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Utilization of Palm Oil Fuel Ash as a Filler in PG 70 Asphalt Mixtures for AC Mod-WC

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ABSTRACT

The Pavement Design Manual 2024, which requires the use of asphalt PG 70 for loads above 30 million ESAL and the increasing volume of palm oil waste that requires handling and reuse, as well as the need for alternative materials to be used as fillers, make it necessary to develop environmentally friendly materials by combining asphalt PG-70 and palm oil fuel ash as fillers. This pavement mixture is expected to be a mixture containing environmentally friendly road construction materials as well as a solution to the utilization of palm oil waste that can withstand high traffic loads. Testing of aggregate materials, asphalt, and asphalt mixtures was carried out at the Civil Engineering Laboratory of Medan State Polytechnic, in accordance with SNI, which refers to the General Specifications for Road and Bridge Construction Work 2018 Revision 2. The results obtained were that palm oil fuel ash as filler in asphalt mixture PG 70 gave an average value of stability above 1000 kg, density of 2-3 gr/ml, and VFA above 65% in all variations of filler content, for VIM values between 3-5% in the 50% and 75% variations, and VMA values above 15% in the 50%, 75% and 100% variations, while the flow value did not meet the standard value of 2-4 mm for all variations of filler content. Asphalt mixture PG 70 with palm oil fuel ash filler produces good density and stability values, but under repeated loading it will easily cause waves and rutting in the pavement due to the rigid nature of the mixture with a very high flow value and thus allow bleeding because the value of VFA is also very high.

I. Introduction

Oil palm is one of the leading commodities of the plantation subsector in Indonesia. North Sumatra is one of the potential areas for oil palm development which until now has domestic and international market opportunities. Oil palm can be processed into a variety of products derived from fruit, fronds, stems, and waste. The processing of oil palm fresh fruit bunches into crude palm oil (CPO) will produce solid waste and liquid waste. The current increase in waste volume is directly proportional to the increase in palm oil production. The waste generated from palm oil processing is in dire need of handling and reutilization into other products so as not to have a negative impact on the environment [1].

One of the results of palm oil solid waste is derived from the remaining combustion of oil palm shell boilers and oil palm fruit fiber. Oil palm shells which have a very thick and hard skin structure, greyish white in color due to high temperature combustion, tightly porous so that they are more rigid and dense, contain a lot of sericite or Silica dioxide (SiO_2) of 89.9105% [2], which can increase the compressive strength of asphalt mixtures because it can reduce shrinkage and increase resistance to cracking [3]. Palm oil waste ash or also called Palm Oil Fuel Ash (POFA) is ash that has undergone a grinding process from the crust in the process of burning shells and fruit fibers at a temperature of 500 - 700° C in the boiler furnace kitchen which is used for Steam Power Plants (PLTU). The combustion

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will produce ± 3 - 5 ton/week of boiler crust [4] (Jamizar, Rani, & Putri, 2013). Palm fruit shells and fibres are used mostly as boiler fuel for Palm Oil Mills. The steam from the boiler is utilized to produce Electrical energy. Combustion at 800-900°C produces ± 5% ash. POFA and fibre ash does not contain enough nutrients to be used as fertilizer, so it has not been widely used. With its small size and light weight, ash is easily carried by the wind to become a fog that reduces visibility, which can cause traffic accidents and health problems [5].

The problem that then arises is the residue of combustion in the form of ash (POFA) with an increasing amount throughout the year and until now it is still not optimally utilized so that it increasingly requires large land to accommodate POFA.

POFA is a by-product of burning palm fibre and palm kernel shells as biomass fuel in palm oil mills. POFA can be used as a filler in asphalt mixtures because it fills the gaps between aggregate particles, increasing the stability of asphalt mixtures [6]. POFA can also be used as pozzolan, which is a fine material containing silica and alumina that can react and form cementitious materials. POFA contains high silicon dioxide and has the potential to be used as a substitute for cement. Proper utilization of POFA can reduce the use of cement and reduce the volume of waste so that it is very beneficial for environmental sustainability [7].

