Durability Performance of Asphalt Concrete Wearing Course Using Marble Waste as Filler

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Abstract: Filler is one of pavement mixture component. According to some previous researches, marble waste as filler can increase Marshall characteristic values which represent asphalt concrete mixture performance. Another performance parameter is durability. This study aims to analyze durability of asphalt concrete mixtures using marble waste as filler experimentally in laboratory. Data collection of asphalt mixture characteristic was done with several variations of marble content in the mixture composition. Based on Marshall testing result, 25% marble content by filler weight is the optimum marble content. This composition is then used for durability testing with several variations in immersion time. The results showed that the use of marble waste was not able to increase the mixture durability because it has a greater strength loss than the sample without marble. These results indicate that based on Residual Strength Index and Stability Reduction Index, samples without marble are more durable than samples contain marble.

Keywords: Asphalt Concrete, Filler, Durability, Marble Waste

1. INTRODUCTION

Durability is related to how the pavement mixture reacts to the influence of water and temperature for a long time. Low durability of the pavement surface layer is one of the main causes of damaged and failed road pavement services. The value of the durability potential of asphalt concrete is reviewed based on the residual strength index and stability reduction index. One effort to improve the durability performance is by modifying the asphalt concrete mixture using alternative materials that have indicators to improve pavement characteristics.

The availability of material greatly affects the implementation of road pavement construction. Filler is one of the materials used in hot asphalt mixtures. Filler acts as one of the major constituents in asphalt concrete mixture. Fillers not only fill voids in the coarse and fine aggregates but also affect the aging characteristics of the mix. Filler that commonly used in mixtures is finely divided mineral matter, such as stone ash. Industrial waste products, which are mostly untapped, are an alternative that possible to use in asphalt mixture, especially fillers.

Marble waste is waste from marble mining that usually unused and has undergone a pulverization process so that it becomes fine grains. According to some previous experimental researches, the use of marble waste as filler can increase the value of Marshall's parameters which represent the performance of asphalt concrete mixture. These results indicate that using marble waste as filler in asphalt concrete mixture will provide good asphalt mixture quality and relatively economical. In addition, the selection of marble waste as filler is because this material is only becomes waste disposal and is still not utilized optimally and effectively. So that it is expected that marble waste can be used as an alternative filler material in highway construction.

The use of marble waste as filler substitute material needs to be studied further by conducting laboratory tests to determine the performance of asphalt mixture durability with marble waste as one of its components in order to obtain an overview of the feasibility of marble waste to be considered as an alternative material in highway construction. The type of bitumen used in the mixture is Pertamina's 60/70 asphalt production. The aggregate percentage is based on the Asphalt Concrete Wearing Course mix specification from Bina Marga 2010. Examination of the characteristics of coarse aggregates, fine aggregates and asphalt is carried out at the Highway and Transportation Laboratory, Faculty of Engineering, Moslem University of Indonesia. Testing includes Marshall Test and Durability. The physical properties of marble waste are not included in this research.

2. LITERATURE REVIEW

A review of previous similar studies is a comparison to add insight for this study. Similar researches that have been done are:

a) Effect of Aging and Immersion Duration on Mixed Durability of Asphalt Concrete Wearing Course (Setiawan, 2014).
   This study aims to analyze the durability of the AC-WC mixture due to the effects of aging and Immersion period. The parameters used to see the mix durability level of AC-WC are the Residual Strength Index and Durability Index. Based on the study results, the effect of aging and immersion time had a significant effect on the durability of the mixture of AC-WC. Aged specimens produce residual strength values below the minimum required by Bina Marga (2010), which is 90%, while the Durability Index of specimens undergoing aging show a considerable decrease in strength as immersion time increases compared to normal specimens, so that aged objects is considered not sufficiently resistant to damage caused by the influence of water and temperature.
b) Laboratory Study of Marble Waste as a Filler in AC-BC Layer Concrete Asphalt Mixture (Zulkifli, 2012).
   This study aims to examine Marshall characteristics, refusal desnsity, and the stability value of the remaining Marshall’s stability from a mixture of asphalt concrete Bearing Coarse (AC-BC) which uses marble waste as a filler. The bar-chart method is used to determine the optimum asphalt level, followed by absolute density test (VIM refusal) and immersion for 24 hours as an additional test. The results showed that the more marble waste used to replace stone dust filler, the value of VIM and flow increased. VIM value increases from 4.5% (0% marble waste) to 4.8% (100% marble waste) while flow increases from 3.5 mm to 3.7 mm. For void filled with bitumen (VFB) increased from 70% to 71%, while the stability value decreased from 2040 kg to 1840 kg at the use of 100% marble waste. The Marshall Stability Index left an average of 0.915% in each addition of 50% of marble waste but still within the limits indicated by the specifications. This shows that the asphalt concrete mixture (AC-BC) that uses filler from marble waste can be resistant to plastic deformation due to traffic loads.
c) Utilization of Marble Waste as a Substitute for Coarse Aggregates in Concrete Asphalt Mixtures Against Marshall Characteristics (Amal & Saleh, 2016).
   This study aims to determine the benefits of marble waste as a coarse aggregate substitute for Marshall characteristics in the asphalt concrete mixture. Mixture with marble waste as a coarse aggregate substitute use variations of 5%, 10%, 15%, 20%, 25%, 30%, and 35%.

