Utilization of Marble Powder Waste as a Filler Substitute in Asphalt Concrete – Wearing Course (AC-WC)

Rindu Twidi Bethary[1], Dwi Esti Intari[2], Muhammad Indra Kurniawan[3]
[1,2,3]Department of Civil Engineering, Sultan Ageng Tirtayasa University, Indonesia

Article Info

Article history:

Received July x, 2023
Accepted July x, 2023
Published August x, 2023

Keywords:

Waste Marble Powder, Asphalt Concrete Wearing Course, Marshall Test

ABSTRACT

This study discusses the effect of the addition of marble powder waste as a filler substitute in asphalt concrete wear layer (AC-WC) which aims to determine the effect of the strength of asphalt concrete with the addition of marble powder waste filler substitution on Marshall characteristics and to determine the effectiveness of the use of marble powder waste filler substitute in asphalt concrete wear layer (AC-WC) compared to asphalt concrete mixture without marble powder waste filler substitute. The asphalt concrete test specimens were made with the planned asphalt content of 4.5%, 5.0%, 5.5%, 6.0% and 6.5% and the variation of marble powder waste filler replacement of 0%, 1%, 2% and 3% with each test specimen variation of 3 pieces. The results showed that the stability value with marble powder waste filler replacement is 1192.44 kg, where the stability value is greater than asphalt concrete without marble powder waste filler replacement which is 988.47 kg.

Available online at http://dx.doi.org/10.36055/fondasi

Corresponding Author:

Rindu Twidi Bethary,
Department of Civil Engineering,
Sultan Ageng Tirtayasa University,
Jl. Jendral Soedirman Km 3, Banten, 42435, Indonesia.
Email: rindubethary@untirta.ac.id

1. INTRODUCTION

Roads play a very important role in supporting smooth transportation for the growth of an area, so good pavement is needed so that traffic becomes safe, comfortable and smooth [1]. One type of asphalt pavement layer that is structural and commonly used in Indonesia is asphalt concrete with wearing course (AC-WC), this wearing course is the most vulnerable to damage caused by repeated vehicle loads and weather [2].

Asphalt concrete pavement is a construction layer consisting of coarse aggregate, fine aggregate, filler and asphalt as a binder [3]. Filler is a constituent material of flexible pavement layers as a cavity filler, filler in the form of fine grains that pass sieve No. 200 which serves to modify the gradation of aggregates in asphalt mixtures [4]. In general, the type of filler that is often used is stone ash, but along with the high construction of highways by utilizing stone ash as filler continuously, the existence of stone ash is decreasing so that other filler alternatives are needed [5].

Tulungagung is known as one of the largest marble-producing cities in Indonesia [6]. Marble is obtained from nature through mining, in the process of cutting and sawing marble stones produces waste in the form of marble powder which is still left alone around the mining area and has not been utilized properly [7]. The most prominent impact is air pollution from marble dust that can interfere with breathing and also pollute the surrounding environment [8].

The use of marble powder as a filler can increase the tensile strength of asphalt concrete so that the mixture is stronger in carrying traffic loads and also becomes more flexible. Marble powder can harden when mixed with water, seen from its potential, marble powder can be used as a filler or filler as well as a binder [9].

Marble powder contains Calcium Oxide (CaO) at 52.69%, which is almost the same as cement. The composition of marble powder filler content must be optimum or right, if the marble powder filler content is excessive, the asphalt concrete mixture will become stiff so that the mixture will be more easily cracked or destroyed [10].

Based on the background that has been described, the authors want to conduct research that aims to determine the effect of using marble powder waste as a substitute for filler on Marshall characteristics in wear layers with the use of marble powder variations of 0%, 1%, 2% and 3%.

2. METHODS

This research was conducted at the Civil Engineering Laboratory of the Faculty of Engineering, Sultan Ageng Tirtayasa University with standards in the General Specifications of Bina Marga 2018 Revision 2. The method used in this research is the Marshall method, where in this test the results will be obtained in the form of Marshall characteristics, namely VIM, VMA, VFA, Stability, Flow and Marshall Quotient. The variation of marble powder content used is 0%, 1%, 2% and 3%, then varied with asphalt content of 4.5%, 5.0%, 5.5%, 6.0% and 6.5%. After that, the optimum asphalt content value for each variation of marble powder will be used to determine the ideal proportion of asphalt concrete mixture.

