Jurnal Komposit: Jurnal Ilmu-ilmu Teknik Sipil ISSN: 2615-3513
Vol. 7 No. 2 (2023) pp. 161 – 165 e-ISSN: 2655-934X
DOI: http://dx.doi.org/10.32832/komposit.v7i1.9190

AC-WC Strength Analysis with the Marshall Method on Fly Ash Mixture as a Substitute for Stone Ash Materials

Ade Nurdin, Erlangga, M. Nuklirullah
Civil Engineering Study Program, Jambi University
E-mail: adenurdin@unja.ac.id; rio02erlangga@gmail.com; m.nuklirullah@unja.ac.id

ABSTRACT

The layers contained in flexible pavement, one of which is the Asphalt Concrete-Wearing Course (AC-WC) layer, is a layer that is quickly damaged compared to other layers, because this layer is located at the top and is directly related to environmental conditions and vehicle wheel loads. One of the efforts that can be made to increase the strength of the road pavement structure in the AC-WC layer is by utilizing the remaining material from burning coal as a substitute for stone ash. The material used is fly ash mixed with successive levels namely (0: 100), (25:75), (50:50), (75:25) and (100:0). The optimum asphalt content (OAC) used was 6.75%. Based on the results of the physical characteristic test using the Marshall test, the fly ash material to be used meets the required specifications. As it is affected by aggregate gradation, bitumen content and compaction process, the flow rate increases simultaneously. The stability value obtained from the asphalt content of 5.781% (10%) variant is 1097.0 kg, higher than the other variants. Only 2 sample variants meet VIM specifications. Obtained optimum asphalt value of 5.75% which is close to the initial optimal asphalt estimated.

Key words: *Coal Fly ash, Marshall Test, AC-WC, Optimum Asphalt Content, MQ-optimum*

INTRODUCTION

Infrastructure development is growing rapidly including roads and bridges, where a layer of flexible pavement or commonly called asphalt is generally used as a road pavement layer. However, due to the relatively high rainfall in Indonesia, some areas affected by rain become waterlogged. 10% of road damage in Indonesia is caused by water and 30% is caused by overloading. This of course disturbs the comfort of road users on asphalt roads due to the incompatibility of the asphalt mixture with the specifications of the Highways (Directorate General of Highways, 2020).

The binder material (asphalt) in the road pavement mixture is the main factor and affects the performance of the asphalt mixture, especially on flexible pavements. Pavement layers using concrete asphalt are one of the most widely used pavements, because apart from being easy to obtain, asphalt is more efficient and can be used extend the life of the road itself (Fahmi et al, 2021).

Construction material from artificial aggregate or stone ash is mineral filler or filler with a particle size generally less than 0.075 mm which is a by-product or processed crushed stone using a stone crusher. The texture of rock ash has fine grain, sharp and gray in color. Has durable, hard properties and is a pozzolanic element (contains silica and alumina compounds which are not cementitious, but their fine form when mixed with water can turn into a solid mass) (Bigatti & Cronan, 2002).

Fly ash comes from the residue of burning coal in power plants. Fly ash has a melting point of 1300°C and has a density of between 2.0-2.5 g/cm^3. Fly ash is one of the residues produced in combustion and consists of fine particles (Umboh et al, 2014; Insan et al, 2020). Fly ash (*fly ash*) is results side from the coal burning process at power plant. Availability abundant fly ash moment this, as well condition as a waste material make fly ash is one of the basic material choices for geopolymer.

Fly ash has been categorized as factory waste; therefore, it is appropriate for us to reduce factory waste and make optimal use of it. (ACI Committee 232, 2010). Coal fly ash obtained from Pelita Wira Sejahtera factory on Talang Duku, Muaro Jambi Regency.

Beside its practical use (without calcination process), its utilization is also very profitable for environment. Based on ACI Committee 232, size details escaped fly *ash* sieve No. 200 with *specific gravity* between 2.15-2.8. Content the depends from origin of coal as well design from generator electricity from each power plant. (ACI Committee 232, 2010)

Efforts to improve and utilize the strength of the road pavement structure, by substitute the material needed in this AC-WC layer, using fly ash. The purpose of this study was to determine the optimum asphalt content obtained at AC-WC (Asphalt Concrete-Wearing Course) with coal fly ash (10%, 25% and 50%) for rock ash replacement and to analyze the effect of using fly ash on testing strength of AC-WC (Asphalt Concrete-Wearing Course) with normal asphalt using coal fly ash

*(*Sadillah et al, 2018).