The results of this study note that the use of marble waste can improve Marshall characteristics. The mixture composisition with marble waste as a substitute for coarse aggregate produced optimum marble content of 17.5%, resulting Marshall stability 1050 kg, Marshall quotient 2.5 KN/mm, and film thickness 8.8 mm.

d) Assessment Of Marble Waste Powder In Asphalt Concrete Mixes As A Filler Particularly In Tigray Region (Maytsebri – Shire Road Upgrading Project) (Kinde, 2017).
This research concluded that using marble waste powder as a filler in hot asphalt concrete mixtures led to produce lighter mixtures almost with higher percentage of air voids as compared with corresponding mixtures containing Portland cement. It is generally concluded that the marble waste powder can effectively be used as a filler in paving mixes in place of most commonly used fillers such as cement and stone dust. Use marble waste in paving mixes may give a solution to the marble waste utilization and disposal problems and also give a means to make the environment safe and clean.

e) The Use of Sulaimania Marble Waste to Improve The Properties of Hot Mix Asphalt Concrete (Abed and Eyada, 2018).
The laboratory tests have been conducted in this research in order to evaluate the properties of each type of filler, which consist of the grain size distribution, the specific gravity (Gs), specific surface area (SA), pore volume (PV), mineral composition, pH and chemical composition.To study the effect of Sulaimania Marble on the performance of HMA mixture, several tests were made consist of Marshall stiffness, Indirect tensile strength, Moisture susceptibility and Creep tests. Many conclusions were achieved referring the importance of using Sulaimania Marble waste (SM) in the enhancing most of the properties of HMA concrete.

f) A Review On Different Types Of Wastes Used As Fillers In Bituminous Mix (Varma and Lakshmayya, 2018)
The research outlines the ongoing research on different mineral fillers used in bituminous mixes. Many studies regarding their effects on bituminous mixes were also analysed in combination with filler mastic. This paper summarizes the interaction of mineral filler with different properties like temperature, strength, and adhesion between aggregates, low-temperature cohesive strength of asphalt and the chemical composition of mineral fillers. The mineral filler will be influenced by the low-temperature cohesive strength of asphalt, the adhesion between aggregates and bitumen. There will be Effect of Some Aggregate and Filler Characteristics on Behavior and Durability of Asphalt Paving Mixtures, Influence of the properties of filler on high and medium temperature performances of asphalt mastic, Effect of the chemical composition of fillers in the filler–bitumen interaction. Ultimately, all the waste materials tested can be reused as either an aggregate or an additive to asphalt concrete. Based on the results, in consequence of increased awareness of environmental issues and natural resources constraints, the studied waste materials can be advantageously utilised in road construction.

3. RESEARCH METHOD

3.1 Research Objectives

In general, this research aims to analyze the durability performance of asphalt concrete mixtures by utilizing marble waste as filler. Specifically, to achieve these general objectives, sub-objectives are made which are the details of the objectives of this study, namely:

a) Determine the effect of increasing content of marble waste as filler on the performance of asphalt concrete mixtures. To achieve this goal, Marshall test was carried out on asphalt mixture samples using a filler combination of stone ash and marble waste in mixture composition. The level of marble waste as filler was varied to determine its effect on the test results for each Marshall parameter such as VIM, VMA, VFA, Density, Stability, Flow, and Marshall Quotient.
b) Analyzing the durability performance of asphalt concrete mixtures by utilizing marble waste as filler. To find out the effect of marble waste as filler on durability performance, a comparison was made between samples using marble ash and samples without marble ash. Durability performance was tested by immersing briquette samples with several variations in immersion time.

3.2 Data Collection Method

In general, this research was carried out using experimental-based research methods in the laboratory. The main testing component emphasized in this study is testing of the durability performance of asphalt mixture by utilizing marble waste as filler which is preceded by examining property of all material to be used and asphalt mixtures characteristic.

Stages begin with literature studies which focused on literature relating to testing durability in concrete asphalt mixtures and previous research which also used marble waste as a paved mixed material. The next step is to prepare equipment and needed for testing. The equipment used is all equipment available in the laboratory relating to the testing of material properties and asphalt mixtures characteristic. The material used is coarse aggregate, fine aggregate, filler combined between stone ash and marble ash, and asphalt pen 60/70. At this stage marble ash which has passed the number 200 of filter will be prepared which will be used as filler combined with stone ash. The location for taking marble waste is in Pangkep district, South Sulawesi Province.

Figure 1. Marble ash and stone ash as filler in mixture

The next stage is the testing phase in the Laboratory. The test begins with the examination of material properties both on coarse, fine, and asphalt aggregates with reference to the specifications of each test. After the test results meet the specifications, the test can be continued, but if the results obtained do not meet the specifications, then a retest is conducted.

The next testing step is determining the mixture composition. This stage aims to determine the optimum asphalt content from several variations in the composition of the asphalt weight followed by adjusting the aggregate weight both coarse and fine aggregates. The optimum asphalt content was obtained from the analysis of asphalt mixture characteristics by reviewing some parameters of the Marshall testing results, namely VIM, VMA, VFB, flow, stability, and Marshall Quotient. For each parameter that fulfills the specifications, it is then plotted into a graph according to the minimum and maximum values in the specifications and then determined the average asphalt content from the upper and lower limits of the asphalt content that meets the requirements as optimum asphalt content. The specifications that apply to each Marshall parameter are as follows:

Table 1. Specifications of Asphalt Concrete Modified

Mixed properties		Asphalt Concrete		
		WC	BC	Base
Asphalt Absorption (%)	Maks		1.7	
Number of impacts		75		112
	Min		3	
Void in Mix (VIM) (%)	Maks		5	
Void in Mineral Aggregate (VMA) (%)	Min	15	14	13
Void Filled with Asphalt (VFA) (%)	Min	65	63	60
	Min	1000		1800
Marshall Stability (kg)	Maks	-		-
	Min	3		5
Flow (mm)	Maks	-		-
Marshall Quotient (kg/mm)	Min	300		350
Residual Stability (%) after being soaked for 24 hours, 60˚C	Min		75	
Density	Min		2.2 kg/mm3	
Dinamic Stability (tracks/mm)	Min		2500	

The optimum asphalt content is then used as asphalt content for all marble ash variations in determining the mixture composition. The variation in the levels of marble waste tested is in interval every 25% combined with stone ash based on material weight. The composition is then mixed in the form of briquettes with a certain mixing and compaction temperature.

Durability testing is carried out on briquettes with certain content of marble ash and have immersed with period variation from 1-5 days of immersion. Each briquette with a certain immersion period is then tested by Marshall testing again to measure the performance of the mixture. At this stage, asphalt mixture characteristics are collected for each variation of immersion time. This data will then be reviewed at a later stage.

3.3 Data Analysis Method

The next stage is data analysis. At this stage graphical and analytical analysis is carried out to determine the relation and influence of each of the following parameters:

a) Analysis of the effect by increasing marble waste content as filler on the performance of asphalt concrete mixture.