The wearing course, also known as the wearing layer, is the first layer to withstand vehicle loads and receive friction and vibration of braking vehicle wheels. The wear layer also serves to spread the load it receives to the foundation layer. Therefore, the wear layer must use an asphalt binder that produces an impermeable layer, so that rainwater that falls on it does not seep into the layer below which can lead to damage to the pavement structure, high stability, and durability during the service period [8]. One of the causes of damage and decreased strength of flexible pavement is the low strength and durability in the wear layer and bonding material of pavement construction. To overcome this, an additional material is needed that can increase the strength of the asphalt mixture in the asphalt concrete layer [9].

Asphalt mixtures are formed from a bond between coarse aggregate, medium aggregate, fine aggregate, fillers plus asphalt as a binder and additives and stabilizers if required. Mud on the aggregate also affects the weakening of asphalt adhesion and bonding between aggregate grains which will cause damage faster before reaching the planned age, one of which is the formation of holes in the road surface layer [10]. The addition of fillers to asphalt mixtures aims to fill the voids between aggregates so that the bond between aggregates becomes more solid, so that the air voids become smaller and produce friction resistance and high intergranular locking, which will increase the stability of the mixture [11]. The material that is often used as a filler is stone ash derived from stone crushers. With the rapid development of road construction, it also has an impact on the need for filler use, so an alternative material is needed to replace stone ash as a filler in asphalt mixtures. The waste of burning oil palm shells in the form of ash is expected to be one of the alternative fillers in asphalt mixtures.

With the Circular Letter Number 15/SE/Db/2024 about Manual Desain Perkerasan Jalan 2024 which states that for wear layers and intermediate layers in the planning of new pavements with planned traffic ESAL> 30 million, the use of modified asphalt is recommended, namely PG-70 Asphalt (Performance Grade). And for additional layers on existing pavements that have a cumulative load of >10 million ESA4 and ESA5 for the calculation of additional layers with asphalt mixtures are also recommended to use modified asphalt [12].

PG 70 asphalt has a high stability value so that it can withstand deformation due to traffic loads without experiencing permanent changes in shape such as waves (permanent deformation), grooves or bleeding (the release of asphalt to the surface), is resistant to weather changes and can withstand heavy traffic loads. PG 70 asphalt has a higher softening point value than pertamina asphalt, so it is stronger in the face of extreme weather like in Indonesia compared to pertamina asphalt which has a lower softening point [13]. So that the use of modified asphalt is intended to extend the service life, fatigue life and deformation resistance of the pavement surface layer due to heavy traffic loads. Modified asphalt can also widen the range of traffic load volumes for the use of thin asphalt overlays and wear layers with heavy traffic.

Based on the description above, the release of Manual Desain Perkerasan Jalan 2024, the increasing volume of palm oil waste that requires handling and reuse, and the need for alternative materials to be used as fillers, a study was conducted to determine the effect of POFA as a filler in a mixture of penetration grade asphalt (PG70). Thus, it is expected that the use of palm oil boiler ash as a filler and PG-70 asphalt will become a pavement mixture containing environmentally friendly road construction materials as well as a solution for the use of palm oil waste that can withstand heavy traffic loads.

II. Method

Modified Asphalt Concrete consists of Modified AC-WC with a maximum aggregate size of 19 mm, Modified AC-BC with a maximum aggregate size of 25.4 mm, and Modified AC-Base with a maximum aggregate size of 37.5 mm. The combined gradation of CA, MA, FA and Filler aggregate fractions must fulfil the limits given in Table 1. The aggregate material used in this study came from the Binjai area of North Sumatra Province, the asphalt used was PG 70 modified asphalt and POFA which consisted of palm oil shells and fibres from Pusat Penelitian Kelapa Sawit (PPKS)of North Sumatra Province. All tests were carried out in the Civil Engineering laboratory of Politeknik Negeri Medan.