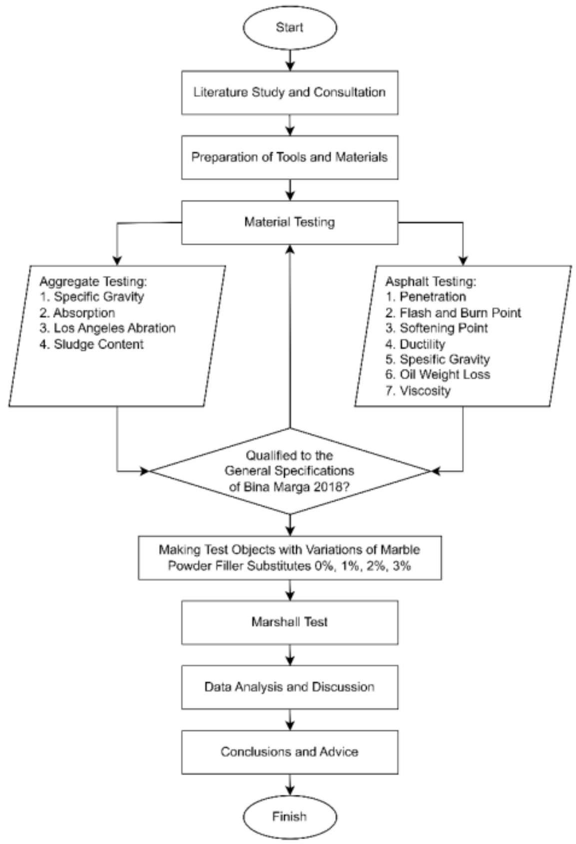

Figure 1 Research Flow Chart

In this study, the middle gradation value was used, this is so that the aggregates are evenly distributed in one grain size range, mixtures with this gradation tend to have few pores, are easy to compact and have high stability values.

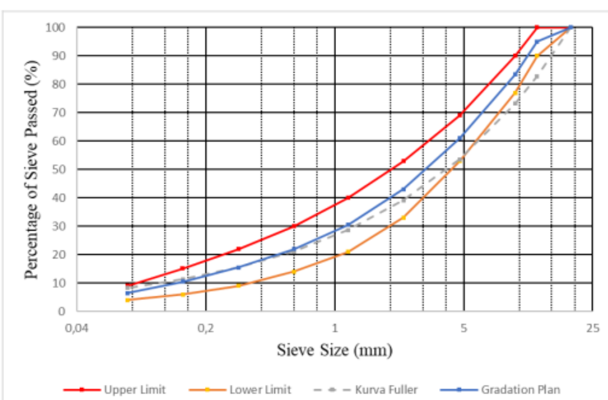

Figure 2. Graph of Gradation Plan

3. RESULTS AND DISCUSSION

Tests carried out before Marshall testing are testing the characteristics of coarse aggregate, fine aggregate, filler and asphalt. After the material has met the requirements, then proceed to the stage of making test objects which will later be tested by the Marshall method.

3.1 Characteristic Testing of Coarse Aggregate, Fine Aggregate, Filler and Asphalt

This test aims to check the feasibility of the material to be used before it is used as a test piece to be tested for Marshall. This test uses SNI testing standards and 2018 Bina Marga Specifications Revision 2. The following results are obtained from testing the characteristics of the material.

a. Testing Coarse Aggregates and Fine Aggregates

Table 1. Testing Results of Coarse Aggregate Characteristics

Type of Testing	Results	Specification Min	Specification Max	Testing Method
Coarse Aggregate				
Bulk Specific Gravity	2,622	2,5	-	SNI 1969-2016
Apparent Specific Gravity	2,637	2,5	-	SNI 1969-2016
Saturated Surface Dry	2,661	2,5	-	SNI 1969-2016
Absorption	0,558	-	3	SNI 1969-2016
Sludge Content	0,438	-	1	SNI ASTM C117-2012
Los Angeles Abration	19,240	-	40	SNI 2417-2008
Fine Aggregate				
Bulk Specific Gravity	2,590	2,5	-	SNI 1970-2016
Apparent Specific Gravity	2,639	2,5	-	SNI 1970-2016
Saturated Surface Dry	2,723	2,5	-	SNI 1970-2016
Absorption	1,885	-	3	SNI 1970-2016
Sludge Content	2,400	-	5	SNI ASTM C117-2012