This study uses variation coal *fly ash* as replacement stone ash with percentage 10%, 25%, 50%. *Fly ash* own the specific area is 170-1000 m^2/ kg. Size average particle size of sub-bituminous coal fly ash 0.01 mm - 0.015 mm, area surface 1-2 m^2/g, with spherical shape. On results *design mixture formula* (DMF) in the laboratory form composition (comparison aggregate with asphalt) depending on the fraction aggregates used in the field and those designed in the laboratory. DMF then interpreted in a known *Asphalt Mixing Plant* (AMP). with *Job Mix Formula* (JMF). Formula mixture design *Design Mix Formula* (DMF) is determined based on Marshall procedure (Alamsyah et al., 2020).

The objective of this study is to compare results strength *Asphalt Concrete-Wearing Course* (AC-WC) with *fly ash* as replacement stone ash use Marshall method and compare with results of Buanti's study (2018). Method testing use volumetric tests, mechanical tests, and Marshall immersion test, using 5 combinations fly ash fillers and asbuton with ratios (0:100), (25:75), (50:50), (75:25) and (100:0). Optimum asphalt content (KAO) used is 6.75%.

RESEARCH METHODS

the method used in this research is to obtain results of marshall test, using coal fly ash as replacement stone ash on the Asphalt Concrete - *Wearing Course* (AC-WC) (Adi, 2017). The type of data used is the primary data where the data obtained from marshall tests on the test object at the Laboratory Material Construction, Department of Works Public and Public Housing Jambi Province. Coal ash used as material replacement on AC-WC with 3 variations namely 10%, 25%, and 50% were made for 3 test objects each, so that needed as many as 9 samples as well as normal asphalt as much as 3 samples as reference comparison (Pradani, Sadli, & Fithriayuni, 2016) .

Variables used in research about comparison strength results marshall on the mix asphalt AC-WC against normal asphalt (Rachman, Syammun, & Heikal, 2021). The stages of the research carried out are as follows:

1. Data collection. Collected data is primary data, in the form of results rate asphalt with material substitute stone ash becomes *fly ash* coal from Marshall test.
2. Marshall testing, refers to SNI 06-2489-1991 (1991)
3. Analysis and processing of the data obtained Then analyze result. At stage This done compositional data analysis Asphalt (*Mix Formula*) (Alamsyah, Said, & Alifuddin, 2020) based on asphalt content data from Marshall test results. Based on the asphalt content results, the Marshall Quotient value can be calculated using the following formula:
   MQ = S/t (1)
   with *S* as stability value covered (kg), *t* as melt rate/flow (mm) and *MQ* as *Marshall Quotient Value* (kg/mm).
   Flow or melting shows the magnitude of the decrease or deformation that occurs in the hard layer due to holding the received load. The flow value is influenced by aggregate gradation, bitumen content and compaction process which includes temperature and compaction energy. (Buanti, 2018). Mixtures that have low flow values and high stability tend to be stiff and brittle, while mixtures that have high flow values and low stability tend to be plastic and easily deformed when subjected to traffic loads in the field.
4. Data processing, to compare *MQ* value of normal asphalt and asphalt with fly ash replacement.
5. Conclusion from results obtained from stages above.

Testing of Test Objects

There are 12 samples needed for test object, which 9 samples using coal *fly ash* material as replacement for stone ash with variations of 50%, 25%, 10%, and 3 normal asphalt samples. (Hasmiati, 2014).

After the test object is made, the specific gravity test and Marshall test are carried out on each sample. Before tested, sampled weighed in dry condition, then soaked in water for 3-5 minutes. After soaked, sample re-weighed in water. To generate surface dry density, sample is weighed after drying using dry rug. This testing stage will produce data on the unit weight which serves to determine the void content in the mixture (VIM%) (Susanto, 2020).

Furthermore, sample test object is inserted to in *waterbath* with 60ºC for 30 minutes. And tested using into the *marshall test* equipment to determine stability and melting point. Correction factor from *proving ring* on the marshall is 0.045 (Akbar, 2019).

Composite Journal: Journal of Civil Engineering Sciences ISSN: 2615-3513
Vol. 7 No. 2 (2012) pp. 161 - 165 e-ISSN: 2655-934X
DOI: http://dx.doi.org/10.32832/komposit.v7i2.9190

Analysis of Marshall Test Results

The result of Marshall test is shown in Table 1 below.

