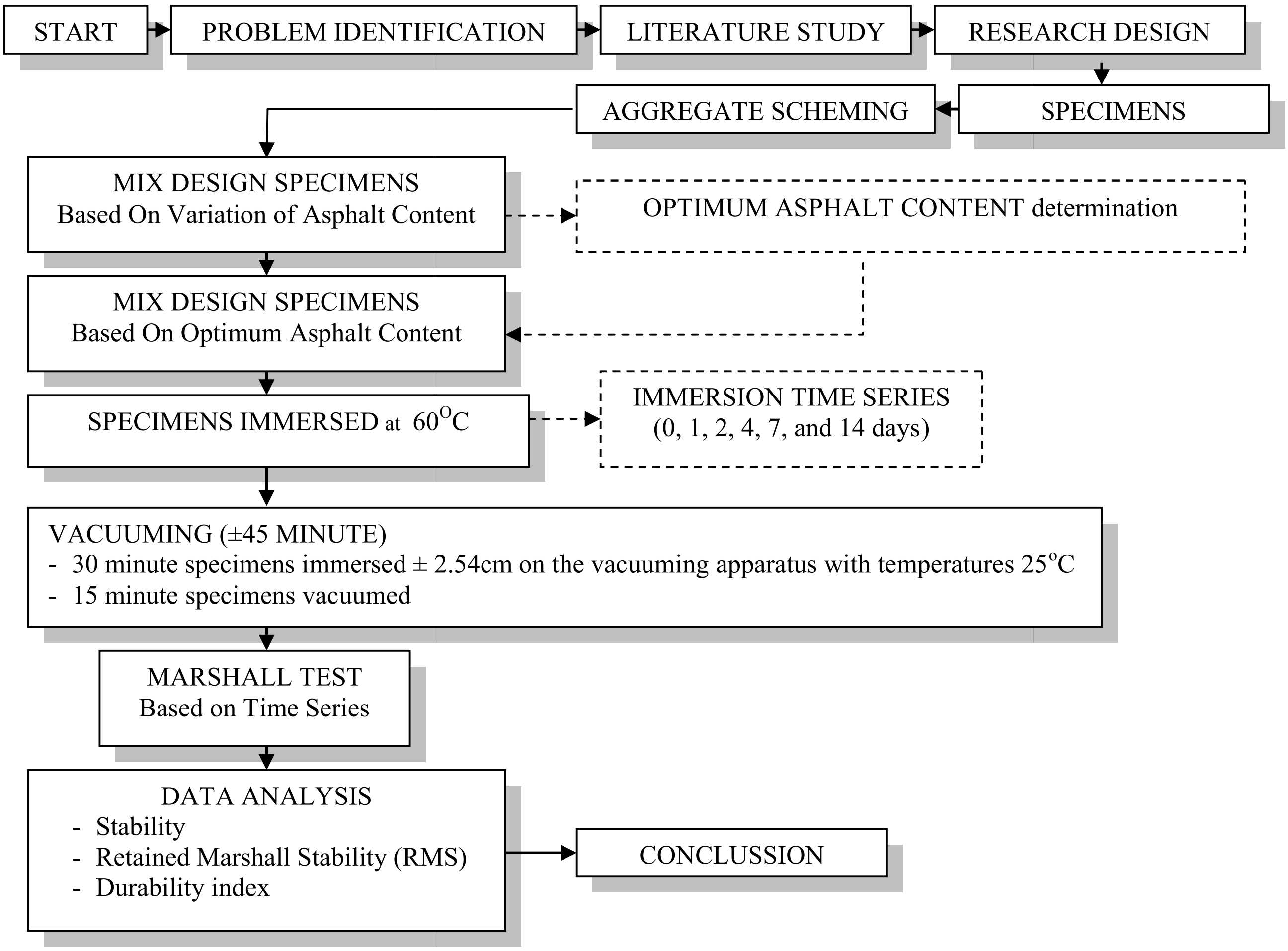


Figure.4. Research procedure flowchart

5. RESULT

5.1 Discussion on Marshall Stability and Retained Marshall Stability (RMS)

The Marshall Stability and Retained Marshall Stability (RMS) calculations for all aggregate variation are shown in Table 1 to 2.

