Resistance of Fine Graded Asphalt Concrete Wearing Course to Rutting at Varying Temperatures and Densities

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Abstract

One of the road pavement distresses is rutting. Rutting occurs as the effect of the vehicle tires that roll continuously on the same wheel-path of the road pavement. Rutting occurs due to repetitive wheel loadings which cause the road to be fatigue. This research attempts to measure the capability of Asphalt Concrete Wearing Course (ACWC) layer to support rutting at varying temperatures and densities. This research is carried out using Wheel Tracking Machine that is able to measure predicted rut depth on an asphalt mixture specimen due to repetitive wheel loadings. The wheel of Wheel Tracking Machine has a width of 5 centimeters and a pressure of 6.5 kg/cm^2. The wheel of Wheel Tracking Machine moves at speed of 42 passing per minute. The test is carried out for 1 hour and the rutting is observed at the 42nd, 210th, 420th, 630th, 1260th, 1890th, and 2520th passing. The ability of asphalt concrete layer to support rutting is defined as Dynamic Stability (DS) expressing the number of wheel passing required to create 1 mm depth rutting. The specimens are in a plate form of 30 cm in length and width and 5 cm in thick, and are of 3 density: 2.293 gr/cm^3; 2.200 gr/cm^3; and 2.084 gr/cm^3. The specimens are then tested using Wheel Tracking Machine at temperatures of 30^{o}C, 45 ^{o}C, and 60^o C. The research results show that more dense ACWC has better ability to support rutting. The higher temperature in ACWC mixture results a decrease in the ability to support rutting. At higher temperature, the density does not give a significant influence in supporting rutting.

Keywords: asphalt concrete, rutting, density, temperature

1. Introduction

The road infrastructure is a critical component in trade distribution and industry service. The road network is a binding tool for national unity in social, cultural, economical, political, and security aspects. Thereby, the existence of reliable and widely-covering road infrastructure in all regions of Indonesia is a primary need that shall be given the best efforts. The function of the road as one of transportation components plays an important role in supporting the whole transportation activity in Indonesia.

Recently, the total length of existing roads in Indonesia has been approximately 355,856 kilometers including National Roads 34,629 km, Provincial Roads 50,044 km, District Roads 245,253 km, Urban Roads 23,469 km, and other kinds of road 773 km. Not all the roads are in a good condition. The National Highways in the good condition are approximately 52.2 % only, while the District and Urban Highways in good condition are 22.48% (Ditjen Bina Marga, 2010). Taking a look at the road conditions, it is quite difficult for Bina Marga as the highway administration to maintain the highways to be in a good condition. With the average road preservation cost of 0.3 billion per kilometer length, the road preservation requires a high cost. Thereby, in order to alleviate the road damage, the engineering innovation in road pavement is still needed to create a stronger pavement in supporting traffic loads and climate disturbances.

The water saturated asphalt pavement structure will be easily damaged when accepting wheel loads. The damage occurs due to pumping process that set loose the bounds amongst aggregates and water when the pavement is satured and receives repetitive wheel loads (Kandhal and Rickards, 2001). The water content in aggregate during the hot mix process decreases the resilient modulus and the ability to support deformation (Kim et all., 1985). The size of the cavity in asphalt pavement causes the reduction of asphalt penetration due to oxidation and polymeration of asphalt in the pavement structure so the road to be early damaged (Suroso, 2008). Temperature gives more influence towards the pavement performance rather than loads working on a pavement structure do (Lu et. All, 2009). The heating process during mixing causes short-term aging to asphalt, while heating from sun during road service lifetime causes long-term aging (Kliewe et. All, 1995).

The use of aggregates above Fuller curve in the asphalt mixture brings about a better resistance to rutting than those of below the Fuller curve (Utama, 2005). The thickness of aggregate coating ranging from 9.5 m to 10.5 m gives the best hot mix asphalt mixture resistance to water (Sengoz and Agar, 2006). The use of dush filler and 1% of lime in asphalt concrete mixture increases the resistance to rutting and stripping on the road surface (Kerh et. All, 2005). According to Kim et.all (1985), the water content in aggregate of hot mix asphalt mixture decreases the resilient modulus. The decrease of resilient modulus tends to increase the fatigue life, yet it decreases the resistance to deformation. The addition of 3% of rubber into asphalt concrete mixture reduces the resilient modulus and the tensile strength, yet it increases the resistance to asphalt aging (Xiao and Amirkhanian, 2008). The addition of 6% of Low Density Polyethylene (LDPE) into Split Mastic Asphalt mixture increases the stiffness modulus, but the strain decreases (Hadidy and Qiu, 2009). The addition of Fixonite at a range of 5% to 15% into asphalt concrete compacted at a temperature range 110°C to 130°C can help increase dynamic stability value and reduce deformation rate (Diana, 2005).

