The Effect of Crumb Rubber Substitution and Utilization of Local Materials Laterite on Asphalt Concrete - Binder Course

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Abstract: The opportunity to use crumb rubber for pavement layers is still minimal, while the waste generated is increasing, one way to reduce and utilize the tire material is to add asphalt-concrete mixture - binder course (AC-BC). To increase flexibility, one of them is by using Crumb Rubber from waste tires that pass the No. filter. 4 (4.75 mm) as additive. This study aims to determine the effect of Crumb Rubber as a material and the use of laterite stone as a substitute for coarse aggregate on asphalt mixtures based on the properties of the Marshall mixture. In this study, Marshall test specimens were made with variations of laterite stone as a substitute for coarse aggregate at a level of 50% and the addition of Crumb Rubber at a level of 1%, 2%, 3% and the planned asphalt content was 4%, 4,5%, 5%, 5.5%, and 6% which will then determine the optimum asphalt content, stability, flow, VIM, VMA, VFA and MQ in the Asphalt Concrete – Binder Course. Based on the research results obtained. The best variation isthe use of Crumb Rubber as an additive to Asphalt Concrete – Binder Course by 1% and the addition of Crumb Rubber and the value of Optimum Asphalt Content is 5.58% with Marshall characteristics including stability values of 1082 kg, flow 2.91%, VIM 4.83%, VMA 14.82%, VFA 65.80% and MQ 438 kg/mm. The results showed that the mixture of AC-BC with a substitute for coarse aggregate using 50% laterite stone and Crumb Rubber the requirements for the Asphalt Concrete - Binder Course.

1 INTRODUCTION

Asphalt pavement is a large road leading through one place to another, specifically with a prepared roof that can be used by vehicles. Roads play a significant role with in social and economic growth of a nation (Alakhali, Yahya, 2021). Use of materials for road pavement construction in East Kalimantan is still very dependent on Palu stone and sand, so that road construction costs in East Kalimantan are expensive (Putrawirawan, Ibayasid, 2020). So it is necessary to makeaneffortsothat howto utilize local natural resources in East Kalimantan as an alternative material for making asphalt. One of the natural resources owned by East Kalimantan is Laterite Stone.

The purpose of this research is to find out how much influence the use of laterite stone and Crumb Rubber has on Masrhall characteristics in the Asphalt Concrete - Binder Coarse (AC-BC). To determine the optimum asphalt content (KAO) in the Asphalt Concrete-Binder Coarse (AC-BC). Use of laterite as a substitute for coarse aggregate on AC-BC maximum of 50% and Optimum Asphalt Content value of 5.48% with Marshall characteristics including stability values 1980 kg, flow 3.95%, VIM 4.96%, VMA 16.42%, VFA 72.07% and MQ 510.63 kg/mm. The results showed that the mixture of AC-BC with a substitute for coarse aggregate using laterite met the requirements for Asphalt Concrete – Binder Course (AC-BC) (Putrawirawan, Tristo, Ibayasid, 2019). The addition of 0.75% of Activated Crumb Rubber (ACR)

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additive, improved the resistance to fatigue cracking and rutting about 20% and 32% respectively but susceptible to stripping, even though the addition of ACR additive showed insignificant improvement between ACR and control mixture in Marshall properties, but based on the mechanical performance, the ACR additive eligible to apply and provide the same or better performance compared to conventional and non-ACR mixtures (Kamarudin et al, 2020). The recycled aged Crumb Rubber Modified (CRM) mixtures (with 15%, 25%, and 35% rubberized RAP) can satisfy the current Superpave mixture requirements, including moisture susceptibility and rutting resistance, and in general, there was no significant difference between the control and the recycled CRM mixtures for the properties evaluated (Lee J, S et al, 2008).

2 MATERIALANDMETHOD

2.1 Asphalt Concrete – Binder Course (AC-BC)

Asphalt Concrete – Binder Course (AC – BC) is a pavement layer located below the wear layer (Wearing Course) and above the foundation layer (Base Course). This layer is not directly related to the weather, but must have sufficient thickness and adhesiveness to reduce stress/strain due to traffic loads which will be transmitted to the lower layers, namely Base course and Sub grade (Subgrade).