Table.1. Marshall Stability value for all aggregate variations

Immersion Time Series (days)	Aggregate Variations		
	40% Bantak 60% Clereng	30% Bantak 70% Clereng	10% Bantak 90% Clereng
0	1713	1814	1947
1	1588	1699	1855
2	1391	1604	1750
4	1230	1439	1577
7	1041	1280	1390
14	795	961	1085

Table.2. Retained Marshall Stability (RMS) value for all aggregate variations

Immersion Time Series (days)	Aggregate Variations		
	40% Bantak 60% Clereng	30% Bantak 70% Clereng	10% Bantak 90% Clereng
0	100.0	100.0	100.0
1	92.7	93.6	95.3
2	81.2	88.4	89.9
4	71.8	79.3	81.0
7	60.8	70.5	71.4
14	46.4	53.0	55.7

From Table 1 and 2 show that comparison the Marshall Stability value and Retained Marshall Stability value for all aggregate variations show in the Figure 5 to 6.

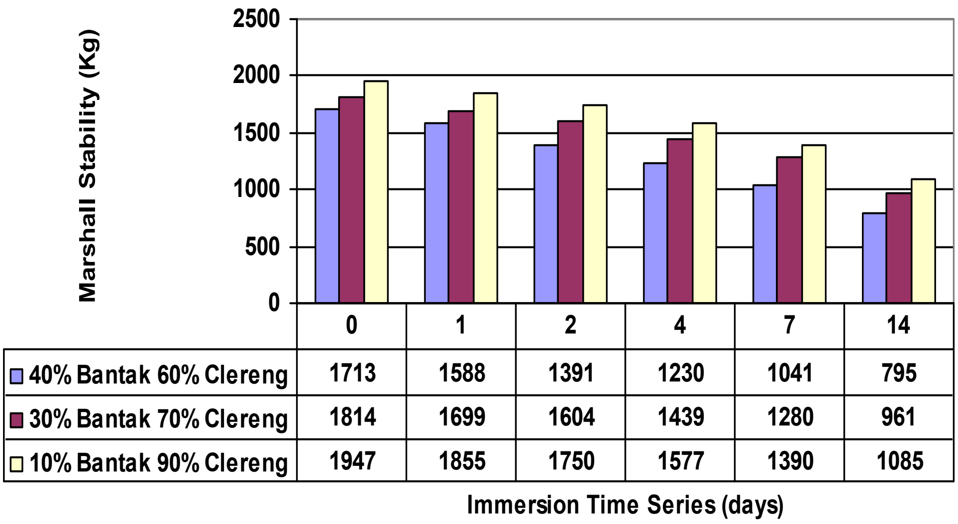
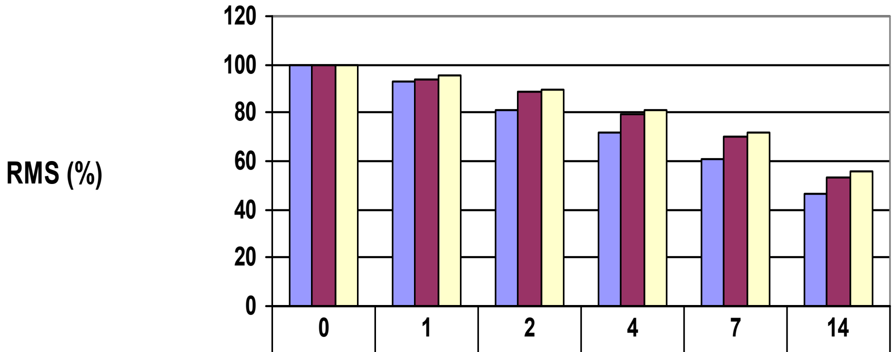


Figure.5. The comparison of the Marshall Stability value for all aggregate variation



	0	1	2	4	7	14
40% Bantak 60% Clereng	100.0	92.7	81.2	71.8	60.8	46.4
30% Bantak 70% Clereng	100.0	93.6	88.4	79.3	70.5	53.0
10% Bantak 90% Clereng	100.0	95.3	89.9	81.0	71.4	55.7

Immersion Time Series (days)

Figure.6. The comparison of the RMS value for all aggregate variation

From Figure 5 show that the value of Marshall Stability decreases during the immersion period of 0, 1, 2, 4, 7 and 14 days. This is due to maximum of 60^{o}C where the water can damage the structural integrity of the asphalt aggregate interface, firstly water can cause loss of cohesion (strength) and stiffness of the asphalt; and secondly, water attacks the adhesive bond between the asphalt and the aggregate in the mixture (stripping). Hence, water is one factor that can make the strength of pavement decrease.

