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Deformation Resistance of Plastic Asphalt Mixture on Various Temperatures in Field

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Abstract:- One of the settlement efforts of plastic waste conducted in Indonesia is by using it as material of asphalt mixture. The plastic waste used is LDPE (low density polyethylene), which is proved increasing deformation resistance of asphalt pavement. The deformation resistance test of asphalt pavement commonly conducted with just one test temperature, it is 60^0c which is assumed as the representation of the highest temperature received by the asphalt pavement at noon. Actually the asphalt pavement itself experience traffic load in various temperatures along the day. These various temperatures are important to be a consideration to investigate that plastic asphalt mixture is not just superior in highest temperature, but also in various temperatures in field along the day. In this research, conducting test on plastic and conventional asphalt mixtures using wheel tracking machine with various temperatures based on temperature measurement at two locations of road in Palembang and Bengkulu cities, which plastic asphalt mixture will be applied. According to the test, the plastic asphalt mixture has higher dynamic stability value than conventional asphalt mixture has in every test temperatures. On test temperature of 35ºc, 40ºc, and 46ºc, the plastic asphalt mixtures have dynamic stability value generate 21.000, 14.700, and 12.600 passing/minute. While the conventional asphalt mixtures have dynamic stability value generate 10.000, 8.625, and 7.292 passing/minute. It is looked that even on test temperature of 46ºc, the dynamic stability value of plastic asphalt mixture is still higher than the dynamic stability value of conventional asphalt mixture tested on lower temperature of 35ºc. Besides of its dynamic stability value, the superior of plastic asphalt mixture seems also in its permanent deformation and deformation rate value.

Keywords:- *Deformation Resistance; Dynamic Stability; Plastic Asphalt Mixture; Temperature; Wheel Tracking Machine.*

I. INTRODUCTION

Indonesia is one of the coutries having large number of plastic waste. In 2015, there were around 3.3 million tons of plastic waste in Indonesia which had not been managed well (Jambeck,2015). The settlement effort of plastic waste is not a simple work. If the plastic waste is burnt, it will produce dangerous poisonous gas. If the plastic waste is buried into the soil, it will need hundred years to unravel. One of the settlement efforts conducted by government of Indonesia is using it as material of asphalt mixture.

Several researchs show that plastic asphalt mixture has several advantages rather than conventional asphalt mixture. One of them is enhancement of deformation resistance in wheel tracking machine test, which the test itself conducted by test temperature of 60ºc (Suaryana Nyoman, 2018). Commonly the test of plastic asphalt mixture using wheel tracking machine conducted with just one test temperature, it is 60ºc which is assumed as the representation of the highest temperature received by the asphalt pavement at noon. Whereas the asphalt pavement itself experience traffic load in various temperatures along the day. Starting from low temperature at morning, then increasing to high temperature at noon, and decreasing to lower temperature at afternoon. The test of asphalt mixture using wheel tracking machine with various temperatures ever conducted by Widodo Sri (2013), but the asphalt mixture tested was not the plastic asphalt mixture. She investigated conventional asphalt mixture in various density. She conducted test of asphalt mixture on test temperature of 30ºc, 45ºc, dan 60ºc. They are a representation of temperature received by flexible pavement from morning to afternoon.

In this research, conducting also analysis on deformation resistance value of wearing course of asphalt mixture using wheel tracking machine with various temperatures. But the difference is that the asphalt mixtures used in this research are plastic and conventional asphalt mixtures, and the test temperature used is the result of direct measurement of temperature received by asphalt pavement in field. The plastic waste used in this plastic asphalt mixture is low density polyethylene (LDPE) with plastic content of 6%. It is because the plastic asphalt mixture with plastic content of 6% had been applied in Indonesia in 2018.

II. LITERATURE REVIEW

A. LDPE Plastic Waste

One of plastic type which can be used as a material of asphalt mixture is LDPE plastic. LDPE plastic has specific gravity between 0.91 – 0.94 g/ml and has melting point ± 115°c. The chemical content of LDPE plastic itself is almost same as high density polyethylene (HDPE) plastic, but physically LDPE plastic is more flexible. LDPE belong to plastic type having good resistance on water and chemical. Commonly LDPE plastic is used as plastic bag and flexible bottle.