2.2 Ingredient of Asphalt Concrete - Binder Course (AC-BC)

Flexible pavement consists of coarse aggregate, fine aggregate, sand, filler and additives. However, the materials used must first be tested according to standards and meet the specifications set by Bina Marga. This is in order to obtain pavement that has good quality and is in accordance with the plan.

2.3 Laterite Stone

Laterite stones is a hardened soil formed naturally resembling rock from the deposition of substances such as nickel and iron. Laterite itself is naturally formed in which there are many elements and nutrients that make up the soil layer hardened like stone. The term Lateriteis derived from the Latin word - later, meaning brick. It was first used in 1807 by Buchanan to describe a red iron-rich material found in the southern parts of India. Laterites are widely distributed throughout the world in the regions with high rainfall, but especially in the inter-tropical regions of Africa, Australia, India, South-East Asia and South America, where they generally occur just below the surface of grasslands or forest clearings. Alexander et al., (1962) (West, Jenbarimiema, Nyebuchi, & Azeruibe, 2020) compiled the physical, chemical and morphological definitions fromvarious researchers and then redefined laterite as a highly weathered material, rich in secondary oxides of iron, aluminum, or both, it is nearly void of bases and primary silicates, but it may contain large amounts of quartz and kaolinite, and it is either hard or capable of hardening on exposure to wetting and drying (West, Jenbarimiema, Nyebuchi, & Azeruibe, 2020).

Figure 1: Laterite stone.

2.4 Crumb Rubber

Crumb rubber is made of tyres or vulcanized rubber. Tyres are basically formed by combining natural and synthetic rubber and carbon black. The tyres are shredded into smaller particle sizes to remove wire and fabric reinforcement. The actual chemical composition of crumb rubber derived from tyres is difficult to assess because of the large variation in tyre types produced by different manufacturers. However, crumb rubber is typically referenced by its size together with basic compositions such as natural and synthetic rubber, steel, fibre and carbon black (Hassan et al, 2015). Crumb Rubber is an environmentally friendly recycled rubber product because it is obtained from recycling waste made from used tire rubber. Crumb Rubber has advantages such as good adhesion, sturdy, durable and long-lasting, more resistant to gasoline and lubricating oil and resistant to weather. Crumb Rubber can be obtained by recycling ambient grinding. Ambient grinding is a process method where used tires are grated, ground and processed at room temperature.

The main ingredients of Crumb Rubber generally come from waste tire rubber (Julián, 2005).

Figure 2: Crumb Rubber.

Chemical content Crumb Rubber has the constituent elements shown in Table 1.

Table 1: Chemical content Crumb Rubber.

Material	**Compotition (%)**
Rubber	48
Karbon *black*	22
Logam	15
Tekstil	5
Zinc Oksida	1
Sulfur	1
AditiveMaterial	8

Crumb rubber is produced through refining the scrap tires of cars, trucks, busses and other transporter tires, steel and synthetic fibers, which account for approximately 40 percent of the structure of the tyres are extracted via a magnetic system and an air gravity system. Crumb rubber is an efficient material to be used as an additive to asphalt binder since it contributes in better performance by increasing the strength and stiffness of pavement and can be used for future development (Alakhali, Yahya, 2021). Crumb rubbers (CRs) have been proposed as pavement components because they are waste materials. Previous studies have attempted to find alternative material in pavement construction that act as additives or property modifier (Hamad, S, Jaya, 2014). The hot mix asphalt modification process in which crumb rubber is initially mixed with mineral aggregate before addition of a binder is known as dry process. This process has the advantage of using conventional blends and, at least in principle, that there is no limit to the content of the rubber introduced (Silvrano, et al, 2005). The dimension of crumb rubber particles used in the dry process is generally bigger than for those used in the wet process. Besides, in the dry process, the crumb rubber substitutes part of the aggregate mineral (Silvrano, et al, 2005). The CRDryprocess is the method wherethe CR particles are partially replaced with the portion of fine aggregates in the mix. In addition, there are several treated dry rubber technologies where the crumb rubber particles are pre-mixed with low viscosity petroleum-based products or aromatic oils compatible with the lighter fractions of asphalt binder. Treated rubber technologies are also integrated in to mixture as a CRDry process (Salih, K, M. Emin, K., 2017).