Mixture performance for each marble ash's content is analyzed based on the testing results for each Marshall parameter.

b) Analysis of the durability performance of asphalt concrete mixture by using marble waste as filler.
At this stage the durability performance of asphalt concrete mixture is analyzed by the presence of certain contents of marble waste as one of the materials in sample composition and then compared with non-marble samples for several immersion period variations.

The standard of durability testing procedure according to Bina Marga (2010) is carried out by immersion the specimens at a fixed temperature of ± 60°C for 30 minutes and 24 hours. Comparison of the value of stability soaked for 24 hours with a value of stability soaked for 30 minutes, expressed in percent, and called the Residual Strength Index (RSI). RSI value can be calculated by the following equation:

$$RSI= \frac{S2}{S1} X100\% \quad (1)$$

where:
RSI: Residual Strength Index (%)
S1: Standard Marshall Stability by immersion for 30 minutes at ± 60 ° C, (kg)
S2: Standard Marshall Stability by immersion for 24 hours at ± 60 ° C, (kg)

The higher RSI value shows the more durable paved mixture is. The minimum RSI value required by Bina Marga is 90%, so if the RSI value is above 90%, the asphalt mixture is considered sufficiently resistant to damage caused by the influence of water and temperature. Some researchers conducted a research on the durability level by testing a longer immersion period. Craus,J. et al (1981) state that one-day immersion criteria do not always reflect the durability of the mixture after a longer period of immersion. Therefore, in this research, RSI values were calculated not only for one-day immersion criteria but also for longer period of immersion by the following equation:

$$RSI= \frac{Si}{S1} x100\% \quad (2)$$

where:
S_i: Standard Marshall Stability by immersion for t_i, (kg)
S1: Standard Marshall Stability by immersion for 30 minutes at ± 60 ° C, (kg)

In Craus's research, J. et al (1981) introduced two types of durability indices, namely:

a) First Durability Index (FDI)
The First Durability Index is defined as sequential slope of the durability curve. The First Durability Index can also be defined as the sensitivity of stability decreasing of the test object for the duration of immersion. The First Durability Index expressed in (r) is calculated based on the following equation:

$$r = \sum_{i=0}^{n-1} \frac{S_i - S_{i+1}}{t_{i+1} - t_i} \quad (3)$$

where:
r : Index of Decreasing Stability (%)
S_{i+1} : Percentage of residual strength at time t_{i+1} (%)
S_i : Percentage of residual strength at time t_i (%)
t_i, t_{i+1} : immersion period, starting from the beginning of testing (hours)

The more gentle the decline in the value of FDI, the smaller the loss of strength and the steeper the decrease in the value of FDI, the greater the loss of strength or the more sensitive to immersion. A positive r value indicates stability decreasing or loss of strength, while a negative r value indicates stability increasing or acquisition of strength.

b) Second Durability Index (SDI)

The Second Durability Index is defined as average percentage of the strength loss during a day period between the durability curve with the line So = 100 percent. The Second Durability Index stated in (a) is calculated based on the following equation:

$$a = \frac{1}{2tn}\sum_{i=0}^{n-1}(S_{i} - S_{i+1})[2\,t_n - (t_i + t_{i+1})] \quad (4)$$

where:

a : percentage of strength loss for one day (%)

S_{i+1} : Percentage of residual strength at time t_{i+1} (%)

S_i : Percentage of residual strength at time t_i (%)

t_i, t_{i+1} : immersion period, starting from the beginning of testing (hours)

t_n : total immersion time (hours)

The smaller the SDI value, the smaller the strength loss or the more durable the sample is and the greater the SDI value, the greater the strength loss or the less durable the sample is. This durability index describes the strength loss for one day. A positive value describes a loss of strength, while a negative value describes an increase in strength. Based on this definition, then a <100. Therefore, it is possible to declare the remaining strength of one day (Sa) as follows:

$$Sa = (100 - a) \quad (5)$$

The Second Durability Index value can also be expressed in the form of absolute values of equivalent loss of strength as follows:

$$A = \frac{a}{100} X So \quad (6)$$

where:

A: absolute value strength loses for one day (kg)

So: absolute value of initial strength (kg)

Based on that definition, value of A < So. So it is possible to describe that absolute value of residual strength for a day (Sa) is:

$$Sa = (So - A) \quad (7)$$

4. RESEARCH RESULT AND ANALYSIS

4.1 Material Property Testing

The material used in this study consisted of coarse aggregates, fine aggregates, and fillers. In each material, a test is conducted to determine the characteristics and feasibility of using the material as a pavement mixture material. Each material is tested with a different type of test related to the function and role of each material in the pavement mixture. To determine whether a material is suitable to use or not is by comparing the test data with the specifications of each test. In this study marble waste was used as filler. Therefore, filter test was also carried out on marble samples in accordance with testing for filler material in asphalt mixtures.

Based on the test results it can be seen that every material tested has met the required testing specifications. The results of the filter analysis for marble are adjusted to the specifications for the following filler gradations.

Table 2 Comparison of marble waste gradation and filler gradation specification

Sieve Shaker Number	Filler Specification %pass	Marble Ash %pass
No.30 (0,59 mm)	100	100
No.50 (0,279 mm)	95-100	95.65
No.100 (0,149 mm)	90-100	90.40
No.200 (0,074 mm)	70-100	75.35

The results show that using marble ash in this experiment fulfills the requirements to be used as filler in the asphalt mixture. By this fulfillment, then asphalt mixture briquettes are made with designed compositions to determine optimum asphalt content.