The use of LDPE plastic waste itself is proved increasing the deformation resistance value of asphalt mixture. Suaryana Nyoman (2018) used addition of LDPE plastic waste into asphalt mixture with plastic waste content of 0%, 5% and 10%. The LDPE plastic waste was chopped using plastic chopping machine until has small size. According to the test, the asphalt mixture with addition of plastic waste has higher dynamic stability value than conventional asphalt mixture has. Even the dynamic stability value showed on the plastic asphalt mixture with plastic waste content of 10% reaches eight times bigger than conventional asphalt mixture.

B. Plastic Asphalt Mixture

Several researches relating to the utilization of plastic waste in asphalt mixture show that the asphalt mixture become more elastic and more resistant on deformation. One of them is the research of plastic asphalt waste conducted by the center of research and development of road and bridge of Indonesia (2017). It used plastic waste in asphalt mixture with content of 0%, 5%, 6%, 8%, and 10 %. The result shows that the asphalt mixture with addition of plastic waste has higher dynamic stability than conventional asphalt mixture has. But the value of remain marshall stability experince decreased and the asphalt mixture tend to more brittle in addition of plastic waste content which more than 6%. Then since 2018 the plastic asphalt mixture with plastic content of 6% was used in several cities of Indonesia as pilot project.

C. Temperature Effect on Asphalt Mixture

Global warming and high traffic jam in several cities make the temperature received by flexible pavement becoming higher and higher. The high temperature can make the flexible pavement becoming weak, even resulting permanent deformation. Hardiyatmo Hary Christiady (2015) explained that the various temperatures received by flexible pavement will result the temperature gradient along its thickness. The temperature gradient and traffic load which over and over will reduce modulus of asphalt mixture which cause fatigue and permanent deformation.

Widodo Sri (2013) conducted test of asphalt mixture using wheel tracking machine with test temperature of 30°c, 45°c, and 60°c. These various temperatures are assumed as representation of temperature received by flexible pavement in Indonesia. The temperature of 60°c as a temperature representation of flexible pavement at noon, the temperature of 30°c as a temperature representation of flexible pavement at morning and afternoon, and the temperature of 45°c as a temperature representation of flexible pavement at morning towards noon or noon towards afternoon. The result of her research shows that the higher temperature received by asphalt mixture, its ability gets lower on resisting the vehicle tire trace.

D. Deformation Resistance

The test procedure and the calculation of deformation resistance value using wheel tracking machine are explained in Japan Road Association (1989). According to the test result of asphalt mixture using wheel tracking machine, it will be obtained the deformation graph of wheel tracking machine test. It will be used to determine the value of deformation resistance of asphalt mixture based on three parameters, they are permanent deformation, deformation rate, and dynamic stability. The deformation value is calculated between minutes of 45 and 60, which the deformation graph approaches the straight line and indicates that deformation process is in more stable value. The deformation value occuring at minutes 45 is taken as a starting point of deformation or in other words permanent deformation, whereas the deformation value occuring at minutes 60 is taken as an endpoint of deformation. To determine the value of deformation rate and dynamic stability, it can be seen in Equation 1 and 2.

$$\text{Deformation rate (mm/minute)} = \frac{(d_2 - d_1)}{(t_2 - t_1)} \quad (1)$$

$$\text{Dynamic stability (passing/mm)} = 42 \times \frac{(t_2 - t_1)}{(d_2 - d_1)} \quad (2)$$

Which, d_1 = deformation value at minutes of 45; d_2 = deformation value at minutes of 60; t_1 = minutes of 45; t_2= minutes of 60.

III. MATERIALS AND METHODS

This research is an experimental study conducted to investigate deformation resistance value of plastic and conventional asphalt mixtures using wheel tracking machine with various temperatures. Flow chart of this research can be seen in Figure 1.