3 RESULTS AND DISCUSSION

3.1 Result of Testing Material

Based on the results of testing in the asphalt testing laboratory, the values of specific gravity, penetration, softening point and ductility meet the requirements of asphalt, then the results of testing the physical characteristics of aggregates that meet the requirements of technical specifications can be seen in the following tables.

Table 2: The result of Asphalt properties.

No.	Type of testing	Requirement	Result
1	Penetration, 25^{o}C	60-70	67.7
2	Softening point (^{o}C)	Min. 48	52.25
3	Ductility 25^{o}C (cm)	Min. 100	126.7
4	Spcific Ggrafity	Mi. 1	1.040

Table 3: The results of testing the specific gravity and absorption of coarse aggregate.

Type of testing	Requirement	Result
Dry bulk density	Min. 2.5	2.63
Saturated surface dry (SSD)	Min. 2.5	2.68
Apparentdensity	Min. 2.5	2.75
Absorption	Maks. 3%	1.58
Abration	Maks. 40%	20.63

Table 4: The results of testing the specific gravity and absorption of medium aggregate.

Type of testing	Requirement	Result
Dry bulk density	Min. 2.5	2.55
Saturated surface dry (SSD)	Min. 2.5	2.62
Apparentdensity	Min. 2.5	2.74
Absorption	Maks. 3%	2.69

Table 5: The results of testing the specific gravity and absorption of Filler.

Type of testing	Requirement	Result
Dry bulk density	Min. 2.5	2.52
Saturated surface dry (SSD)	Min. 2.5	2.54
Apparentdensity	Min. 2.5	2.58
Absorption	Maks. 3%	1.01

Table 6: The results of testing the specific gravity and absorption of Laterite stone.

Type of testing	Requirement	Result
Dry bulk density	Min. 2.5	2.54
Saturated surface dry (SSD)	Min. 2.5	2.59
Apparentdensity	Min. 2.5	2.67
Absorption	Maks. 3%	2.93
Abration	Maks. 40%	29.63

All material tests which include asphalt, coarse aggregate, fine aggregate, filler and laterite stone have met the requirements of the 2018 Bina Marga technical specifications.

3.2 Marshall Characteristic

3.2.1 Relation of Crumb Rubber with Stability

The average value of the AC-BC in the mixture with crumb rubber content of 0%, 1%, 2%, 3% respectively was1980kg,1082kg,1004kg,1002kg.

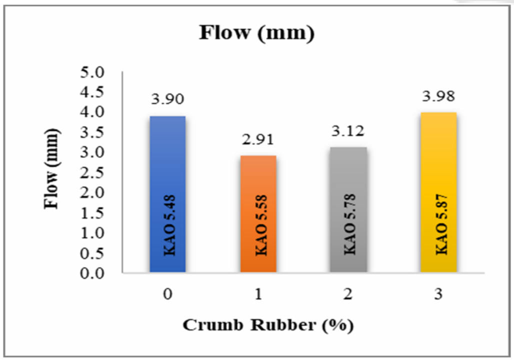

Figure 3: Graph of the relationship between stability and variations in use of Crumb Rubber.

The stability value has decreased. The lowest stability value was obtained at 1% crumb rubber, which was 1082 kg and the highest value was obtained at 0% crumb rubber, which was 1980 kg. However, after that the stability value decreased at levels of 1% to 3%. The decrease in stability was caused by the addition of crumb rubber content in the mixture which resulted in a lack of interlocking between the aggregates and crumb rubber, causing the asphalt to no longer effectively cover the aggregates which could lead to a decrease in the stability. Pavement layers with a stability of less than 800 kg will easily experience rutting, because the pavement is soft so it is less able to support the load.

3.2.2 Relation of Crumb Rubber with Flow

The average flow value of the AC-BC mixture in the mixture with crumb rubber content of 0%, 1%, 2%, 3%, respectively, was 3.90 mm, 2.91 mm, 3.12 mm, 3.98 mm.