On the other hand, the Figure 5 and 6 also show that after the 14 days immersion; the strength of the 3'rd variation (10% Bantak and 90% Clereng) is higher than other variations on 1'st (40% Bantak and 60% Clereng) and 2'nd (30% Bantak and 70% Clereng). This is caused by the higher composition of Clereng and lower of Bantak in the 3'rd variation, where this means less of porosity and water absorption in the mixture. Hence, the strength of this mixture (3'rd variation) is higher than the other aggregate variation.

5.2 Discussion on Durability Index (DI)

Durability index is the method to predicting and controlling moisture damage in asphalt mixtures, where the evaluation of moisture damage in asphalt mixture were based on the ratio of mechanical properties of wet conditioned to the value of unconditioned specimens. Specifically, the term durability as used in this research is the asphalt mixture ability to resist breaking down on the water immersion.

In this research using the ratio of the values from Marshall Properties (Retained Marshall Stability) as measured were then analyzed to develop a method of predicting and controlling moisture damage in asphalt mixtures.

5.2.1 Durability Index calculation for aggregate variation I based on Marshall properties (Retained Marshall Stability).

The durability values take from the RMS value shows below in the Figure.7. And the durability index value for the Variation I show in the Table 3

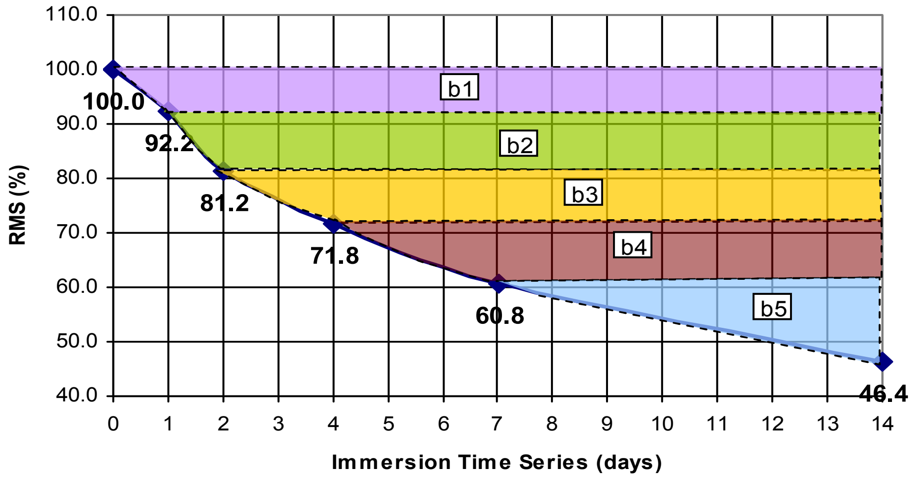


Figure.7. Durability Index curve for aggregate variation I

Table.3. Durability Index calculation

Area Code	Area (cm^2)			Total Immersion days	Durability Index (%)
b1	(14+13)*(0.5*(100-92.2))	=	105.3	14	7.52
b2	(13+12)*(0.5*(92.2-81.2))	=	137.5	14	9.82
b3	(12+10)*(0.5*(81.2-71.8))	=	103.4	14	7.39
b4	(10+7)*(0.5*(71.8-60.8))	=	93.5	14	6.68
b5	(0.5*(60.8-46.4)*7)	=	50.4	14	3.60
				Total Durability Index (%) =	35.01

Hence, the aggregate variation I has the durability index of 35.01%.

5.2.2. Durability Index calculation for aggregate variation II based on Marshall Properties (Retained Marshall Stability)

The durability values take from the RMS value shows below in the Figure.8. And the durability index value for the Variation II show in the Table 4