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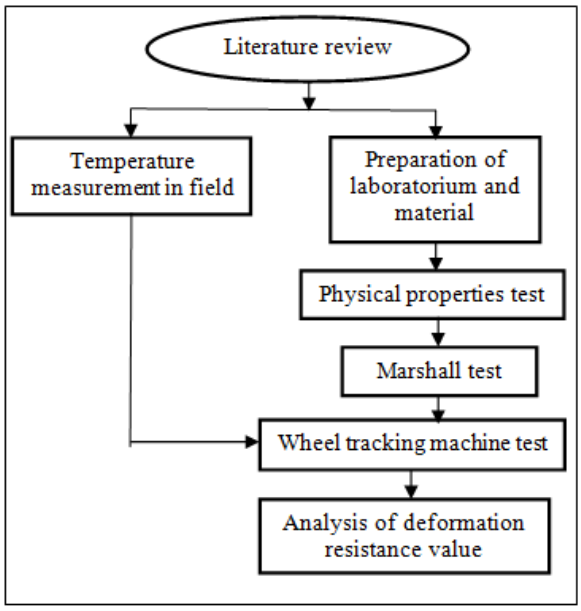

Fig 1:- Research Flow Chart

The research is started with literature review relating to the research itself, such as plastic waste, plastic asphalt mixture, wheel tracking machine test, and etcetera. Then continuing with activity of laboratorium and material preparation, and temperature measurement in field which will be used as test temperature in wheel tracking machine test. The materials are plastic waste of LDPE, aggregate, asphalt, and cement. Before they are used into asphalt mixture, these materials need to be checked first about their physical properties. For aggregate, asphalt, and cement, they must to meet the specification determined in Bina Marga's general specification of road and bridge 2018. Whereas for the LDPE plastic waste, it must to meet the specification of SKH-1.6.10 2017 about interim special specification of hot asphalt mixture using plastic waste. Having they meet all requiring specifications, then determining mix design of marshall test based on AASHTO T-245-97. Then conducting marshall test to obtain the value of optimum asphalt content. This value of optimum asphalt content will be used in making specimen of wheel tracking machine test. Finally conducting wheel tracking machine test with test temperature obtained by temperature measurement in field. The result of wheel tracking machine test will be analyzed to obtain the deformation resistance value of conventional and plastic asphalt mixtures.

A. Temperature Measurement in Field

This stage is aimed to obtain the maximum temperature value received by flexible pavement in field at morning or afternoon, noon, and morning towards noon or noon towards afternoon. These maximum temperatures will be used as test temperature in wheel tracking machine test. The temperature measurement is conducted in Bengkulu and Palembang Cities. They are Indonesia's cities choosed as a location of temperature measurement. Temperature measurement is conducted using hygrothermometer. These maximum temperatures used as a reference for the test temperature of wheel tracking machine test. According to the result of temperature measurement, then the temperatures used in the wheel tracking machine test are 35°c, 40°c, dan 46°c. The result of temperature measurement in field can be seen in Table 1 and 2.

Time	Bengkulu City		Palembang City	
	Day 1 (°C)	Day 2 (°C)	Day 1 (°C)	Day 2 (°C)
06.00 - 07.00	28.4	28.2	29.1	29.4
07.00 - 08.00	30.4	29.3	32.9	32.7
08.00 - 09.00	32.4	30.5	35.5	34
09.00 - 10.00	35.3	34.7	38	36.4
10.00 - 11.00	38.2	36.2	41.4	40.6
11.00 - 12.00	41.9	40	42.4	41.2
12.00 - 13.00	43.6	42.4	44.9	45.7
13.00 - 14.00	41.6	40.4	42.2	41.9
14.00 - 15.00	37.1	37.8	40	39.1
15.00 - 16.00	34.7	35.6	38.4	38.8
16.00 - 17.00	31.1	32.7	34.8	35
17.00 - 18.00	30.3	29.8	32.1	31.7

Table 1:- Temperature Measurement Result

	06.00 – 08.00 And 16.00 - 18.00	08.00 - 10.00 And 14.00 - 16.00	10.00 - 14.00
Minimum	28.2	30.5	36.2
Average	31.1	36.1	41.5
Maximum	35.0	40.0	45.7

Table 2:- Recapitulation of Temperature Measurement Result

B. Preparation of Laboratorium and Material

This research use analysis and experiment methods. In this experiment activity, it is required a laboratorium supporting for conducting an experiment activity of asphalt mixture. The specimens in this research are two kinds, they are sample of conventional and plastic asphalt mixtures. The materials are required to make conventional asphalt mixture referring to Bina Marga's general specification of road and bridge 2018. According to it, the materials used consist of aggregate, filler, and asphalt. Whereas the materials are required to make plastic asphalt mixture referring to SKH-1.6.10 2017 about interim special specification of hot asphalt mixture using plastic waste. According to it, the materials used to make plastic asphalt mixture consist of aggregate, plastic waste, filler, and asphalt.