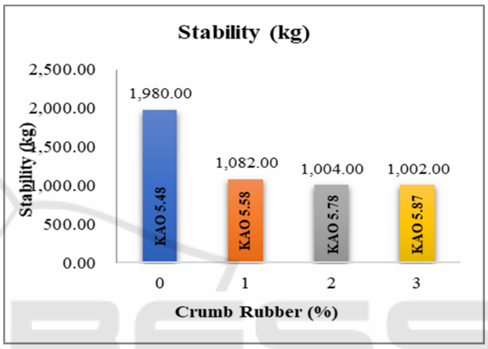

Figure 4: Graph of the relationship between Flow and variations in use of Crumb rubber.

Flow value decreased and increased. The highest flow value was obtained at a content of 3% crumb rubber, which was 3.98 mm, but all crumb rubber content still meet the requirements of the 2018 General Specification, which was a minimum of 2.0 mm. The increase in the average flow value can be caused by the increasing amount of asphalt required so that the properties of the mixture are plastic and easily deformed when loaded.

3.2.3 Relation of Crumb Rubber with Void in Mix (VIM)

VIM value decreased or increased. This is due to the increasing content of laterite stone causing the asphalt to not optimally fill the voids in the aggregate because it has larger voids and the less asphalt content is filled, making the mixture less dense because the aggregates are interconnected and break due to imperfect compaction. The value of VIM in all variations of crumb rubber content still meets the minimum requirements of 3% and a maximum of 5%.

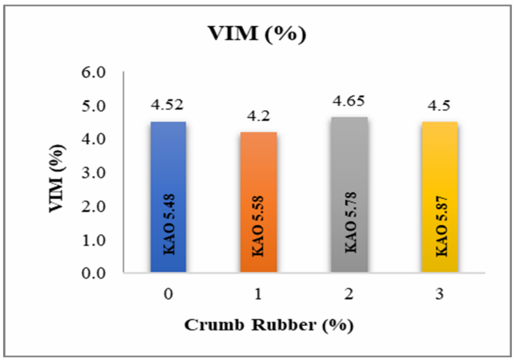

Figure 5: Graph of the relationship between VIM and variations in use of Crumb rubber.

Figure 5 shows that the VIM value decreased at 4% plastic bag content. This is because the increasing content of plastic sacks causes asphalt to fill voids in the aggregate because it has smaller voids and the more asphalt content filled in the mixture can make the mixture denser. The VIM value in all variations of the plastic bag content still meets the minimum requirements of 3% and a maximum of 5%

3.2.4 Relation of Crumb Rubber with Void in Mineral Agregat (VMA)

Mixing crumb rubber as an added ingredient causes the VMA value to decrease. The value of VMA on the use of crumb rubber 0%, 1%, 2%, 3%, decreased by 15.80%, 14.82%, 14.37%, 13.98%. Aggregates form a thick blanket, as a result, the voids between aggregates are getting smaller.

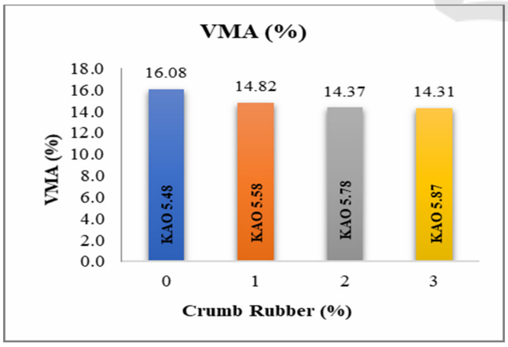

Figure 6: Graph of the relationship between VMA and variations in use of Crumb Rubber.

The decrease in VMA value was due to the increase in crumb rubber content so that the asphalt covering the aggregate formed a thick blanket, as a result the voids between the aggregates were getting smaller.

3.2.5 Relation of Crumb Rubber with Void Filled Agregat (VFA)

Void filled with asphalt (VFA) value decreased and increased. Values at levels of 0%, 1%, 2%, 3% crumb rubber respectively are 72.00%, 65.80%, 72.63%, 77.80%. VFA value for each laterite stone content still meets the general specifications for 2018 which is at least 65%. VFA value that is too high will cause bleeding.