The specific gravity of coarse and fine aggregates was found to be 2.622 gr/cm^3 and 2.590 gr/cm3, which indicates that the aggregates are good for use in asphalt concrete mixtures. If the specific gravity of the aggregate is too small, it will have a large volume, which will affect the use of more asphalt and will also affect the VIM value because it will make the mixture cavity larger. The absorption test of coarse and fine aggregates was found to be 0.558% and 1.885%, which indicates that the aggregates are good for use in asphalt concrete mixtures, if the absorption value is too large, the aggregates will absorb a lot of asphalt so that the asphalt layer is thinner and can reduce the bond between aggregates [11].The mud content of coarse and fine aggregates was found to be 0.438% and 2.400%, which indicates that the aggregates used are of good quality because if the mud content in the aggregates is too much, it can reduce the binding force of the asphalt mixture, which can affect the strength of the asphalt mixture [12]. The coarse aggregate wear test gave a result of 19.240%, which indicates that the aggregate has good resistance to crushing due to mechanical loads during the road construction process [13].

b. Testing Filler

Table 2. Testing Results of Filler Characteristics

Type of Testing	Results	Testing Method
Specific Gravity of Stone Ash	2,537	SNI 1970-2016
Specific Gravity of Marble Powder	2,578	SNI 1970-2016

Based on the specific gravity test of the filler, it is known that the specific gravity of stone ash is smaller than the specific gravity of marble powder, where a smaller specific gravity will cause the mixture to be less asphaltic which is characterized by the value of voids in the mixture will be greater and the value of voids filled with asphalt (VFA) will be smaller [14].

c. Testing Asphalt

Table 3. Testing Results of Filler Characteristics

Type of Testing	Results	Specification		Testing Method
		Min	Max	
Penetration	65,2	60	70	SNI 2456-2011
Flash and Burn Point	326	232	-	SNI 2433-2011
Softening Point	52,5	48	-	SNI 2434-2011
Ductility	111	100	-	SNI 2432-2011
Spesific Gravity	1,034	1	-	SNI 2441-2011
Oil Weight Loss	0,296	-	0,8	SNI 2440-1991
Viscosity	144-155	-	-	SNI 7729-2011

In the penetration test, the results obtained were 65.2, which indicates that the asphalt is good for use in asphalt concrete mixtures because it meets the requirements of 60-70. In the flash point and burn point tests, the results obtained were 326 ^{o}C, which indicates that the asphalt has good safety against the risk of fire because the higher the temperature of the burn point on the asphalt, the better because the asphalt is not flammable during its implementation [15]. In the mushy point test, the result is 52.5 ^{o}C, which shows that the asphalt has good quality because the higher the temperature of the mushy point, the better the asphalt will be because the asphalt is not easily deformed [16]. In the ductility test, the result is 111 cm, which shows that the asphalt used has good flexibility so that the asphalt can bind the aggregates in the asphalt concrete mixture even better. In the asphalt specific gravity test, the result is 1.034 which indicates that the content of mineral oil and other particles in the asphalt is getting less so that the quality of the asphalt is getting better [17]. In the asphalt weight loss test, the result is 0.295% which indicates that the asphalt used is still in good condition because the asphalt is able to withstand weather and temperature. Based on viscosity testing, it is known that the temperature at the time of mixing is 155 ^{o}C and the temperature at the time of compaction is 144 ^{o}C, if the viscosity is too high it will make it difficult during the mixing process, if the viscosity is too low then the asphalt becomes less as a binder so that it can reduce the stability of the mixture [18].