Table 1. Marshall Test Result

Asphalt Content Variant	Stability (kg)	Flow (mm)	VIM (%)	***Marshall Quotient* (MQ) (kg/mm)**
5.789% (50%)	1071.0	3.30	13.27	324.5
5.784% (25%)	1017.5	3.27	8.27	311.5
5.781% (10%)	1097.0	3.20	4.39	342.8
5.780% (N 0%)	872.1	3.17	3.75	275.4

Source: data processing, 2022

Table 2. Flow Results Comparation to Bina Marga Specification

Asphalt Content Variant	Bina Marga Specification	*Flow* (mm)	Results
5.789% (50%)	2-4	3.30	Fulfilled
5.784% (25%)	2-4	3,27	Fulfilled
5.781% (10%)	2-4	3.30	Fulfilled
5.780% (N 0%)	2-4	3,17	Fulfilled

Source: data processing, 2022

From the results the resulting graph the highest *flow* value by 3.30 mm, at the asphalt content of 5.789%.

Stability mixture in testing Marshall showed with stability value reading mark, corrected with sample thickness. Stability is the ability of the pavement layer to withstand deformation due to traffic loads acting on it. Stability value affected by friction between details aggregate (*internal friction*), grain aggregate *interlooking* and good binding capacity from asphalt layer. Compaction process aside, aggregates quality and asphalt grades also has an effect (Rachman et al., 2021). Stability value shown as following:

Table 3. Stability Results Comparation to Bina Marga Specification

Asphalt Content Variant	Specification	Stability (Kg)	Results
5.789% (50%)	Minimum 800	1071.0	Fulfilled
5.784% (25%)	Minimum 800	1017,5	Fulfilled
5.781% (10%)	Minimum 800	1097,0	Fulfilled
5.780% (N 0%)	Minimum 800	872,1	Fulfilled

Source: data processing, 2022

Based on results testing stability carried out above,all of samples fulfilled the specs given (Min. 800 kg), Stability highest obtained at a rate bitumen 5.781% with value 1097.0 Kg.

VIM (Void in Mixture) is the number of voids in the mixture expressed as a percentage. The air cavity contained in the mixture is needed to provide space for the elements of the mixture according to their elastic properties. Therefore, the VIM value determines the characteristics of the mixture. The value of VIM is influenced by aggregate gradation, asphalt content and density. A VIM value that is too low is not good, this will cause bleeding on the hard coating. In addition to bleeding, with a low VIM, the stiffness of the hard coating will result in cracking when it receives traffic loads, because it is not flexible enough to accept the deformation that occurs. VIM value obtained from the calculation of the weight of the test object in the water.

Table 4. VIM results Comparation to Bina Marga Specification

Asphalt Content Variant	Bina Marga Specification	VIM (%)	Results
5.789% (50%)	3-5	13,27	Not Fulfilled
5.784% (25%)	3-5	8,27	Not Fulfilled
5.781% (10%)	3-5	4.39	Fulfilled
5.780% (N0%)	3-5	3.75	Fulfilled

Source: data processing, 2022

Based on the test results, none of the samples met the VIM value specifications.

Table 5. *Marshall Quotient* (MQ) Comparation to Bina Marga Specification

Asphalt Content Variant	Bina Marga Specification	MQ (Kg/mm)	Results
5.789% (50%)	Minimum 250	324.5	Fulfilled
5.784% (25%)	Minimum 250	311.5	Fulfilled
5.781% (10%)	Minimum 250	342.8	Fulfilled
5.780% (N 0%)	Minimum 250	275.4	Fulfilled

Source: data processing, 2022

Based on the results obtained, all MQ value fulfilling standard or specification with minimum conditions.

RESULTS AND DISCUSSION

Determination of Optimum Asphalt Content

After is value of *flow*, Stability, VIM (*Void in Mixture*), and *Marshall Quotient* (MQ), then the optimum mix percentage value can be calculated from the four percentage percentages of asphalt content. The results of percentage data on asphalt can be seen on table below.