Table 1. Materials Testing

No.	Test Type	Number of Specimens	Standart
1	Sieve analysis of fine aggregate, medium aggregate and coarse aggregate	3 (@1 per aggregate type)	SNI ASTM C136:2012
2	Specific gravity and water absorption of fine aggregates	2	SNI 1970:2016
3	Specific gravity and water absorption of medium and coarse aggregates	4 (@2 per aggregate type)	SNI 1969:2016
4	Aggregate wear/ Abrasion	2	SNI 2417:2008
5	Sand Equivalent Testing	2	SNI 03-4428-1997
6	Asphalt Penetration	2	SNI 2456: 2011
7	Specific gravity of asphalt	2	SNI 2411:2011
8	Softening Point	2	SNI 2434:2011
9	Ductility	2	SNI 2432:2011
10	Flash Point	2	SNI 2433:2011
11	Marshall Testing	30	RSNI M-06-2004
12	Sieve pass No 200	2	SNI ASTM C117: 2012
13	Specific gravity of filler (POFA)	2	SNI 1964:2008

Source: Direktorat Jenderal Bina Marga, 2020

The method used in this research is a quantitative research method with an experimental model in the laboratory through several tests or checks on the PG 70 asphalt mixture with filler in the form of POFA, referring to the SNI in the Spesifikasi Umum 2018 Untuk Pekerjaan Konstruksi Jalan Dan Jembatan Revisi 2. Compaction of test specimens is carried out with 2 X 75 impacts per surface as a requirement for heavy traffic.

III. Results and Discussion

A. Analysed Data

The mixture to be made is Modified AC (Asphalt Cement) Laston for the wear layer is WC (Wearing Course), using dense graded aggregate material, the test results of sieve analysis for coarse aggregate, medium aggregate and fine aggregate are shown in Table 2 below.

Table 2. Test Results of Sieve Analysis

		COARSE AGGREGATE				MEDIUM AGGREGATE				FINE AGGREGATE			
Sieve Number	Size of Sieve (mm)	Weight Retained	Cumulative Retained Weight	Percentages		Weight Retained	Cumulative Retained Weight	Percentages		Weight Retained	Cumulative Retained Weight	Percentages	
				Retained	Pass			Retained	Pass			Retained	Pass
3/4"	19.5	0	0	0	100	-	-	-	-	-	-	-	-
1/2"	12.5	4446.8	4446.8	81.19	18.81	0	0	0	100	-	-	-	-
3/8"	9.5	927.2	5374	98.12	1.88	55.2	55.2	1.85	98.15	-	-	-	-
No 4	4.75	84.2	5458.2	99.65	0.35	1715.6	1770.8	59.23	40.77	0	0	0	100
No 8	2.36	0.8	5459	99.67	0.33	1019.9	2790.7	93.35	6.65	112.4	112.4	22.2	77.8
No16	1.18	0.6	5459.6	99.68	0.32	99.1	2889.8	96.66	3.34	129	241.4	47.68	52.32
No 30	0.6	0.4	5460	99.69	0.31	14.6	2904.4	97.15	2.85	91.4	332.8	65.73	34.27
No 50	0.3	0.9	5460.9	99.7	0.3	8.7	2913.1	97.44	2.56	62.9	395.7	78.16	21.84
No 100	0.15	1.4	5462.3	99.73	0.27	13.7	2926.8	97.9	2.1	45.7	441.4	87.18	12.82
No 200	0.075	5.9	5468.2	99.84	0.16	15.5	2942.3	98.42	1.58	31.2	472.6	93.34	6.66
PAN		8.9	5477.1	100	0	47.2	2989.5	100	0	33.7	506.3	100	0
Jumlah		5477.1				2989.5				506.3			

The percentage of weight loss in the sieve analysis tests for coarse aggregate, medium aggregate and fine aggregate met the weight loss tolerance of <1% as shown in Table 3.