3.2 Marshall Testing Results with Plan Asphalt Content

This test was carried out with a Marshall tool in accordance with SNI 06-2489-1991 procedures, the time required from the time of removal from the waterbath should not exceed 30 seconds. Then the test specimen was loaded at a speed of about 50 mm per minute until the maximum loading was reached and then recorded the stability and load flow. The following are the results obtained from the Marshall test.

a. VIM

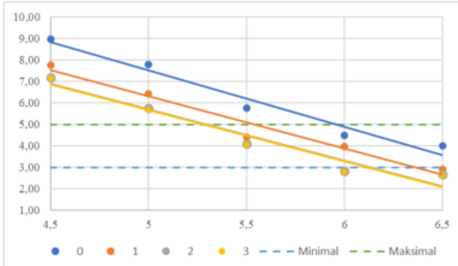

Figure 3 Graph of VIM Value

The VIM value decreases with the addition of asphalt content, this is because the volume of voids contained in the mixture decreases due to the addition of asphalt which fills the voids in the mixture. In mixtures with more marble powder fillers tend to have smaller voids in the mixture (VIM) than mixtures with stone ash fillers, this is because the specific gravity of marble powder is greater than stone ash which causes the value of voids in the mixture (VIM) to be smaller.

b. VMA

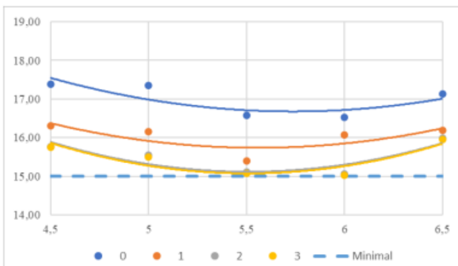

Figure 4 Graph of VMA Value

The VMA value decreases with the addition of asphalt content, this is because the voids between aggregate grains in the mixture decrease due to the addition of asphalt content that fills the voids between aggregate grains. In mixtures that use marble powder filler tend to have a smaller VMA than mixtures without marble powder filler replacement, this is because marble powder has a finer texture than stone ash which makes marble powder better at filling the voids between aggregate grains so that the VMA value in the mixture becomes smaller.

c. VFA

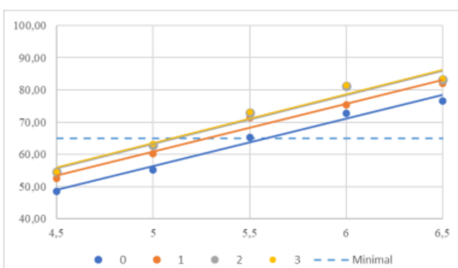

Figure 5 Graph of VFA Value

The VFA value increases with the addition of asphalt content, this is because the amount of asphalt used can fill the voids in the mixture. From the results of the filler specific gravity test, it is known that the specific gravity of marble powder is greater than the specific gravity of stone ash, so the amount of marble powder used causes the voids in the mixture to become smaller which makes the voids filled with asphalt (VFA) will be greater.

d. Stability

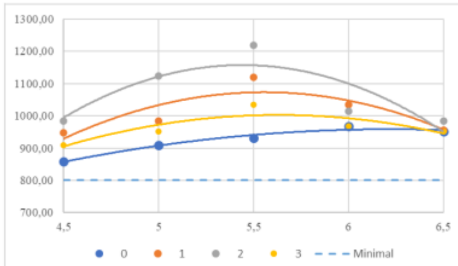

Figure 6 Graph of Stability Value

The stability value increases with the addition of asphalt content up to its maximum limit after which the stability value of the mixture will decrease, this is due to the mixture experiencing fatness where the thickness of the asphalt blanket becomes excessive which can reduce the interlocking properties between aggregates. At each addition of marble powder, the stability value increases, this is because the calcium oxide content contained in marble powder can increase the interlocking properties between aggregates for the better so as to increase the stability value of the mixture.

e. Flow

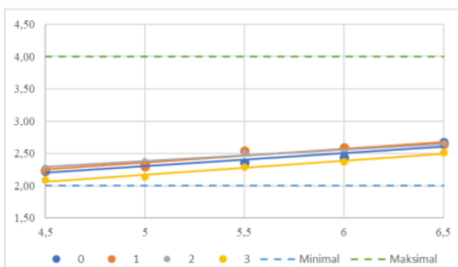

Figure 7 Graph of Flow Value

The flow value in each variation of marble powder content increases along with the addition of asphalt content, this indicates that the mixture becomes more resistant to changes in shape due to receiving traffic loads.