Composite Journal: Journal of Civil Engineering Sciences
Vol. 7 No. 2 (2012) pp. 161 - 165
DOI: http://dx.doi.org/10.32832/komposit.v7i2.9190

ISSN: 2615-3513
e-ISSN: 2655-934X

Table 6. Optimum Asphalt Content

No.	Marshall Characteristics	Specification	Asphalt Content Variant			
			5.789% (50%)	5.784% (25%)	5.781% (10%)	5,780% (N 0%)
1.	Melt	2-4	3.30	3,27	3,20	3,17
2.	Stability	Minimum 800	1071.0	1017,5	1097,0	872,1
3.	VIM	3-5	13,27	8,27	4.39	3.75
4.	MQ	Minimum 250	324.5	311.5	342.8	275.4

Source: data processing, 2022

Data shown in table 6 served in chart (fig. 1). Minimum asphalt content and asphalt maximum grade with objective to obtain results optimum asphalt content (OAC).

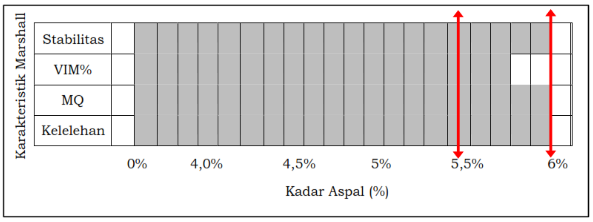

Figure 1. mix optimum results polymer

Based on the results obtained from Table 6. and figure above, minimum and maximum asphalt content is 5.5% and 6%, so the OAC calculated as shown.

$$OAC(\%) = \frac{5.5+6}{2} = 5.75\% \qquad (2)$$

The difference between initial Asphalt Content on all samples and calculated OAC is only 0,03%.

Influence of fly ash as substitution material for Stone Ashes

Flow rate from normal sample and three variation of coal fly ash as replacement for stone ash meets Bina Marga specifications. Due to affected by aggregate gradation, asphalt content and compaction processes, flow value is simultaniously increasing.

Stability value obtained from asphalt content 5.781% (10%) variant is 1097.0 kg, which is higher from 5.789% (1071.0 kg) variant, 5.784 (1017.5 kg) variant, and 5.780% (872.1 kg) variant, due to adhesive and hardening asphalt characteristic on mixture. Mixture formula and compaction effort affect the value of stability at the time of making the sample. Whole testing stability already fulfil Bina Marga 2018 specifications, minimal 800 kg.

VIM (*Void in Mixture*) on testing sample fulfils Bina Marga 2018 specifications, except for the 5.789% and 5.784% samples with VIM values are 13.27% and 8.27%, not fulfils the specifications. A pavement layer with the VIM value of ≤3% will increase the possibility of bleeding. On the other hand, a VIM value that is ≥5% indicates that there are many cavities in the mixture, so the mixture is not dense and not airtight or watertight, causing the asphalt to easily oxidize which results in weakening of the asphalt bond to the aggregate and asphalt is no longer a good binding material because the rock will loosen.

The results of *marshall quotient* value meets Bina Marga specification min. 250 kg/mm. MQ has increased due to the addition of asphalt in the mixture. This excess asphalt causes the mixture to be stiff because of the large stability value and small flow value.

Relationship between four indicators in marshal test related to each other due to characteristic of Marshall consists on stability, *flow*, VIM, and MQ. However, the main factor to influence strength asphalt is VIM. This strengthened by previously relevant research (Buanti, 2018). This result showing asphalt optimum content fulfils the 2018 Bina Marga specifications (5.7%). This only differs by 0.03% from the estimated OAC and the obtained OAC.

CONCLUSION

Based on results of characteristic physique tests for material to be used has fulfil the required specifications. Due to affected by aggregate gradation, asphalt content and compaction processes, flow value is simultaneously increasing. Stability value obtained from asphalt content 5.781% (10%) variant is 1097.0 kg, which is higher from another variants. Only 2 sample variants have fulfilled the VIM specification. Obtained optimum asphalt value is 5.75%, which is approximate the initial optimal asphalt estimated.

BIBLIOGRAPHY

ACI Committee 232. (2010). The use of *fly ash* in concrete. *Concrete (London)*, 44(5), 60–61.