Table 3. Results of Aggregate Specific Weight Test

Material	Bulk Specific Gravity	Specific Gravity SSD	Apparent Specific gravity	Water Absorption
CA	2.668	2.692	2.733	0.894
MA	2.651	2.674	2.713	0.865
FA	2.615	2.644	2.694	1.122

From the results of the specific gravity test shown in Table 3, the effective specific gravity value of the average bulk specific gravity and apparent specific gravity for CA material is 2.701, MA is 2.682 and FA is 2.654.

Some tests were conducted only to determine the consistency of material behaviour and properties, as it did not have standard requirements in the Specifications such as POFA Specific Weight, Penetration, Specific Weight, Softening Point and Ductility of PG 70 Asphalt. Thes result sown in Table 4.

Table 4. Results of Testing Properties of Aggregate Materials and PG 70 Asphalt

Test	Standard	Result	Description
Differences in specific gravity of coarse and fine aggregates	Max 0.2	0.046	Required
Water absorption of aggregates	Max 3 %	Coarse Aggregate = 0.894 Medium Aggregate = 0.865 Fine Aggregate = 1.122	Required
Specific Gravity of POFA	-	1.8765	No special requirements
Abrasion	Max 40 %	19.26%	Required
Sand Equivalent	Min 50%	82.42%	Required
Penetration of PG 70 Asphalt	-	52.7	No special requirements
Specific gravity of PG 70 Asphalt	-	1.059	No special requirements
Softening point of PG 70 Asphalt	-	24.01°C	No special requirements
Flash Point of PG 70 Asphalt	≥ 230	282 °C	Required
Burning point of PG 70 Asphalt	-	290 °C	No special requirements
Ductility of PG 70 Asphalt	-	14.85	No special requirements

Based on the Marshall Characteristic values obtained, the calculation of the Optimum Asphalt Content (KAO) value of 5.41% was carried out which became the basis for planning the PG 70 asphalt mixture with POFA filler. POFA was substituted as stone ash filler in PG 70 asphalt mixtures with 0%, 25%, 50%, 75% and 100% replacement variations, and the resulting marshal characteristic values are shown in Table 5 below.

Table 5. Results of Marshall Characteristics of PG 70 Asphalt Mixture with POFA Filler

Test Result	Variation of POFA Filler (%)				
	0	25	50	75	100
Density (gr/ml)	2.321	2.337	2.323	2.285	2.267
Stability (kg)	1713.868	2160.201	2016.938	1514.917	1983.151
Flow (mm)	4,30	4.95	5.30	4.45	5.10
VIM (%)	3.370	2.704	3.283	4.874	5.603
VFA (%)	77.976	81.532	78.340	70.608	67.748
VMA (%)	15.2267	14.6430	15.1502	16.5464	17.1858

B. Result and Analysis

The Marshall characteristics results shown in Fig. 1, show that the addition of POFA shows a decrease in the density value although overall the 0%-100% filler variation produces a good density value between 2-3 gr/ml. This occurs because the higher the level of POFA filler added, the fewer voids filled by asphalt and the higher the pore content in the mixture, so that mixtures with a high percentage of POFA cause the mixture to be less dense than those with a small addition of POFA.