4.2 Marshall Test for Determining Optimum Asphalt Content

This test is carried out to obtain the optimum asphalt content value (OAC) and determine th the stability to flow of the asphalt mixture. Analysis of of the asphalt mixture characteristics was obtained by reviewing some parameters of the Marshall test results, namely VIM, VMA, VFB, flow, stability, density, and Marshall Quotient. In the implementation of the Marshall test, five variations of bitumen content were used (4.5%; 5%; 5.5%; 6%; & 6.5%). Based on the test results obtained data as follows:

Table 3. Marshall Test Recapitulation of AC-WC Pen 60/70 Mixture for determination of Optimum Asphalt Content (OAC)

Mixed properties	**Testing Result**					**Specifications**
Asphalt Content; %	**4.5**	**5.0**	**5.5**	**6.0**	**6.5**	
Density	2.419	2.402	2.386	2.369	2.353	≥2.2 kg/mm3
VIM; %	7.453	6.114	4.753	4.170	3.397	3-5%
VMA; %	16.049	15.864	15.675	16.182	16.522	≥ 15%
VFA; %	53.587	61.478	69.791	74.235	79.894	≥ 63%
Stability; kg	865.47	936.45	951.93	985.75	938.38	800-1800 kg
Flow; mm	3.03	2.77	2.43	2.40	2.70	2-4 mm
MQ; kg/mm	285.92	340.03	391.35	411.49	356.98	Min 250 kg/mm

Each parameter result tested is considered in determining the optimum asphalt content. Asphalt content which is considered as the optimum value is what meets each requirement. If seen in table 3, the density, VMA, stability, flow, and Marshall Quotient values for all asphalt contents meet specifications. But for VIM and VFA parameters, some asphalt contents does not meet specifications. The results obtained from testing the characteristics of the mixture are recapitulated in the following graph:

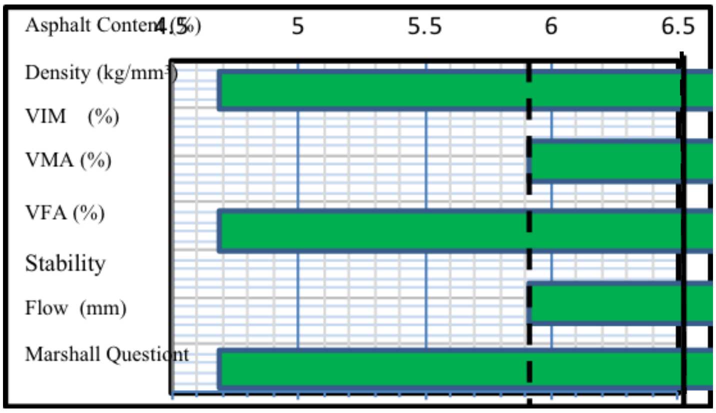

Figure 2. Determination of Optimum Asphalt Contents

The value inputted in the graph above is the bitumen content that meets the specifications for each Marshall testing parameter. To determine the optimum asphalt content, the middle values from the upper and lower limits of the asphalt content are taken from each variation as follows:

$$\text{OAC} = \frac{5.5+6.5}{2} = 6\%$$

From the graph above, the lowest and highest asphalt level values obtained that meet the specifications are 5.5%, and 6.5%. It can be seen that the VIM and VFA parameters that determine the upper and lower limits because all asphalt content meets the specifications for other parameters. Furthermore, from the maximum and minimum limits, a median value of 6% is obtained. It is this middle value that is determined as the optimum asphalt content (OAC) which will then be used in the planning of the AC-WC mixture by involving marble waste as filler fillers combined with stone ash with certain compositions.

4.3 Marshall Testing for Determination of Optimum Marble Waste Content

After obtaining the optimum asphalt content, the concrete asphalt samples were tested using the optimum asphalt content composition combined with several variations of marble waste content as fillers. The filler material that mentioned is fine aggregate which passes number 200 o sieve shaker and held in PAN. Based on the analysis of the aggregate composition for 6% asphalt content which is the optimum asphalt content, the aggregate weight that passes the no. 200 is 62.48 grams. The contents of marble waste used are expressed as a percentage of the total filler weight as follows:

Table 4. Filler Composition on Testing Samples

Marble Waste Ash		Stone ash	
%	Weight (gram)	%	Weight (gram)
0	0	100	62.48
25	15.62	75	46.86
50	31.24	50	31.24
75	46.86	25	15.62
100	62.48	0	0

Determination of marble waste content percentage as shown in table 4 was carried out to analyze the effect of gradual addition of marble waste to Marshall and durability testing at the next stage. Based on the above composition, samples were tested to define the Marshall properties, namely Stability, Flow, VIM, VMA, VFA, Marshall Quotient, and Density for each content of marble waste used. This stage aims to determine the optimum content of marble in mixture composition to further be the marble waste content used in durability testing. The testing results are as follows:

Table 5. Marshall Test Recapitulation of AC-WC 60/70 Mixture with Marble Waste as Filler

Mixed Properties	Testing Result					Specification
Marble Content; %	0	25	50	75	100	
Density	2.369	2.369	2.369	2.369	2.369	≥2.2 kg/mm3
VIM; %	4.235	3.538	3.024	2.451	1.767	3-5%
VMA; %	16.239	15.629	15.180	14.678	14.080	≥ 15%
VFA; %	73.992	77.382	80.078	83.302	87.447	≥ 63%
Stability; kg	989.66	1015.78	979.50	876.71	789.16	800-1800 kg
Flow; mm	2.75	2.50	3.10	3.90	4.70	2-4 mm
MQ; kg/mm	359.82	406.77	316.42	225.14	167.97	Min 250 kg/mm

Based on the results of the test, the optimum contents of marble can be determined. All values of the test results are included in the graph to determine the effect of adding marble content to the mixture performance.