f. Marshall Quotient

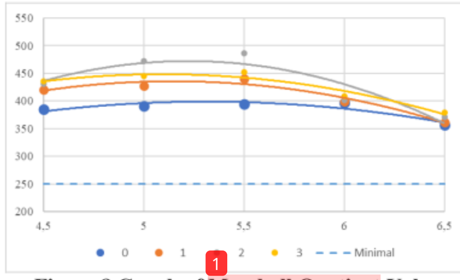

Figure 8 Graph of Marshall Quotient Value

The Marshall Quotient value increases along with the addition of asphalt content to its maximum limit after which the Marshall Quotient value will decrease. The mixture without marble powder has a smaller MQ value than the mixture using marble powder, this is because the calcium oxide content contained in marble powder can increase the hardening process which makes the mixture stiffer than the mixture without marble powder.

3.3 Marshall Testing Result with Optimum Asphalt Content

The next test is Marshall testing using the optimum asphalt content of each marble powder content. The optimum asphalt content at 0% marble powder content is 6.25%, at 1% marble powder content is 5.75%, at 2% and 3% marble powder content is 5.50%. The optimum asphalt content value is obtained from the results of the previous Marshall characteristics test, the following are the results of the Marshall test using the optimum asphalt content.

Table 4. Recapitulation of Marshall Test Results with Optimum Asphalt Content

Marshall Characteristics	Marble Powder Content	Asphalt Content	Results	Specifications
VIM	0	6,25	4,22	3% - 5%
	1	5,75	4,15	
	2	5,50	4,08	
	3	5,50	4,03	
VMA	0	6,25	16,80	Min 15%
	1	5,75	15,70	
	2	5,50	15,11	
	3	5,50	15,06	
VFA	0	6,25	74,90	Min 65%
	1	5,75	73,64	
	2	5,50	72,99	
	3	5,50	73,26	
Stability	0	6,25	988,47	Min 800 kg
	1	5,75	1098,30	
	2	5,50	1192,44	
	3	5,50	1072,15	
Flow	0	6,25	2,48	2 mm - 4 mm
	1	5,75	2,55	
	2	5,50	2,52	
	3	5,50	2,46	

Marshall Characteristics	Marble Powder Content	Asphalt Content	Results	Specifications
MQ	0	6,25	398,45	Min 250 kg/mm
	1	5,75	430,66	
	2	5,50	473,18	
	3	5,50	435,80	

The highest VIM and VMA values are found at 0% marble powder content with an optimum asphalt content of 6.25%, which is 4.22%, this is because the amount of asphalt used will fill the air voids between aggregates in the asphalt mixture. The highest VFA value is found at 0% marble powder content with an optimum asphalt content of 6.25%, which is 74.90%, this is due to the increasing number of voids in the mixture so that the asphalt will fill the air voids. The highest stability value is found at 2% marble powder content with an optimum asphalt content of 5.50%, which is 1192.44 kg, this is because the marble powder content is almost the same as cement so that marble powder can help bond between aggregates so as to increase stability in asphalt mixtures. The flow value of asphalt mixtures that use marble powder fillers tends to be smaller than asphalt mixtures without marble powder fillers, this is because the use of too much marble powder can make the asphalt mixture more rigid. The Marshall Quotient value increases to its optimum value, after which it decreases this is because marble powder can increase flexibility in asphalt mixtures but must be at the right level, if too much marble powder is used it can make the asphalt mixture stiffer so that the mixture is prone to cracking.

It can be seen that the optimum asphalt concrete mixture is found at 2% marble powder content with an optimum asphalt content of 5.50%, where a stability value of 1192.44 kg is obtained. The optimum asphalt concrete mixture is seen from all Marshall characteristics that have met the requirements and also the stability value, the stability value is needed for the strength and durability of the asphalt mixture in withstanding traffic loads. However, overall all variations of marble powder content have met the requirements of the Marshall characteristics.