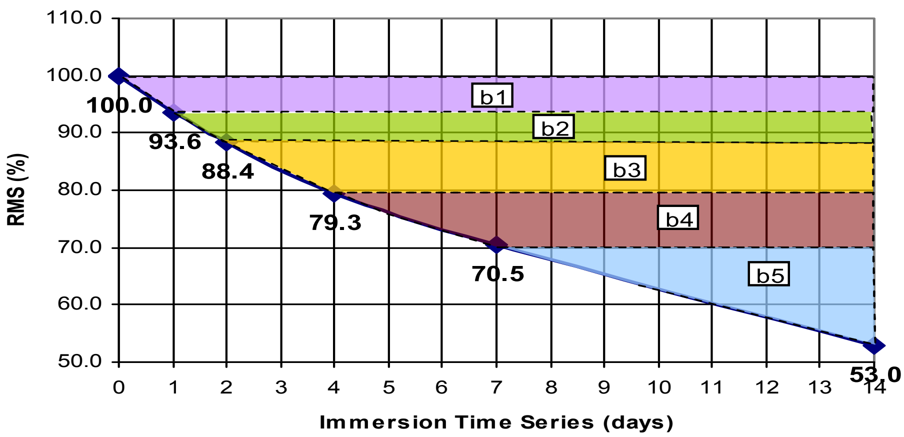


Figure.8. Durability Index curve for aggregate variation II

Table.4. Durability Index calculation

Area Code	Area (cm^2)		Total Immersion days	Durability Index (%)
b1	(14+13)*(0.5*(100-93.6)) =	86.4	14	6.17
b2	(13+12)*(0.5*(93.6-88.4)) =	70	14	5.00
b3	(12+10)*(0.5*(88.4-79.3)) =	100.1	14	7.15
b4	(10+7)*(0.5*(79.3-70.5)) =	74.8	14	5.34
b5	(0.5*(70.5-53.0)*7) =	62.3	14	4.45
			Total Durability Index (%) =	28.11

Hence, the aggregate variation II has the durability index of 28.11%.

5.2.3.Durability Index calculation for aggregate variation III based on Marshall Properties (Retained Marshall Stability)

The durability values take from the RMS value shows below in the Figure.9. And the durability index value for the Variation III show in the Table 5

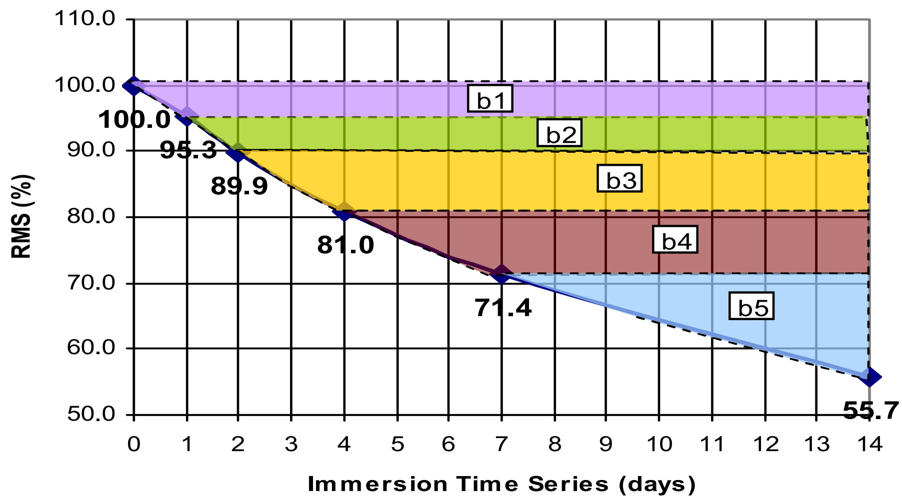


Figure.9. Durability Index curve for aggregate variation III

Table.5. Durability Index calculation

Area Code	Area (cm^2)		Total Immersion days	Durability Index (%)
b1	(14+13)*(0.5*(100-95.3)) =	63.45	14	4.53
b2	(13+12)*(0.5*(95.3-89.9)) =	67.5	14	4.82
b3	(12+10)*(0.5*(89.9-81.0)) =	97.9	14	6.99
b4	(10+7)*(0.5*(81.0-71.4)) =	81.6	14	5.83
b5	(0.5*(71.4-55.7)*7) =	54.95	14	3.93
			Total Durability Index (%) =	26.10

Hence, the aggregate variation III has the durability index of 26.10%.

5.2.4.Comparison of Durability Index based on Marshall Properties for all aggregate variation

Water absorption solely of Bantak as coarse aggregate is 1.640 % and water absorption of Clereng as fine aggregate is 1.635 %. Meanwhile, the water absorption for the variation I, II, and III are 2.991 %, 2.565 %, and 1.981 % respectively. The comparison of durability index values for all aggregate variation based on RMS value is show in Table 6.

Table.6 Durability Index value based on RMS value

Immersion time series	Aggregate Variations , DI based on RMS		
(days)	40% Bantak 60% Clereng	30% Bantak 70% Clereng	10% Bantak 90% Clereng
0 to 1	7.52	6.17	4.53
1 to 2	9.82	5.00	4.82
2 to 4	7.39	7.15	6.99
4 to 7	6.68	5.34	5.83
7 to 14	3.60	4.45	3.93

From Table 6 show that comparison the durability index value based on RMS value for all aggregate variations show in the Figure 10.