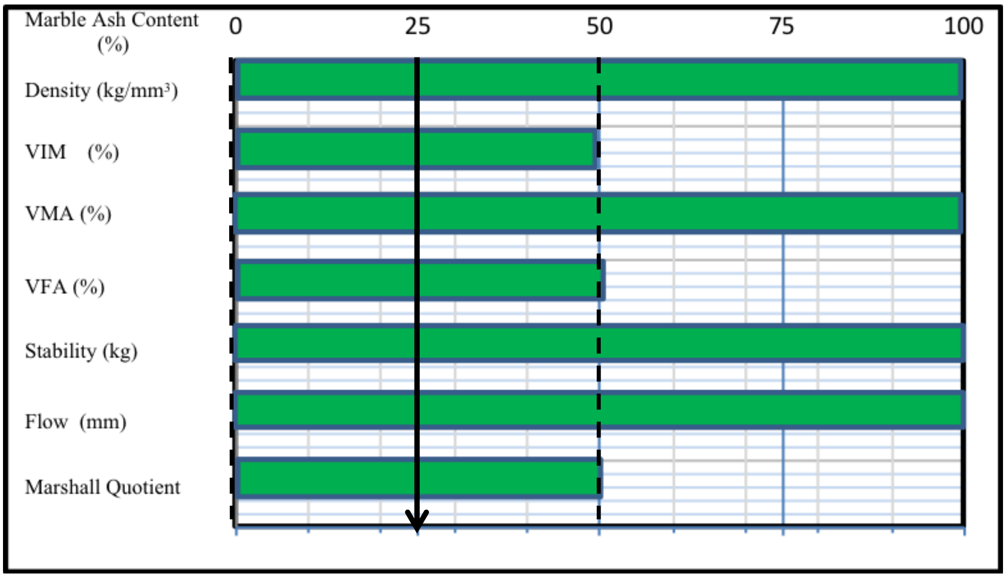

Figure 3. Determination of Optimum Marble Ash Content

Based on graph shown in figure 3, the relation between the marble content and the mixture characteristic is used to determine the optimum marble content. The middle value on the graph that meets all of the Marshall test characteristics is determined as the optimum marble content which is by 25%.

$$OMC = \frac{0\% + 50\%}{2} = 25\%$$

OMC values will be used in planning durability testing mixes with immersion duration of 1, 2, 3, 4, and 5 days for samples with marble and compared with samples without marble.

4.4 Durability Testing

The second stage of Marshall testing using optimum asphalt content by 6% and marble content by 25% with different immersion time duration is done to determine the durability of mixture. Durability is the ability of asphalt concrete to accept traffic loads such as vehicle weight and friction between wheels and road surface, and resist abrasion due to the influence of temperature and climate, such as air and water.

The durability performance of asphalt mixture can be measured by several indicators, namely the Residual Strength Index and Stability Reduction Index includes the First Durability Index (FDI) and the Second Durability Index (SDI). Specimen immersion is carried out for 1, 2, 3, 4 and 5 days at 60 °C. The comparison value describes as the residual stability index or the Residual Strength Index (RSI) in percent (%). Durability testing was carried out on two types of testing samples, namely samples without marble ash and samples using marble ash with a grade of 25% of the total filler weight. The asphalt content used is the same for both types of samples, by 6% of mixture total weight.

Table 6. Comparison of RSI Value and Duration of Immersion Variations for Mixture with and without Marble Ash

Immersion Period	Temperature 60^o	Without Marble Ash			With Marble Ash		
		1	2	Mean	1	2	Mean
0.5 Hour	Initial Stability (kg)	1091.02	936.59	1013.81	1027.87	1003.68	1015.78
24 hours (1 day)	Stability (kg)	980.01	954.81	967.41	1015.78	979.50	997.64
	RSI (%)	89.83	101.95	95.42	98.82	97.59	98.21
48 hours (2 days)	Stability (kg)	906.94	882.76	894.85	892.92	943.22	884.53
	RSI (%)	83.13	94.25	88.27	86.87	93.98	87.08
72 hours (3 days)	Stability (kg)	810.20	905.49	857.85	804.04	922.66	831.28
	RSI (%)	74.26	96.86	84.62	78.22	91.93	81.84
96 hours (4 days)	Stability (kg)	882.76	786.02	834.39	869.94	751.31	770.98
	RSI (%)	80.91	83.92	82.30	84.64	74.86	75.90
120 hours (5 days)	Stability (kg)	830.40	698.59	805.06	659.05	698.59	706.49
	RSI (%)	76.11	74.59	79.41	64.12	69.60	69.55

The following calculation is an example of RSI calculation for sample 1 without marble Ash using equation 2:

$$\mathrm{RSI}_{(2\ \text{days of immersion})} = \frac{Si}{S1} x100\% = \frac{906.94}{1091.02} x100\% = 83.13\%$$

The Residual Strength Index value (RSI) is taken from the comparison of the stability value of immersion 1, 2, 3, 4 and 5 days. RSI value for samples with marble (after immersion for 24 hours at 60ºc) decreased to 98.21% from the initial value, specifically from the stability value of 1015.78 kg decreased to 997.64 Kg and the RSI value decreased to immersion day 5th with RSI value of 69.55%. This value is smaller than 75% so that it does not meet the requirements.

Meanwhile, same trend occur for non-marble specimens after 24-hour immersion, the RSI value decreased to 95.42% from the initial value, specifically from the stability value of 1013.81 Kg it decreased to 967.41 kg and continued to decline until day 5 (120 hour at the temperature 60º C). For non-marble specimens from day 1 to day 5 immersion still meets the specifications, the minimum stability Marshall is 75%. Decreasing of RSI Value of each mixture can be seen in the following figure.

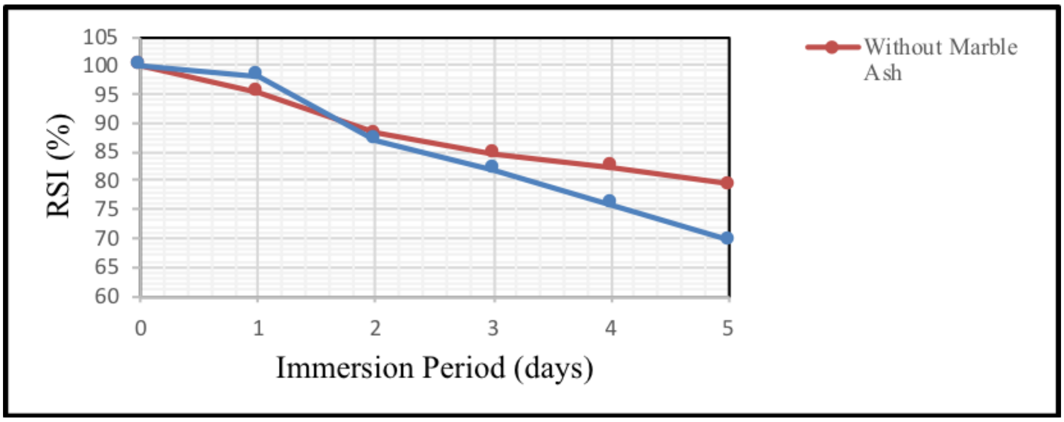

Figure 4. Comparison of RSI Values for Each Time Immersion between Samples With and Without Marble as filler

In the figure above, it can be seen that for the two types of specimens tested in this study there was a decrease in the RSI value along with the immersion time. However, if we look closely, the decline of the graph for samples with marble is sharper compared with the decline of the graph for non-marble samples. In other words the line gradient, which declares the relation of RSI and immersion period, for samples with marble is greater than for sample without marble. This result can be interpreted that the presence of marble ash as filler in the asphalt mixture causes a more significant decrease in stability along with the immersion time compared to material composition which is conventionally used in AC-WC mixtures.