3.6 Residual Marshall Stability Testing Results

The residual Marshall stability is carried out to see the durability value of the asphalt mixture indicated by the immersion index and the decrease in stability value. The residual Marshall stability test was carried out by immersing the test specimens in a waterbath for ± 24 hours with a temperature of 60 ^{o}C with the aim of obtaining a large mixture air cavity with extreme conditions so as to get a more flexible mixture even under the worst conditions.

Table 5. Residual Marshall Stability Test Results

Marshall Characteristics	Marble Powder Content	Asphalt Content	Results	Min 90% of Marshall Results
Residual Marshall Stability	0	6,25	950,117	889,623
	1	5,75	1044,257	988,47
	2	5,50	1127,937	1073,196
	3	5,50	1023,337	964,935

From the test results it can be seen that the residual Marshall stability value increases with the addition of marble powder content at each optimum asphalt content. This is due to the use of marble powder which can help the interlocking properties of the aggregate to be better so as to increase the residual Marshall stability and also the use of large marble powder can reduce the voids in the mixture which makes the mixture more impermeable so that it is not easily oxidized by water and air.

4. CONCLUSION

4.1 Conclusion

Based on the results of research that has been carried out on asphalt concrete wear layer (AC-WC) mixtures with marble powder filler substitutes, it can be concluded as follows

a. Based on the results of the study, the use of marble powder filler substitutes can increase the stability value of the mixture, the asphalt mixture without marble powder filler substitute is 930.94 kg while the asphalt mixture with marble powder filler substitute is 1192.44 kg, This is because there is a Calcium Oxide (CaO) content which is almost the same as cement in marble powder which can increase the stiffness of the asphalt mixture.

b. Mixtures with marble powder filler substitutes are more effective in using asphalt content, where mixtures with marble powder filler substitutes have an optimum asphalt content of 5.50% while mixtures without marble powder filler substitutes have an optimum asphalt content of 6.25%, where the addition of marble powder filler substitutes can reduce asphalt usage by 0.75%.

4.2 Advice

After conducting research, there are several suggestions that can be given, namely as follows

a. Further research is needed on the effect of the compound content in marble powder on asphalt concrete mixtures.

b. When mixing the test material, it must be slow because the shape of the marble powder is small so it is vulnerable to loss when blown by the wind.

c. At the time of making test objects, more careful supervision is needed, especially at the mixing temperature and compaction temperature because it can affect the test results.

REFERENCES

[1] F. S. Ridwan and Nadia, "ANALISIS PENGARUH PEMANFAATAN ABU SEKAM SEBAGAI FILLER PADA CAMPURAN ASPAL BETON," vol. 8, no. 2, pp. 1–8, 2018.

[2] K. H. Putra and M. Firdausi, "Studi Eksperimental Penambahan Serbuk Arang Kayu Dengan Kadar 10% Terhadap Filler Semen Pada Campuran Perkerasan AC-WC," vol. 4, no. 2, pp. 7–10, 2019, doi: 10.53712/rjrs.v4i2.782.

[3] S. Sukirman, *BETON ASPAL CAMPURAN PANAS*. Bandung: Granit, Yayasan Obor Indonesia, 2003.

[4] Zulkifli, H. Parung, and W. Tjaronge, "KAJIAN LABORATORIUM LIMBAH MARMER SEBAGAI FILLER DALAM CAMPURAN ASPAL BETON LAPIS ANTARA (AC-BC)," pp. 1–20, 2010.

[5] S. J. Akbar and Wesli, "STABILITAS LAPIS ASPAL BETON AC-WC MENGGUNAKAN ABU SEKAM PADI," vol. 2, no. 4, pp. 310–320, 2012.

[6] A. S. Amal and W. Saputra, "Pemanfaatan Limbah Abu Marmer Sebagai Filler Terhadap Karakteristik Marshall Pada Campuran Lapis Tipis Aspal Pasir (Latasir) B," vol. 16, no. 2, pp. 67–79, 2018.

[7] M. T. Syarkawi, A. J. Gusdi, and S. R. Rusman, "ANALISA DEFORMASI PENGGUNAAN LIMBAH MARMER SEBAGAI FILLER PADA CAMPURAN ASPAL BETON," vol. 4, no. 1, pp. 28–40, 2019.