One of the pavement distresses is rutting. Rutting occurs as the wheel rolls on the same wheel path on the road. The rutting occurs as the pavement material goes through fatigue after being rolled on by repetitive wheel loadings. When it reaches fatigue condition, the asphalt's stability reduces so the wheelpath is formed. In the prior researches, the parameter of density of asphalt concrete and temperature of asphalt mixture is not taken into account.

The research is conducted towards fine graded Asphalt Concrete Wearing Coarse (ACWC) in the aim of finding out the influence of density and temperature towards the capability of ACWC in supporting rutting. The temperature is taken into account as a parameter as the pavement temperature range in Indonesia between 25°C to 60°C.

1. Research methodology

The research is carried out at laboratory using Wheel Tracking Machine as shown in Figure 1. The wheel of Wheel Tracking Machine moves at the speed of 42 passing per minute. The wheel of Wheel Tracking Machine is made of rubber tire with the width of 5 cm and the pressure of 6.5 kg/cm^2. The test is conducted for 1 hour, thus the total passing is 2520. The Machine is facilitated by a computer that is able to provide a report on the relationship between the number of passing and rut depth. The computer records the number of passing ad the rut depth at 1st, 5th, 10th, 15th, 30th, 45th, and 60th minute. The capability of asphalt concrete pavement to support rutting is defined by Dynamic Stability (DS) that expresses the number of passing needed to produce 1 mm rut depth. Dynamic Stability is formulated as follows:

$$DS = \frac{(L_{60} - L_{45})}{(d_{60} - d_{45})} \quad (1)$$

where :

DS = dynamic stability

L_{60} = Number of passing at 60th minute

L_{45} = Number of passing at 45th minute

D_{60} = Rut depth at 60th minute

D_{45} = Rut depth at 45th minute

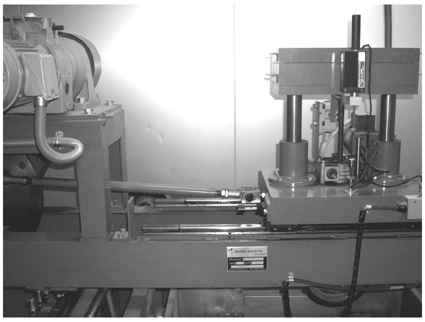

Figure 1. Wheel Tracking Machine

The specimen is an asphalt concrete plate with the width of 30 cm, the length of 30 cm, and the thickness of 5 cm. The asphalt concrete used as a specimen is fine graded Asphalt Concrete Wearing Course (ACWC) with the asphalt content of 6.7%. The aggregate mixture of ACWC has gradation as shown in Table 1, while the characteristic of ACWC mixture is shown in Table 2. The asphalt used as binding agent is asphalt cement with the penetration of 60/70. The specimens are of 3 densities 2.293 gr/cm^3, 2.200 gr/cm^3, and 2.084 gr/cm^3. The specimens are then tested using the Wheel Tracking Machine at the temperature of 30^o C, 45^o C, and 60^o C.

The varying densities in the test of ACWC represent the variation of layer thickness of asphalt concrete in the field. The density of asphalt concrete layer varies due to the varying characteristics of asphalt concrete in receiving compaction force. The density of asphalt concrete layer also varies due to the uneven distribution of working wheel loads. These loads cause the varying density increment of asphalt concrete layer after several operating hours.

The temperatures used in this research represent the real pavement temperatures in Indonesia at daytime. Temperature of 60^{o}C represents the pavement temperature at noon, while 30^{o}C represents the temperature at morning and late afternoon, and 45^{o}C represents the temperature at between morning and afternoon. The gradation of ACWC mixture is shown in Table 1 and the characteristic is shown in Table 2.