C. Physical Properties Test

Material physical properties test is required to see whether materials are worthy or not to be used in this research. If the preparing materials have met the specification, then they can be used in the research. However, if the preparing materials have not met the specification, they should to be replaced by other materials.

➢ *Asphalt*

Asphalt material used in this research is asphalt with penetration of 60/70. The test of asphalt material refer to Bina Marga's general specification of road and bridge 2018. The result of asphalt material test can be seen in Table 3.

Name of Test	Test Result	Specification
Penetration test (0,1 mm)	63.6	60 – 70
Softening point (°C)	48.8 – 49	> 48
Ductility test (cm)	140	> 100
Flash point (°C)	304	> 232
Specific gravity	1.015	> 1.0

Table 3:- Asphalt Test Result

➢ *Aggregate*

Aggregate materials used in this research was got from Palembang city. They are coarse, medium, and fine aggregates. Then they were filtered appropriate to the requirement of asphalt mixture. The aggregate material test refer to Bina Marga's general specification of road and bridge 2018. Based on this test, all materials have passed the specification. The result of aggregate material test can be seen in Table 4.

Name of Test	Test Result	Specification
- Abrasion of 100 cycles (%) - Abrasion 500 cycles (%)	5.85 % 22.16 %	Max 8% Max 40%
Sand equivalency (%)	61.74 %	Min 50%
Specific gravity and absorption a. Coarse aggregate - Bulk - SSD - Apparent	 2.662 2.690 2.741	 Difference among specific gravities ≤ 0.2
- Absorption	1.087 %	Max 3%
b. Medium aggregate - Bulk - SSD - Apparent	2.636 2.668 2.723	Difference among specific gravities ≤ 0.2
- Absorption	1.217 %	Max 3%
c. Fine aggregate - Bulk - SSD - Apparent	2.562 2.595 2.650	Difference among specific gravities ≤ 0.2
- Absorption	1.297 %	Max 3%
Fine aggregate angularity(%)	45.50%	Min 45%
Coarse aggregate angularity a. One or more fractured face b. Two or more fractured face	 99.86% 98.95%	 Min 95% Min 90%
Viscosity (%)	95%	Min 95%
Elongation (%)	3.79%	Max 10%

Table 4:- Aggregate Material Test Result

➢ *Plastic Waste*

The plastic waste utilization into asphalt mixture is one of the government's ways to handle plastic waste problem. The plastic waste make the asphalt mixture experiencing the enhancement of dynamic stability value, more elastic and more resistant to deformation. The plastic waste type used in this research is LDPE (low density polyethylene). LDPE plastic waste has good durability against water and high chemical substance. The percentage of LDPE plastic waste used into plastic asphalt mixture is 6%, because the plastic asphalt mixture with plastic waste content of 6% has already apllied in several cities in Indonesia. The plastic waste is mixed using dry process mixing technique. It mix the plastic waste first with aggregate in temperature of 170 ^{o}c, then it is mixed again with asphalt. The plastic waste used in this research was recycled and processed until meeting the specification of SKh-1.6.10 2017 about interim special specification of hot asphalt mixture using plastic waste. The result of this plastic waste test can be seen in Table 5.