[8] M. R. Razali, "PENGGUNAAN LIMBAH MARMER SEBAGAI FILLER PENGGANTI PADA CAMPURAN LASTON LAPISAAN ANTARA (AC-BC)," vol. 8, no. 2, pp. 77–84, 2016.

[9] W. Kushartomo and D. P. Sari, "SIFAT MEKANIS BETON NORMAL DENGAN CAMPURAN TEPUNG MARMER," vol. 24, no. 1, pp. 71–78, 2018.

[10] S. F. Badaron, A. Gecong, M. K. Anies, W. M. A. Achmad, and E. P. Setiani, “Studi Perbandingan Kuat Tarik Tidak Langsung Terhadap Campuran Aspal Beton Dengan Menggunakan Limbah Marmer dan Abu Sekam Padi Sebagai Filler,” vol. 4, no. 2, pp. 144–154, 2019.

[11] F. Rondonuwu, O. H. Kaseke, A. L. . Rumayar, and M. R. . Manoppo, “PENGARUH SIFAT FISIK AGREGAT TERHADAP RONGGA DALAM CAMPURAN BERASPAL PANAS,” vol. 1, no. 3, pp. 184–189, 2013.

[12] Sumiati and A. Hasan, “KERUSAKAN DINI LAPISAN PERKERASAN ASPAL BETON AC-BC,” vol. 9, no. 2, pp. 111–117, 2013.

[13] S. Arifin, M. Kasan, and N. Pradani, “PENGARUH NILAI ABRASI AGREGAT TERHADAP KARAKTERISTIK BETON ASPAL,” vol. 5, no. 1, pp. 1–11, 2007.

[14] H. Ali, “TINJAUAN PENGGUNAAN ABU BATU DAN ABU VULKANIK SEBAGAI FILLER TERHADAP DURABILITAS ASPHALT CONCRETE-WEARING COURSE (AC-WC),” vol. 17, no. 1, pp. 1–10, 2013.

[15] W. Sulila, “ANALISA MUTU MATERIAL ASPAL RETONA BLEND 55 DAN ASPAL MINYAK,” vol. 3, no. 1, pp. 29–34, 2015.

[16] J. Rangkang, F. Sondakh, and E. Saerang, “PENGARUH PEMANASAN BERULANG TERHADAP SIFAT FISIS ASPAL,” vol. 1, pp. 1–18, 2013.

[17] M. Aminsyah and R. S. Syahid, “PENGARUH PENAMBAHAN LATEKS PADA CAMPURAN ASPHALT CONCRETE-BINDER COURSE (AC-BC),” vol. 6, pp. 464–473, 2019.

[18] N. L. Senduk, O. H. Kaseke, and T. K. Sendow, “PENGARUH VISKOSITAS ASPAL DAN DAMPAKNYA TERHADAP KARAKTERISTIK MARSHALL,” vol. 3, no. 1, pp. 77–84, 2015.

Jurnal_-_Muhammad_Indra_Kurniawan_-_3336180029.pdf

ORIGINALITY REPORT

17%	8%	15%	3%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	"Proceedings of the Second International Conference of Construction, Infrastructure, and Materials", Springer Science and Business Media LLC, 2022 Publication	3%
2	Rani Bastari ALKAM, Lambang Basri SAID, Suriati Abd. MUIN. "Durability Performance of Asphalt Concrete Wearing Course Using Marble Waste as Filler", Journal of the Eastern Asia Society for Transportation Studies, 2019 Publication	2%
3	www.atlantis-press.com Internet Source	1%
4	N Martina, Rinawati, M F R Hasan, Y Setiawan, E Yanuarini. "Analysis of the use of rubber waste to improve the performance of the asphalt concrete mixture against tidal floods", IOP Conference Series: Earth and Environmental Science, 2021 Publication	1%
5	www.researchgate.net	

Internet Source

1%

---

6 link.springer.com
Internet Source

1%

---

7 Elsa Eka Putri, Purnawan, Bayu Martanto Adji, Bobby Herman. "Chapter 97 Literature Study: Alternative Materials for Hot Rolled Sheet-Wearing Course (HRS-WC) Pavement", Springer Science and Business Media LLC, 2023
Publication