Another thing that can be observed from the graph above is that the remaining percentages of Marshall stability after 1 day of immersion for marble specimens is still greater than the RSI value for non-marble specimens with the same immersion time. These results are interpreted that mixture contained marble ash has greater resistance for short immersion period, but when the optimum period is passed, the mixture stability will decrease significantly.

In addition to the residual strength index, the stability reduction index can also be used to measure the durability performance of pavement mixture. The stability reduction index can be described by the First Durability Index (FDI) and the Second Durability Index (SDI). From the results of this study, the value of the First Durability Index (FDI) can be seen in the following table 7.

Table 7. First Durability Index Value

Immersion Period	Temperature 60º	Without Marble Ash	With Marble Ash
0.5 Hour	Initial Stability(kg)	1013.81	1015.78
24 hours	r (%)	0.191	0.076
(1 day)	R (kg)	1.933	0.756
48 hours	r (%)	0.298	0.464
(2 days)	R (kg)	2.478	2.734
72hours	r (%)	0.152	0.218
(3 days)	R (kg)	2.166	2.562
96 hours	r (%)	0.096	0.247
(4 days)	R (kg)	1.896	2.550
120 hours	r (%)	0.121	0.265
(5 days)	R (kg)	1.740	2.577

The first durability index is stated by the variable r in % and R in kg calculated according to equation (3). From table 7, it can be seen that specimens without marble ash have a smaller average Stability Reduction Index than on specimens with marble ash. This is indicated by the average value of r in samples without marble = 0.17 % and R = 2.04 kg which are smaller than samples with marble with an average value of r = 0.26% and R = 2.24 kg. This result shows that the utilization of marble waste as filler decreases the durability of the asphalt mixture if it is reviewed by the First Durability Index variable.

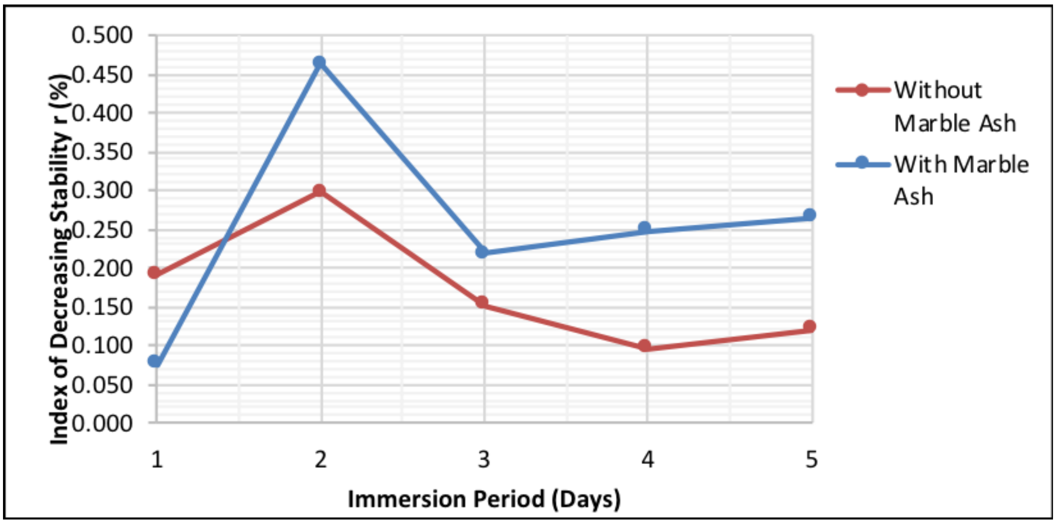

Figure 5. Comparison of r values (%) for Each Time Immersion between Samples With and Without Marble as filler

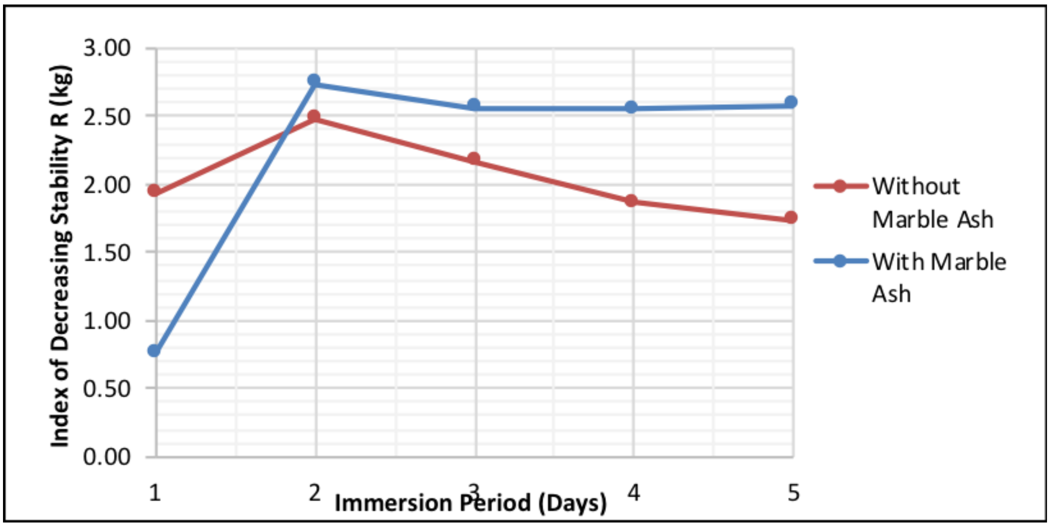

Figure 6. Comparison of R values (kg) for Each Time Immersion between Samples With and Without Marble as filler

Based on figure 5 and 6, if result test is analyzed from the First Durability Index indicator (r dan R), samples without marble ash has an average Stability Decrease Index that is smaller than samples with marble ash. The maximum decline occurs on the second day of immersion with r=0.298% and R= 2.478kg for sample without marble ash. Meanwhile, for sample with marble ash, the maximum decline occurs on the second day of immersion as well, with r=0.464% and R= 2.734 kg. this result illustrates that immersion significantly affects the performance of the durability of the asphalt mixture after the second day of immersion.