Adi, A. S. (2017). Penggunaan Abu Batubara Hasil Pembakaran Asphalt Mixing Plant (AMP) sebagai Bahan Campuran Lapis Aspal Beton (Laston). *Jurnal Teknologi Mineral dan Batubara*, 13(1), 31–44. https://doi.org/10.30556/jtmb.vol13.no1.20

17.144

Akbar, M. (2019). Durabilitas Lapisan Asphalt Concrete-Wearing Course (AC-WC) dengan Menggunakan Abu Terbang sebagai Bahan Pengisi di Lingkungan Air Gambut. Universitas Riau, 6(2), 1–13. (PDF-Indonesian)

Alamsyah, S. L. B., & Alifuddin, A. (2020). Konsep *Design Mix Formula* (DMF) Lapis Tipis Beton Aspal (LTBA) Mengacu Spesifikasi Umum 2018 Bina Marga terhadap Sifat - Sifat (ITS) dan Deformasi Bagaimana karakteristik Campuran Beraspal. *Jurnal Teknik Sipil - Macca*, 5(2), 141–152. (PDF-Indonesian)

Badan Standardisasi Nasional (1991) SNI 06-2489. Metode Pengujian Campuran Aspal dengan Alat Marshall. (PDF-Indonesian)

Buanti, D. H. (2018). Analisis Pengaruh Penggunaan *Fly ash* dan Asbuton sebagai Filler pada Asphalt Concrete-Wearing Course (AC-WC). *Doctoral Dissertation*, Universitas Mataram. (Indonesian)

Direktorat Jenderal Bina Marga. (2020). Spesifikasi Umum Bina Marga 2018 Untuk Pekerjaan Konstruksi Jalan dan Jembatan (Revisi 2). Kementerian Pekerjaan Umum Dan Perumahan Rakyat, 1036. (PDF-Indonesian)

Fahmi, A. K. A., Qomariah, Q., & Yunaefi, Y. (2021). Karakteristik Campuran Beton Aspal (AC-WC) Dengan Menggunakan Variasi Kadar Filler Limbah Abu Terbang Batubara. *Jurnal JOS-MRK*, 2(1), 51–57. (PDF-Indonesian) https://doi.org/10.55404/jos-mrk.2021.02.01.51-57

Hasmiati, L. O. M. N. A. (2014). Mix Design Asphalt Concrete Wearing Course (AC-WC) dengan Menggunakan *Fly ash* Batu Bara Sebagai Pengganti Filler. *Jurnal Stabilita*, 2(1), 133–144. (PDF-Indonesian)

Insan, M. K., Hariati, F., & Taqwa, F. M. L. (2020). Studi Pemanfaatan Fly Ash dan Bottom Ash sebagai Material Stabilisasi Tanah Dasar (Studi Kasus: Pekerjaan Subgrade untuk Jalan Lingkungan di PLTU Sulawesi Utara II, Kabupaten Minahasa Selatan, Sulawesi Utara). *Jurnal Komposit: Jurnal Ilmu-ilmu Teknik Sipil*, 3(2), 39-44. (PDF-Indonesian)

Pradani, N., Sadli, M., & Fithriayuni, D. (2016). Analisis Perancangan Tebal Perkerasan Lentur Menggunakan Metode Pd T-01-2002-B, Metode Manual Desain Perkerasan (MDP) dan Metode Nottingham pada Ruas Jalan I Gusti Ngurah Rai Palu. *Forum Profesional Teknik Sipil*, 4(2), 140–155. (PDF-Indonesian)

Rachman, F., Syammaun, T., & Heikal, F. (2021). Pengaruh Limbah Batu Bara sebagai Filler terhadap Karakteristik Marshall dan Indek Kekuatan Sisa pada Campuran Aspal Beton AC-WC. *Tameh: Journal of Civil Engineering*, 8(1), 23–33. (PDF-Indonesian) https://doi.org/10.37598/tameh.v8i1.64

Sadillah, M., Arifin, M. Z., & Wicaksono, A. (2018). Sebagai Filler Terhadap Karateristik Marshall Beton Aspal Lapis Aus (AC-WC). *Jurnal Rekayasa Sipil & Lingkungan*, 2(1), 87–98. (PDF-Indonesian)

Susanto, H. A. (2020). Perbandingan Karakteristik Pengujian Marshall Campuran Aspal Beton dengan Filler Pasir Besi dan Abu Batu. *Potensi : Jurnal Sipil Politeknik*, 22(1), 13–20. (PDF-Indonesian) https://doi.org/10.35313/potensi.v22i1.1807

Umboh, A. H., Sumajouw, M. D., & Windah, R. S. (2014). Pengaruh Pemanfaatan Abu Terbang (*Fly Ash*) dari PLTU II Sulawesi Utara sebagai Substitusi Parsial Semen Terhadap Kuat Tekan Beton. *Jurnal Sipil Statik*, *2*(7). (PDF-Indonesian)