Table 1. Gradation of ACWC Aggregate Mixture

Size (mm)	19	12,5	9,5	4,75	2,36	1,18	0,6	0,3	0,150	0,075
% passing	100	95,0	81,0	61,5	46,1	35,8	26,6	18,8	12,0	7,0
Required % passing	100	90-100	72-90	54-69	39,1-53	31,6-40	23,1-30	15,5-22	9-15	4-10

Source : *Direktorat Jenderal Bina Marga*, 2010

Table 2. Characterization of Fine Graded ACWC Mixture

Characteristic of ACWC Mixture	Value	Requirement
Void in mixture (%)	4,3	3,5 - 5
Void in Aggregate (%)	19	> 15
Asphalt Filled Void (%)	78	> 65
Marshall Stability (kg)	2,000	> 800
Flow (mm)	3.4	> 3
Marshall Quotient (kg/mm)	580	> 250

Source : *Direktorat Jenderal Bina Marga*, 2010

3. Research result and discussion

The result of fine graded ACWC specimen test using the Wheel Tracking Machine at varying density and temperature is shown in Table 3. While the influence of density and temperature of ACWC towards the capability in supporting rutting is provided in Figure 2.

Table 3. Test Result of ACWC using Wheel Tracking Machine

No.	ACWC Material		Dinamic Stability
	Density (gr/cm^3)	Temperature (^{o}C)	(passing/mm)
1	2,293	60	391.3
2	2,200	60	290.3
3	2,084	60	252.0
4	2,293	45	1,909.0
5	2,200	45	1,235.3
6	2,084	45	630,0
7	2,293	30	3,150.0
8	2,200	30	2,100.0
9	2,084	30	1,312.5

From the Figure 2, it is found that the more dense ACWC asphalt concrete layer has a better capability in supporting rutting. At temperature 30^{o}C the dynamic stability of asphalt concrete increase as addition of density according to equation y = 8,714.4 x – 16,917. At temperature 45^{o}C the equation is y = 6,066.2 x – 12,085 and at temperature 60^{o}C the equation is y = 652.96 x – 1,120.3. Meanwhile, as the ACWC asphalt concrete has higher temperature, the capability in supporting rutting reduces. From equations it can be also found that at temperature 60^{o}C, the density of asphalt concrete not give significant influence in supporting rutting.

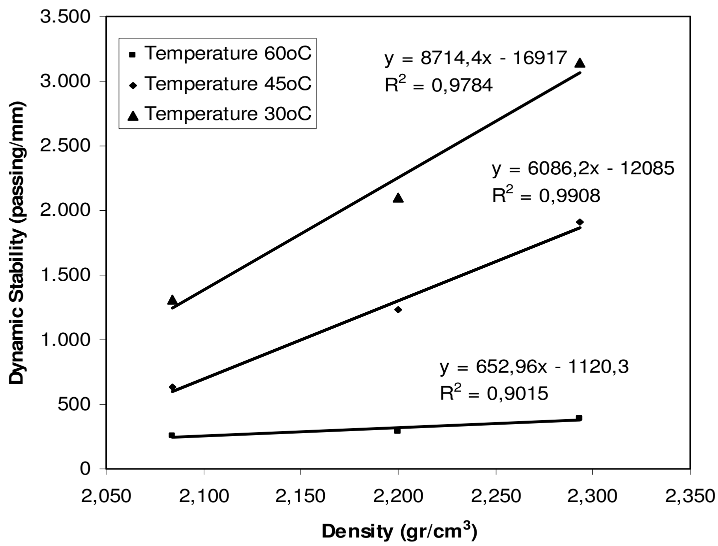

Figure 2. Influence of Desity and Temperature towards Dynamic Stability of ACWC

The influence of density and temperature towards dynamic stability of ACWC mixture is expressed using 2 independent variables in the following equation :

$$Y = -7226{,}4 + 5151{,}2\, X_1 - 62{,}5\, X_2 \quad (2)$$

where : Y = Dynamic stability (passing/mm)

X_1 = Density (gr/cm^3)

X_2 = Temperature (^{o}C)

Equation 2 is limited into densities between 2.08 gr/cm^3 and 2.31 gr/cm^3 and temperatures between 30^{o}C and 60^{o}C. The sensitivity of density is about 0.05 gr/cm^3 and the sensititivity of temperature is about 1^{o}C. Every increasing density 0.05 gr/cm3 will enhancing the dynamic stability about 255 passing/mm, but increasing 1^{o}C of temperature the dynamic stability will reduce about 62,5 passing/mm. So it can be concluded that density gives more influence towards ACWC's dynamic stability rather than temperature does. The dynamic stability of ACWC mixture will be maximized by the density of 2.31 gr/cm^3 and the temperature of 30^{o}C.