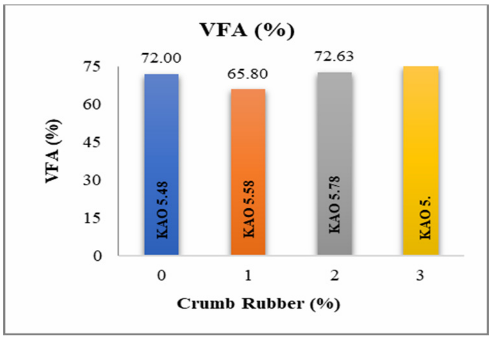

Figure 7: Graph of the relationship between VFA and variations in use of Crumb rubber.

VFA value that is too small will cause the mixture to be less water and airtight. This will cause the asphalt film layer to become thin so that the pavement will crack easily when it receives a load so that the asphalt mixture is easily oxidized.

3.2.6 Relation of Crumb Rubber with Marshall Quotient (MQ)

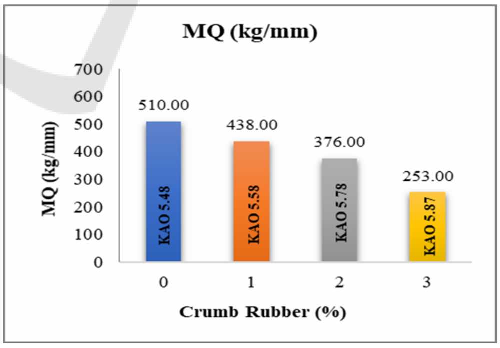

Figure 8: Graph of the relationship between MQ and variations in use of plastic bags.

Along with a decrease in stability causes a decrease in the valueof MQ and causesan increase in thevalue of flow. As a result of the decrease in the MQ value, the mixture will become less brittle and soft when the mixture will be increased the amount of compaction.

The use of crumb rubber resulted in the Marshall Quotient value decreased.

3.2.7 Relation of Crumb Rubber with Optimum Asphalt Content (OAC)

The optimum asphalt content of each proportion of the use of crumb rubber as an additive can be seen in Table 4.28. From the results of the Marshall test, the optimum asphalt content for each variation was 5.48% for 0% crumb rubber; 5.58% for 1% crumb rubber; 5.73% for 2% crumb rubber; 5.87% for 3% crumb rubber.

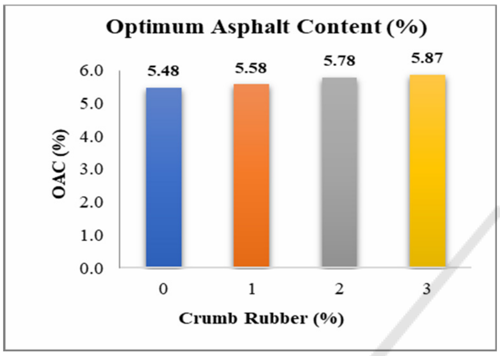

Figure 9: Graph of the relationship between Optimum Asphalt Content (OAC) and variations in use of Crumb rubber.

The effect of using crumb rubber as an additive in the mixture will increase the value of the optimum asphalt content in the AC-BC asphalt mixture. Judging from the OAC value which continues to show an increase in the OAC value. This means that the use of crumb rubber greatly affects the value of KAO, the more use of crumb rubber as an added material, the value of the optimum asphalt content will also be higherfor each variation of the content of crumb rubber which can be seen in Table 7.

Table 7: Value of Characteristic Marshall Asphalt Concrete – Binder Course.