Name of Test	Test Result	Specification
Material passing sieve of 9,5 mm (%)	100	100
Material passing sieve of 4,75 mm (%)	95	min 90
Thickness (mm)	0.03	Max 0.07
Water content (%)	2	Max 5
Melting point (°c)	115	100 – 120

Table 5:- The Result of LDPE Plastic Waste Test

D. Physical Properties Test

The stage of marshall test is conducted according to AASHTO T-245-97, aiming to obtain the value of optimum asphalt content, which will be used as asphalt content in specimen composition of wheel tracking machine test. The marshall test is conducted on conventional and plastic asphalt mixtures. The determination of optimum asphalt content value is adjusted to Bina Marga's general specification of road and bridge 2018. The value of optimum asphalt content which is obtained from the marshall test of conventional asphalt mixture is also used as value of asphalt content of plastic asphalt mixture, but its weight has been reduced 6% (of the asphalt weight) as weight of the plastic waste. The marshall test result of the plastic asphalt mixture must to meet the Indonesia's specification of SKH-1.6.10 2017 about interim special specification of hot asphalt mixture using plastic waste.

E. Wheel Tracking Machine Test

The test conducted in this stage is the test of deformation resistance of hot asphalt mixture with giving various test temperatures. This test is conducted by wheel tracking machine with the test standard referring to Japan Road Association (1989). When the test is going on, the tire speed is 42 pass/minute and the tire pressure is 6.4 $\pm$ 0.15 kg/cm^2. This machine is also equipped with ability giving temperature treatment to the specimen. So in this research, the test sample is given the test as tire steel passing on it with certain number of passing and this test take place in various test temperatures. The temperature used in this test is the temperature obtained from the temperature measurement result in field.

IV. RESULT AND DISCUSSION

A. Marshall Test Result

The Marshall test result of conventional asphalt mixture is adjusted to the specification of Bina Marga's general specification of road and bridge 2018. According to the marshall test result, the value of optimum asphalt content meeting the specification is 6.1%. This value is also used as value of asphalt content in marshall test of plastic asphalt mixture, but its weight has been reduced 6% (of the asphalt weight) as the weight of plastic waste. The marshall test result of plastic asphalt mixture must to meet the Indonesia's specification of SKH-1.6.10 2017 about interim special specification of hot asphalt mixture using plastic waste. According to the marshall test of plastic asphalt mixture, it is got that the asphalt content used into this plastic asphalt mixture has met the specification. The result of marshall test of conventional and plastic asphalt mixture can be seen in Table 6 and 7.

Asphalt Content (%)	VMA (%)	VFA (%)	VIM (%)	Flow (mm)	Stability (Kg)
Specification	min 15 %	min 65 %	3% - 5%	2 - 4 (mm)	min 800
4.6	16.76	46.69	8.93	3.10	1660
5.1	16.83	53.50	7.82	2.80	1535
5.6	16.17	63.55	5.90	2.55	1340
6.1	15.14	76.85	3.51	2.90	1202.5
6.6	15.50	82.77	2.67	3.05	930

Table 6:- The Marshall Test Result of Conventional Asphalt Mixture

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Asphalt Content (%)	VMA (%)	VFA (%)	VIM (%)	Flow (mm)	Stability (Kg)
Specification	min 15 %	min 65 %	3% - 5%	2 - 4 (mm)	min 800
6.1	16.21	70.90	4.72	3.30	1430

Table 7:- The Marshall Test Result of Plastic Asphalt Mixture

B. The Result of Wheel Tracking Machine Test

According to the result of wheel tracking machine test, it is looked that the asphalt mixture experiences larger deformation in higher test temperature. However, the deformation of the two asphalt mixtures between the test temperature of 35ºc and 40ºc have larger deformation range than the deformation range between the test temperature of 40ºc and 46ºc. The graph of wheel tracking machine test result of the two asphalt mixtures can be seen in Figure 2 and 3.

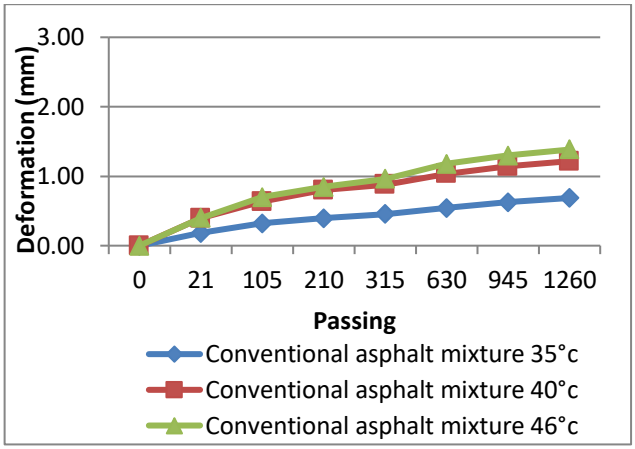

Fig 2:- The Deformation Graph of Wheel Tracking Machine Test Result of Conventional Asphalt Mixture