Another indicator used to assess the level of asphalt mixture durability is the value of the Second Durability Index (SDI). This durability value describes the strength loss for one day. The Second Durability Index (SDI) is given the symbol 'a'. The positive value means that the specimen has lost strength due to immersion behavior.

Table 8. Second Durability Index Value

Immersion Period	Temperature 60°	Without Marble Ash	With Marble Ash
24 hours (1 day)	A (%)	4.11	1.60
	Sa (%)	95.89	98.40
	A (kg)	41.66	16.29
	Sa (kg)	972.15	999.49
48 hours (2 days)	A (%)	5.01	7.79
	Sa (%)	90.88	90.60
	A (kg)	50.79	79.17
	Sa (kg)	921.35	920.31
72hours (3 days)	A (%)	1.82	2.62
	Sa (%)	89.06	87.98
	A (kg)	18.50	26.62
	Sa (kg)	902.85	893.69
96 hours (4 days)	A (%)	0.69	1.78
	Sa (%)	88.36	86.20
	A (kg)	7.04	18.09
	Sa (kg)	895.82	875.60
120 hours (5 days)	A (%)	0.29	0.64
	Sa (%)	88.07	85.57
	A (kg)	2.93	6.50
	Sa (kg)	892.88	869.15

The second durability index is stated by variable A (absolute value of strength loses for one day (kg)) and Sa (absolute value of one day remaining strength) which can be calculated by equation 4 to 7. Based on the test results shown in table 8, the SDI value stated in variables A and Sa for samples without marble is smaller than the value of SDI for samples with marble. This means that for samples without marble it has a smaller value of losing strength than the sample with marble ash.

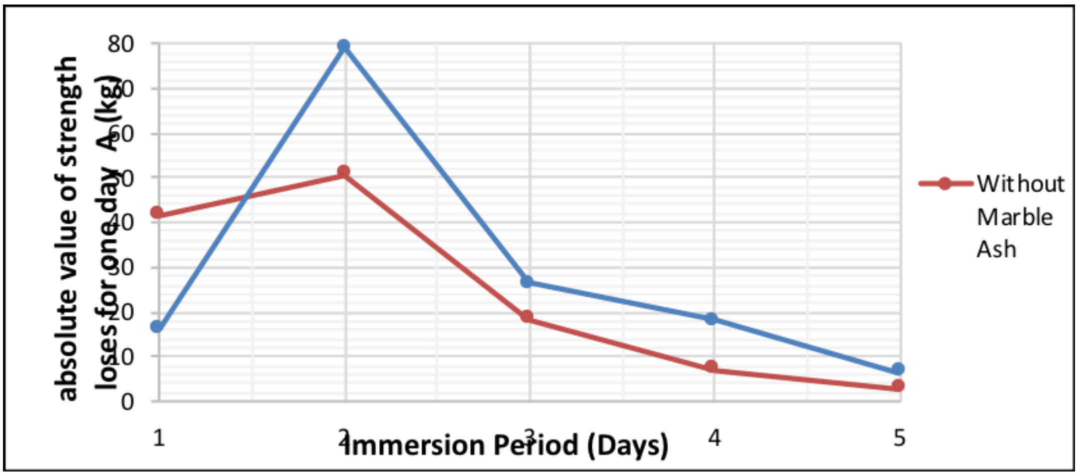

Figure 7. Comparison of A values (kg) for Each Time Immersion between Samples With and Without Marble as filler

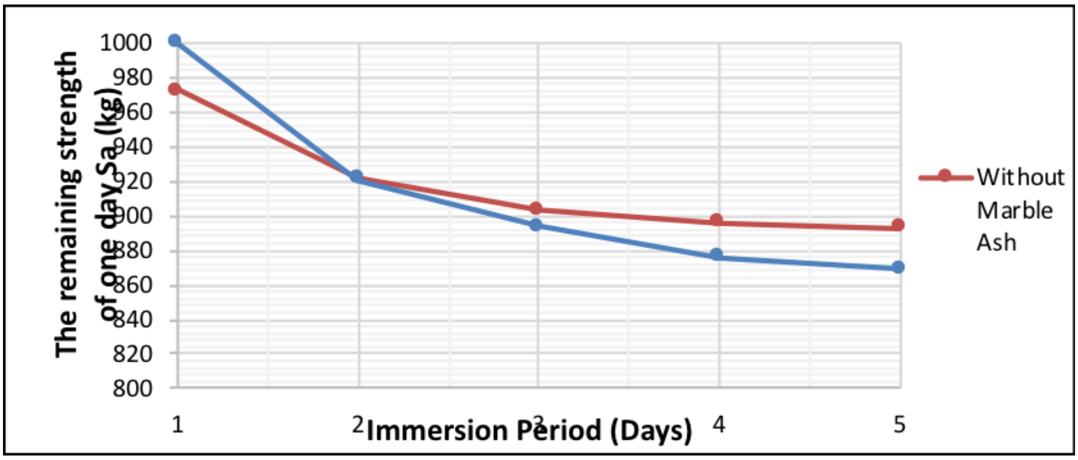

Figure 8. Comparison of Sa values (kg) for Each Time Immersion between Samples With and Without Marble as filler

These results indicate that based on SDI indicators, the test specimen without marble is more durable than the sample with marble. Therefore, it is possible to state that the use of marble ash in asphalt mixtures is not able to increase the durability of the mixture based on RSI, FDI, and SDI indicators.