Crumb Rubber (%)	0%	1%	2%	3%	Spec.
OAC (%)	5.48	5.58	5.78	5,87	-
Stability (kg)	1980	1082	1004	1002	Min. 800
Flow (mm)	3.90	2,91	3.12	3,98	2 – 4
VIM (%)	4.52	4,83	4.92	3,74	3 – 5
VMA (%)	16,08	14,82	14,37	14,31	Min. 14
VFA (%)	72.00	65,80	72,63	75,08	Min. 60
MQ (kg/mm)	510	438	376	253	Min 250

4 CONCLUSIONS

Based on the test results of the Asphalt Concrete – Binder Course (AC-BC) mixture using 50% laterite stone as a substitute for coarse aggregate and crumb rubber as an added ingredient, the maximum addition of crumb rubber is 3% with an KAO value of 5.58% and the value of the Marshall test properties. namely stability = 1082 kg, flow = 2.91 mm, VIM = 4.83%, VMA = 14.82%, VFA = 65.80%, and MQ = 438 kg/mm. All variations of the mixture meet the standards according to the technical specifications of Bina marga 2018, the greater the addition of crumb rubber, the lower the stability value but still within the recommended technical specification standards.

REFERENCES

Alakhali, A, Yahaya, M, Almalik, A, (2021), Effects of Crumb Rubber at Different Sizes in Asphalt Mixtures on Mechanical Properties. National Confrence on Wind & Earthquake Engineering.

Hamad, S, Jay, P, Hassan (2014), Influences of Crumb Rubber Sizes on Hot Mix Asphalt Mixture. Artikel in Jurnal Teknologi Malaysia.

Hassan, N. A., Gordon D. Airey, Putra Jaya, R Mashros, N. (2017). A Review of Crumb Rubber Modification in Dry Mixed Rubberised Asphalt Mixtures. *Article in Jurnal Teknologi, September 2014 DOI: 10.11113/jtv70.3501.*

Hendarsin, S. L. (2000). *"Perencanaan Teknik Jalan Raya"*. Bandung: Politeknik Negeri Bandung-Jurusan Teknik Sipil.

Julián, B., Sanchez, C., Belleville, P., & Popall, M. (2005). Applications of hybrid organic–inorganic nanocomposites. Journal of Materials Chemistry, 15(35-36), 3559-3592.

Karminto, Aji, S., & Hamid, S. (2019). Pemanfaatan material Lokal batu Laterit dan Pasir Mahakam dalam Campuran Apal Karet Terhadap Jumlah Siklus Pembebanan. *Prosiding Konferensi Nasional Pascasarjana Teknik Sipil (KNPTS) X 2019*, *(pp. 127-137). Bandung*.

Lee, J, S, Chandra K. Akisetty, Serji N. Amirkhanian, (2008). Laboratory Characterization of recycled crumb rubber modified asphalt mixture after extended aging. *Article in Canadian Journal of Civil Engineering · November 2008DOI:10.1139/L08-079.*

Putrawirawan, A, Tistro R, Ibayasid, (2019) Study of The Use of Laterite Stone From Tenggarong Seberang District in Asphalt Concrete Mixture – Binder Course (AC-BC). *Prosiding Seminar Nasional Penelitian & Pengabdian Kepada Masyarakat2019 (pp.88-95).*

Salih K, M. Emin, K, (2017), effect of Addition of Dry Crumb Rubber on the Performance of Terminal Blend

Crumb Rubber Modified Asphalt Mixtures. *Article in Transportation Research Record Journal of the Transportation Research Board DOI: 10.3141/2633-11. January 2017.*

S N N Kamarudin, M R Hainin, M N M Warid, M K I M Satar and N A Hassan (2020). Performance of Asphalt Mixture Incorporating Activated Crumb Rubber as Additive. *IOP Conf. Series: Materials Science and Engineering, ISECE 2020 doi:10.1088/1757-899X/1144/1/012081.*

Silvrano, A, Dantas Neto, Márcio Muniz de Farias, Luis Guelherme (2005) The Use of Crumb Rubber In Asphalt Mixtures Using The Dry Process, *International Symposiumon PavementRecycling. March 14-16.*

West, T., Jenbarimiema, Nyebuchi, & Azeruibe, D. (2020). Laterite Rock Modified Asphalt Concrete Mix Design Properties and Swell Behaviour under Soaked Conditions for Rural Roads. *International Journal of Constructive Research in Civil Engineering, 11-25.*

Wulandari, S, Tjandra, D, (2017) Use of Crumb Rubber as an additive in Asphalt Concrete Mixture. *Sustainable civil Engineering Structur and Construction Material, 171, p 1384-1389.*