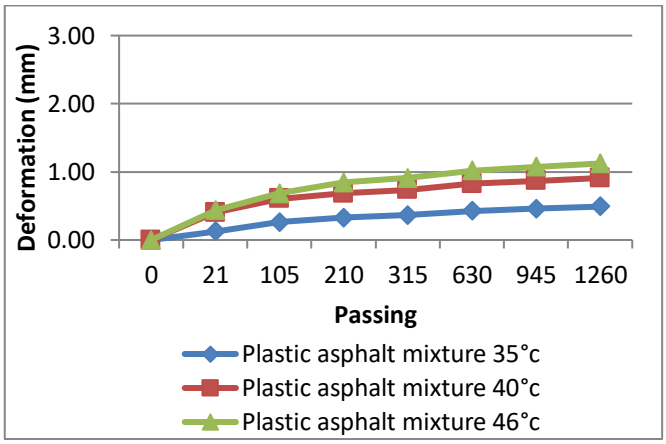

Fig 3:- The Deformation Graph of Wheel Tracking Machine Test Result of Plastic Asphalt Mixture

According to the deformation graph of the two asphalt mixtures, then determining the value of deformation resistance based on the three parameters of deformation resistance, they are permanent deformation, deformation rate, and dynamic stability. The value of deformation resistance of the two asphalt mixtures can be seen in Table 8 and 9.

Parameter	Conventional Asphalt Mixture		
	35°c	40°c	46°c
Permanent deformation (mm)	0.54	1.04	1.18
Deformation rate (mm/minute)	0.0042	0.0049	0.0058
Dynamic stability (passing/mm)	10000	8625	7292

Table 8:- The Deformation Resistance Value of Conventional Asphalt Mixture

Parameter	Plastic Asphalt Mixture		
	35°c	40°c	46°c
Permanent deformation (mm)	0.43	0.83	1.02
Deformation rate (mm/minute)	0.0020	0.0029	0.0033
Dynamic stability (passing/mm)	21000	14700	12600

Tabel 9:- The Deformation Resistance Value of Plastic Asphalt Mixture

➢ *Permanent Deformation Value*

Accoding to the value of permanent deformation in Table 8 and 9, we can see that the plastic asphalt mixture is still superior in every test temperatures. It is showed by its lower permanent deformation value than conventional asphalt mixture has. The comparison of permanent deformation value between the two asphalt mixtures is relatively same in every test temperature. But in test temperature of 35ºc to 40ºc, there is a significant increment of deformation value, nearly doubled. The comparison of permanent deformation value of the two asphalt mixtures can be seen in Figure 4.

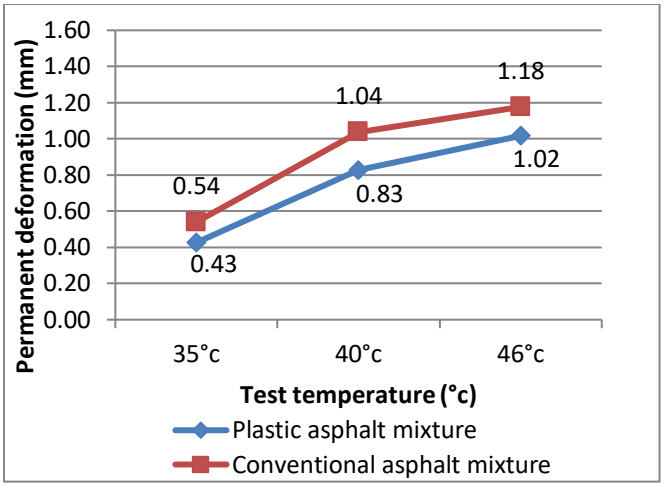

Fig 4:- The Graph of Permanent Deformation Value Between Plastic and Conventional Asphalt Mixtures

➢ *Deformation Rate Value*

According to the deformation rate value in Table 8 and 9, it is looked that the plastic asphalt mixture is still superior in every test tempertures. Its superior shows by lower deformation rate value. It means that plastic asphalt mixture is harder to be deformated than conventional asphalt mixture. The graph of deformation rate value of the two asphalt mixtures can be seen in Figure 5.