5. DISCUSSION

Based on research result and analysis, the following paragraph explains the answers to the purposes study:

a) The effect of increasing the marble waste's content as filler on the performance of asphalt concrete mixture by Marshall testing as basic binder compatibility testing.
   Effect on the addition of marble ash content to the the asphalt mixture performance, expressed in several Marshall's parameters as follows:
   1) *Effect of Marble Waste on Density*.
      The use of marble waste as a filler in asphalt mixture produces a constant density value for each level of marble ash. This constant density value is related to the condition of the material where in each variation is used constant asphalt content so that both the weight and volume of each sample are the same. In addition, all the density values obtained for each marble content meet the specifications of at least 2.2 gr / cm.
   2) *Effect of Marble Waste on Void In Mix (VIM)*
      VIM value decreases along with the addition of marble ash content. VIM values obtained from the use of marble waste (100% marble content) are smaller than the use of stone ash (0% marble content). With the lower VIM value, the smaller the void in the mixture, which means the mixture is getting better. However, the addition of marble waste exceeding the level of 50% causes the value of VIM to be too small which can cause the pores in the mixture could not hold enough asphalt due to continued compaction of the traffic load. This happens because the absorption of marble waste is smaller than stone ash.
   3) *Effect of Marble Waste on Void in Mineral Aggregate*
      VMA values decrease along with the addition of marble ash content. This shows that the presence of marble ash as filler in the mixture is able to fill the void between the aggregates in the mixture. The decrease in VMA value due to more

and more granules of marble fill the pores between the aggregates the higher the bulk density of the mixture as a result of the reduced volume of the mixture.. However, when its compared to the requirements, for the level of marble waste that is greater than 50%, the VMA value is too small, where if the VMA value is too small it can affect the durability of the asphalt mixture.

4) *Effect of Marble Waste on Void Filled with Asphalt*
VFA value increases through increasing content of marble waste. The VFA obtained from the addition of marble is higher than the VFA obtained from the use of stone ash, this is due to the absorption of marble waste against asphalt is not good so the effective amount of asphalt that fills the pores between the aggregates on the addition of marble is higher so that the air void of the mixture gets smaller and the air void filled with bitumen gets bigger.

5) *Effect of Marble Waste on Stability*
With the addition of marble waste's content, the value of stability has increased to the optimum limit at the marble content of 25% and then decreased significantly. From the marble content 0-75% the stability of the mixture still meets the minimum specifications of 800 kg but at the marble content of ≥75% the value of stability is 789.16kg and does not meet the specifications. Therefore, excessive amount of marble waste utilization is not good, because the binding capacity of the asphalt layer is ineffective for locking between particles so that friction occurs between the grains.

6) *Effect of Marble Waste on flow*
The flow value has decreased from 0% to 25% of marble content because there is a decrease in the aggregate ability to bind the asphalt in the mixture along with the addition of marble waste to the optimum point. The flow value then increases consistently at the addition of marble waste content up to 100%. Flow value for 0% marble content up to 75% (from total filler weight) meets specifications while for ≥75% marble content does not meet the specifications of maximum 4mm. This is presumably because the mixture still has the ability to withstand the occurrence of deformation due to traffic load if the marble content is still in small quantities but if the marble content in the filler is too much it can cause the mixture to become stiff and easily cracked if it receives a load that exceeds its carrying capacity. It is in line with the characteristic of marble which is more rigid and brittle than the characteristic of stone ash.

7) *Effect of Marble Waste on Marshall Quotient*
The addition of marble contents caused the value of MQ tends to increase for marble content 0-25% and then decreased in the addition of marble waste ≥25%. The MQ value obtained for each of the 0-50% marble levels fulfills the specifications of minimum 250 kg/mm and does not meet specifications at marble content of ≥75%. These results indicate that the strength of the asphalt mixture in accepting load increases with the addition of marble to 25%. If the marble content exceeds this value, then there is an insignificant decrease until the 50% content then decreases more drastically for marble content greater than 50%, meaning that the use of marble as filler with an amount that is too large can reduce the strength of the mixture.

b) Durability performance of asphalt concrete mixture with the utilization of marble waste as filler on asphalt concrete pavement
In this study, the durability performance was measured by three indicators, namely The Residual Strength Index (RSI), the First Durability Index (FDI), and the

Second Durability Index (SDI). Based on the testing result, the three indicators show results that are in line. For RSI values, the two types of specimens in this study experienced a decrease in the value of RSI along with the time of immersion. However, the decline in samples with marble was sharper than in non-marble samples. These results can be interpreted that the presence of marble ash as filler causes a more significant decrease in stability along with the immersion time compared to the material which is usually used in the AC-WC mixture.
If viewed from the First Durability Index (FDI) of samples that do not use marble ash has an average Stability Reduction Index that is smaller than the Stability Reduction Index on marble specimens, which means that the use of marble waste as filler decreases the durability of the asphalt mixture when reviewed with the First Durability Index variable.
If the performance of durability is assessed based on the value of SDI, the decrease in the stability of the sample without marble is smaller than the decrease in the stability of the sample with marble. These results indicate that based on SDI indicators, the test specimen without marble is more durable than the sample with marble. Therefore, based on the assessment of the three durability indicators, the use of marble ash in asphalt mixture was not able to increase the durability of the mixture.

All of the results lead to the evaluation about how feasible marble to be used as pavement material, especially filler. Based on testing result of parameters in this research, marble with sufficient amount can be used as substitution filler material. It cannot fully replaced the conventional material which is stone ash so both materials have to be combined in order to achieve an optimum asphalt concrete performance. The composition recommended in this study is 25% of marble waste and 75% of stone ash. However, based on study result, marble presence in mixture could not improve the durability performance.

Due to resources limitation, this research only examines limited number of samples. Marble content is only varied every 25% addition so the result is not quite accurate. Further research can be conducted to examine the use of marble waste by using content variations that are more accurate and diverse and by using other testing methods to assess the durability performance and Marshall characteristics by using marble as filler material.

6. CONCLUSION

Based on the results and discussion of research data, it can be concluded as follows:

1) The use of marble waste in the AC-WC mixture affects the performance of the mixture. The greater the marble waste content that is used as filler has an effect on the mixture characteristics as follows: decrease in VIM value, decrease in VMA value increase in VFA value, and there is a non-significant effect on the density value, the value of stability, flow, and Marshall Quotient. Marble ash optimum content is reached at 25% of filler total weight.
2) By durability performance, the utilization of marble waste on asphalt mixture is not able to increase the durability of the mixture because the non-marble specimens have a smaller value of strength loss than the test object with 25% marble ash as filler. These results indicate that based on the Residual Strength Index, the First Durability Index, and the Second Durability Index, non-marble specimens are more durable than marble specimens

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