1%

---

8 etd.unsyiah.ac.id
Internet Source

1%

---

9 D E Wibowo, N Fariza, Pramudiyanto, P Mahardi, H Prayuda. "The Effect of Pulp Cane Ash Filler and Concrete Waste as Replacement of Coarse Aggregate to The Marshall Characteristic on Asphalt Concrete Mixtures", IOP Conference Series: Earth and Environmental Science, 2021
Publication

1%

---

10 Submitted to Asian Institute of Technology
Student Paper

<1%

---

11 E Mina, R I Kusuma, N Ulfah. "Utilization of steel slag and fly ash in soil stabilization and their effect to california bearing ratio (CBR) value. (Case study: Kp. Kadusentar road

<1%

Medong village Mekarjaya Subdistrict Pandeglang District)", IOP Conference Series: Materials Science and Engineering, 2019
Publication

12	Submitted to Politeknik Negeri Bandung Student Paper	<1 %
13	jes.ejournal.unri.ac.id Internet Source	<1 %
14	K H Putra, M Firdausi, M Rubbyanto. "The Effect of Coal Powder Addition to Asphalt Concrete - Wearing Course (AC-WC) Mixture to Increase Road Surface Hardness Quality", IOP Conference Series: Materials Science and Engineering, 2019 Publication	<1 %
15	Submitted to Higher Education Commission Pakistan Student Paper	<1 %
16	Veranita, Bambang Tripoli. "The Effect of Using PVC as A Mixed Additive Material Asphalt Concrete Wearing Course", IOP Conference Series: Earth and Environmental Science, 2021 Publication	<1 %
17	Supriadi Supriadi, Yosef Cahyo, Ahmad Ridwan, Agata Iwan Candra. "PENELITIAN PENAMBAHAN BAHAN BATU PADAS PADA	<1 %

CAMPURAN ASPAL BETON", Jurnal Manajemen Teknologi & Teknik Sipil, 2019
Publication

18	F N M Sianturi, S Sulaiman. "Performance analysis of a porous asphalt mixture with the use of concrete waste as a coarse aggregate and the addition of gilsonite materials", IOP Conference Series: Materials Science and Engineering, 2020 Publication	<1 %
19	core.ac.uk Internet Source	<1 %
20	exsys.iocspublisher.org Internet Source	<1 %
21	journal.unj.ac.id Internet Source	<1 %
22	Mahmoud Eissa, Basel Shalaby, Osama Mashaly, Abdelaziz Abdeldayem, Gamal Mosa. "Stability and Volumetric Properties of Hot - Mixes Asphalt (HMA) Using Marble Powder Waste", Journal of International Society for Science and Engineering, 2022 Publication	<1 %
23	Raghav Sharma, Tarun Sharma. "Experimental Study of Compressed Soil Bricks with Partial Replacement of Soil by Bagasse Ash, Marble Powder and Rice Straw",	<1 %

IOP Conference Series: Earth and Environmental Science, 2021
Publication

24	garuda.kemdikbud.go.id Internet Source	<1%
25	ojs.unanda.ac.id Internet Source	<1%
26	123dok.com Internet Source	<1%
27	Leo Sentosa, S Subagio Bambang, Harmein Rahman, R. Anwar Yamin. "Warm mix asphalt mixture using modified asbuton semi extraction modify and synthetic zeolite additive", MATEC Web of Conferences, 2019 Publication	<1%
28	repository.ukitoraja.ac.id Internet Source	<1%
29	Dyah Lintang Trenggonowati, Maria Ulfah, Asep Ridwan, Rasie Arthafia. "Proposed Improvement on Supply Chain System to Minimize The Bullwhip Effect Phenomenon with Monte Carlo Simulation Approach", Journal of Innovation and Technology, 2021 Publication	<1%
30	M Kasaf, C A Prastyanto. "Analysis the use of steel slag as a replacement of natural aggregate in the asphalt concrete binder	<1%

course (AC-BC) mixture", IOP Conference Series: Materials Science and Engineering, 2020

Publication

Exclude quotes	Off	Exclude matches	Off
Exclude bibliography	On		