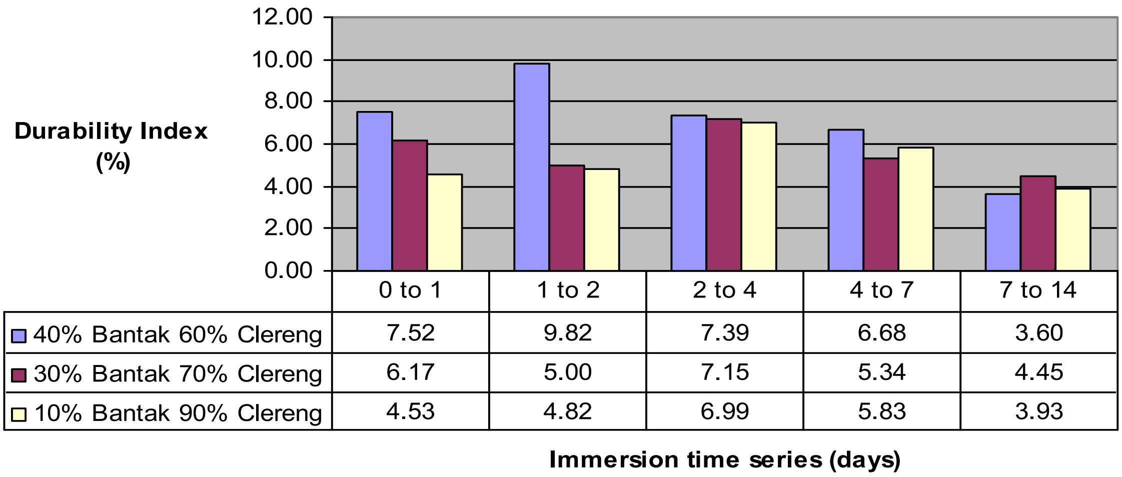


Figure.10. the comparison of durability index based on RMS value for all aggregate variation

From Figure 10 show that aggregate variation III has the total durability index (around 26.10%), hence it's lower than durability index for aggregate variation I (around 35.01%) and aggregate variation II (around 28.11%).
The reason is, for the aggregate variation III the composition of Clereng aggregate as fine aggregate is higher and Bantak as course aggregate is lower, where it means less of porosity and water absorption in the mixture (Clereng characteristics). As a result, the water absorption of this mixture (3'rd variation) is lower than the other aggregate variation.

5.2.5. Mix proportion

There are many factors mix proportion to be considered as the basis of durability index of a pavement such as density, VMA, VFA, density, abrasion, and optimum asphalt content. As the results of the mix proportion, the voids analysis and Marshall Stability at the optimum asphalt content show in Table 7

Table.7 Mix proportion and Marshall Stability for all aggregate variation

Aggregate Variation	I	II	III
VMA (%)	643.1	567.7	561.1
VFA (%)	2421.8	2867.5	3301.7
VIM (%)	211.4	116.4	47.4
density	81.6	83.8	84.6
Abrasion (%)	30.6	29.5	24.7
Optimum Asphalt content (%)	6.2	6.3	7.0
Stability (Kg)	1712.9	1814.2	1946.8
DI RMS (%)	35.01	28.11	26.10
DI TSR (%)	33.70	27.97	25.47

Mix proportion within the aggregate variation I, II, and III shows the increasing of stability as 1712.9 Kg, 1814.2 Kg, and 1946.8 Kg respectively. In contrast, Durability index of aggregate variation I, II, and III as the results RMS (Retained Marshall Stability) and TSR (Tensile Strength Ratio) shows decreasing.
The durability of an asphalt pavement is a function of the air void content. Too high an air void content provides passageways through the pavement for the entrance of damaging air and water. Too low an air void content, on the other hand, may lead to flushing, a condition where excess asphalt squeezes out of the asphalt mixture to the surface. Density and air void content are directly related. The higher the density, the lower the percentage of air voids in the mixture. Specifications require pavement densities that produce the proper amount of air voids in the pavement. Voids in the mineral aggregate (VMA) are the void spaces that exist between the aggregate particles in the compacted paving mixture is available to accommodate the effective volume of asphalt and the volume of air voids necessary in the mixture. Maximum asphalt content increases durability because thick asphalt films do not age and harden as rapidly as thin films. Maximum asphalt content effectively seals off a greater percentage of interconnected air voids in the pavement, making the penetration of water and air difficult. Consequently, the value of void filled with asphalt (VFA) as the characteristic of absorbed asphalts in the mixture is very important for the durability. Abrasion characteristic is important since the quality of the pavement is depends on the materials used. Abrasion shows the ability of aggregate to resist on the compaction.