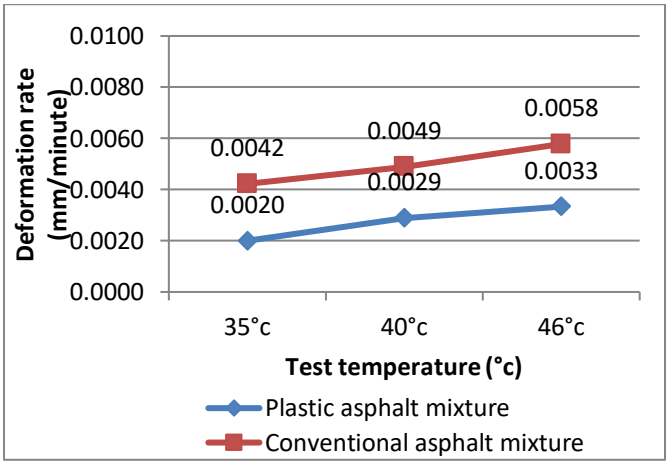

Fig 5:- The Graph of Deformation Rate value Between Plastic and Conventional Asphalt Mixtures

➢ *Dynamic Stability Value*

According to the dynamic stability value in Table 8 and 9, it is looked that plastic asphalt mixture has higher dynamic stability than conventional asphalt mixture has in every test temperatures. Even In the test temperature of 35°c, the plastic asphalt mixture has dynamic stability value nearly doubled of conventional asphalt mixture has. Moreover the dynamic stability value of plastic asphalt mixture in test temperature of 46°c is still higher than the dynamic stability value of conventional asphalt mixture tested in test temperature 35°c, which the hot level of test temperature is lower 11°c. The comparison of dynamic stability value of the two asphalt mixtures can be seen in Figure 6.

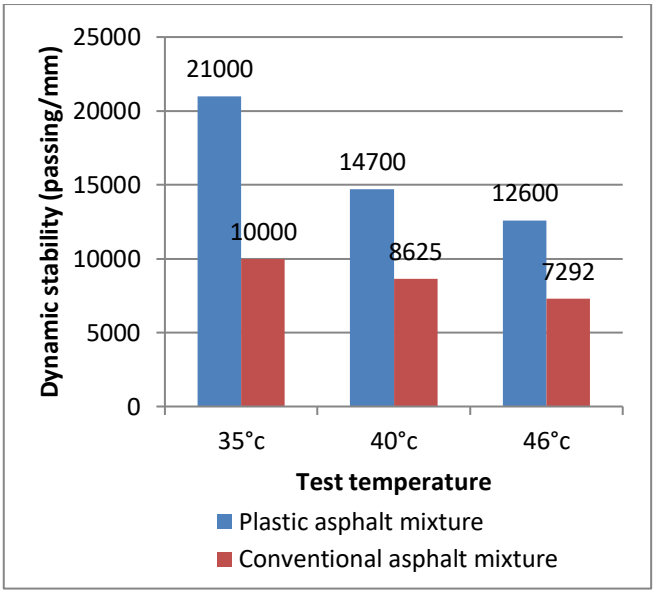

Fig 6:- The Graph of Dynamic Stability Value Between Plastic and Conventional Asphalt Mixtures

V. CONCLUSION AND RECOMMENDATION

A. Conclusion

➢ The result of temperature measurement in Bengkulu and Palembang cities conducted from morning to afternoon show that the asphalt mixture experiences traffic load with temperature between 28°c – 46°c.

➢ According to the relations among temperature in field, permanent deformation, deformation rate, and dynamic stability value, it can be concluded that the plastic asphalt mixture has superior deformation resistance than conventional asphalt mixture has along the day.

B. Recommendation

On the next research, it can conduct more investigation whether the plastic asphalt mixture is still superior or not in lower or cold temperature, because the minimum temperature which can be applied through this wheel tracking machine is just around 25°c.

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