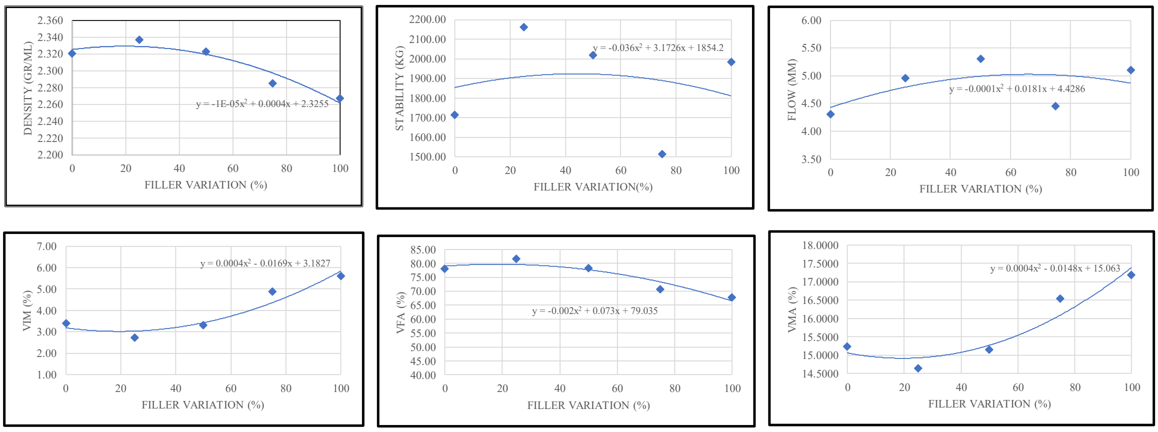

Fig. 1. Relationship Graph of Marshall Characteristics with % Variation of POFA Filler

The stability value of PG 70 asphalt mixture with POFA filler resulted in a minimum value at 75% POFA filler content of 1514.917 kg and a maximum value at 25% POFA filler content of 2160.201 kg. But overall the variation of filler content, the stability value is quite high, above 1000 kg.

All flow values in PG 70 asphalt mixtures with POFA filler do not meet the requirements of the Spesifikasi Umum 2018 for Road and Bridge Construction Revision 2 because the values are above 4 mm. The flow value indicates the amount of deformation of the mixture due to the load acting on the pavement, which is influenced by the type and content of asphalt. The flow value is an indicator of the flexibility of the mixture, which is needed so that the pavement has flexible properties against loading. When loading occurs on the pavement, the mixture will extend to follow the loading so that the pavement does not crack. The enlarged voids filled with asphalt (VFA) make the flow range also greater. The higher the flow value, the stiffer the mixture will be so that during repeated loading it will easily cause waves and grooves in the pavement (Sukirman, 2016).

VIM values that meet the requirements are only in the variation of 0%, 50% and 75% POFA content, while those that do not meet the 25% and 100% variation levels because the value is below 3% for the 25% variation and above 5% for the 100% variation. To fulfil the VIM value requirement, the use of POFA filler must be varied with different filler materials. This is because the level of POFA filler added prevents the asphalt from filling the voids in the mixture. The more POFA filler content used, the larger the cavity formed so that the mixture is porous. VIM values that are too small (less than 3%) can result in bleeding of the pavement when the temperature increases and cause plastic grooves and soaks in the pavement.

The higher the PG 70 bitumen content used, the higher the VFA value. A large VFA value means that more air voids are filled with asphalt, so the resistance of the mixture to water and air will be higher, this condition affects the durability of the asphalt.

The VMA value that meets the requirements of Spesifikasi Umum 2018 for Road and Bridge Construction Revision 2, which is above 15%, is in the variation of 0%, 50%, 75% and 100% POFA filler content. To qualify the VMA value at variations below 50%, the use of POFA filler must be varied with different filler materials. The VMA value is influenced by the asphalt content, the shape and gradation of the aggregate and the amount and temperature of compaction.

IV. Conclusion

From the description above, it can be concluded that the use of POFA as filler in PG 70 asphalt mixtures produces stability values above 1000 kg, density 2-3 gr/ml, VFA above 65% in all variations of filler content, for VIM values above 3-5% are in variations of 50% and 75% filler content, VMA values above 15% are in variations of 50%, 75% and 100% filler content, while the flow of mixtures using POFA does not provide standard values between 2-4 mm for all variations of filler content. PG 70 asphalt mixtures with POFA filler produce good density and stability values so that they can be used for pavements with high traffic volumes, but they are very easy to deform and allow bleeding because the VFA value is very high. The most optimal composition obtained from this research is in the variation of 50% filler content with a stability value of 2016.938 Kg, flow 5.3 mm, density 2.323 gr/ml, VIM 3.283%, VMA 15.1502%, and VFA 78.340%.

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