6. CONCLUSION AND RECCOMMENDATION

6.1 Conclusion

By the discussion on Asphalt Concrete – Wearing Course durability to Bantak aggregate as course aggregate and Clereng aggregate as fine aggregate on the mix which is the theory described in chapter III and discussion on Marshall Calculation results in chapter III. In this research is using immersion time series as 0, 1, 2, 4, 7 and 14 days in water bath at 60^{o}C, and using Marshall test as control or point of reference for the research. The conclusion is based on the fact that:

1. This research using 3 aggregate variations and optimum asphalt content (OAC) where based on previous study and was done by Efa, Dini, and Andar research (2008), whic are: Aggregate variation I (40% Bantak 60% Clereng) has OAC around 6.2%, aggregate variation II (30% Bantak 70% Clereng) has OAC around 6.3%, and aggregate variation III (10% Bantak 90% Clereng) has OAC around 7%.
2. The Marshall Stability value for all aggregate variations based on the 60^{o}C immersion time series in water bath are decreased. This is caused by the water that can damage the structural integrity of the asphalt-aggregate interface. The mechanisms are generally starting with the water can cause the loss of cohesion (strength) and stiffness of the asphalt; and secondly, the water attacks the adhesive bond between the asphalt and the aggregate in the mixture (stripping).
3. For aggregate variation I (40% Bantak 60% Clereng), the Marshall Stability value is descends contrary to the immersion time series. The Marshall Stability value descends became 1713 Kg, 1588 Kg, 1391 Kg, 1230 Kg, 1041 Kg, and 795 Kg for 0 days (unconditioned), 1 day, 2 days, 4 days, 7 days and 14 days, respectively.
4. For aggregate variation II (30% Bantak 70% Clereng), the Marshall Stability value is descends contrary of the immersion time series. The Marshall Stability value descends became 1814 Kg, 1699 Kg, 1604 Kg, 1439 Kg, 1280 Kg, and 961 Kg for 0 days (unconditioned), 1 day, 2 days, 4 days, 7 days and 14 days, respectively.
5. For aggregate variation III (10% Bantak 90% Clereng), the Marshall Stability value is descends contrary of the immersion time series. The Marshall Stability value descends became 1947 Kg, 1855 Kg, 1750 Kg, 1577 Kg, 1390 Kg, and 1085 Kg for 0 days (unconditioned), 1 day, 2 days, 4 days, 7 days and 14 days, respectively.
6. The Retained Marshall Stability (RMS) value for all aggregate variation is descends along immersion time series. This shows specimen strength is becoming lower which contrary to the immersion time series. The RMS value descends became around 28% to 40% after 7 days immersion from unconditioned strength, and the RMS value descends again became around 13 % to 18% for 14 days. Hence, the RMS value is especially beneficial when applied to asphalt whose Marshall Stability (when not containing said surfactant) is reduced by at least 20%, more preferably by at least 30%.
7. The Durability Index value for all aggregate variation is became 35.01% for aggregate variation I, 28.11% for aggregate variation II, and 26.10% for aggregate variation III.
8. Based on the Durability Index, Marshall Stability and RMS results, the aggregate variation III has good quality where the strength of aggregate variation III is higher than aggregate variation I and II. This caused by the higher composition of Clereng and lower of Bantak in the aggregate variation III. This means less of porosity and water absorption in the mixture.

6.2 Recommendations

By reviewing the facts described above, it is suggested that:

1. The resources for highway material is limited, therefore it is suggested to use Bantak and Clereng aggregate as course and fine aggregate on the AC-WC mixture.
2. This research is necessary to arrange a further study using hot mixed asphalt to find the most endure mixture of Bantak and Clereng and also to look the different of the asphalt characteristics which caused by using aggregate variation.
3. Consider to this research methodology, it is necessary to have advance methodology of Bantak and Clereng aggregate application in the road construction.
4. It is needed to arrange further research on Fatigue Resistance to know the durability of the mixture on the fatigue corresponded within the road service life.

5. In order to obtain accurate data, hence it is need to strength the accurate and precise process while the research conducting, whether during the process of design or in the implementation and maintenance during the immersion of specimens.

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