4. Conclusion and recomendation

4.1.Conclusion

From the test results, it can be concluded as follows:

1. More dense ACWC mixture gives better capability in supporting rutting. The rate of enhacing the dynamic stability is about 255 passing/mm for addition of density 0.05 gr/cm^3.
2. Higher temperature of ACWC mixture results in the decrease of capability in supporting rutting. The rate of reducing the dynamic stability is 62,5 passing/mm for addition of temperature 1^{o}C.
3. Higher temperature of ACWC mixture makes density not give significant influence towards capability in supporting rutting.

4.2.Recommendation

The following researches are recommended:

1. The relationship model between aggregate grading and the capability of geogrid reinforced asphalt concrete layer in supporting rutting.
2. The role of different types of geogrid in supporting different types of asphalt concrete layer.
3. The influence of the binder layer towards dynamic stability of geogrid reinforced asphalt concrete.

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Refferences

Diana, I.W, 2005. "*Pengaruh Penambahan Fixonite dan Suhu Pemadatan Terhadap Unjuk Kerja Campuran Beton Aspal*". Jurnal Transportasi Vol.5, No.1, pp 73-86, Forum Studi Transportasi Antar Perguruan Tinggi, Bandung

Direktorat Jenderal Bina Marga, 2010. *Rencana Strategis Bina Marga 2010-2014*. Yayasan Penerbit PU, Jakarta.

Direktorat Jenderal Bina Marga, 2010a. *Spesifikasi Umum Bidang Jalan dan Jembatan Divisi 6 Perkerasan Beraspal*. Pusat Litbang Jalan dan Jembatan Badan Penelitian dan Pengembangan, Bandung.

Hadidy, A.I.A and Qiu, T.Y., 2009. "Effect of Polyethylene on Life of Flexible Pavements ". Construction and Building Materials Vol.23, pp 1456–1464, Elsevier , Miamisburg United States

Kandhal, P.S. and Rickards, I.J., 2001." Premature Failure of Asphalt Overlays From Stripping : Case Histories". National Center for Asphalt Technology of Auburn University, Report 01-01, Alabama.

Kerh,T., Wang, Y.M., Lin, Y., 2005. "Experimental Evaluation of Anti-stripping Additives Mixing in Road Surface Pavement Materials". American Journal of Applied Sciences Vol. 10, No. 2, pp1427-1433

Kim, O.K., Bell, C. A., and Hicks, R. G., 1985. "The Effect of Moisture on the Performance of Asphalt Mixtures"**.** *Water Damage of AsphaltPavements: Its Effect and Prevention, ASTM STP 899, edited by* B.E. ruttingh, pp. 51-72, American Society for Testing and Materials, Philadelphia

Kliewer, J. E., Bell, C. A., and Sosnovske, D. A., 1995. "Investigation of the Relationship Between Field Performance and Laboratory Aging Properties of Asphalt Mixtures". *Engineering Properties of Asphalt Mixtures* *and the Relationship to their Performance, ASTM STP 1265*, edited by Gerald A. Huber and Dale S. Decker, pp.3-20, American Society for Testing and Materials, Philadelphia

Lu,Y., P.J. Wright, P.J., Zhou, Y., 2009, "Effect of Temperature and Temperature Gradient on Asphalt Pavement Response'. Road & Transport Research, Vol 18 No.1 pp 19-30, School of Civil Engineering Southwest Jiaotong University Chengdu, 610031, P.R. China

Sengoz, B., Agar, E., 2006. "Effect of Asphalt Film Thickness on the Moisture Sensitivity Characteristics of Hot-Mix Asphalt". Building and Environment Vol.42 No.1 pp 3621–3628, Elsevier Ltd.

Suroso, T.W., 2008. "Faktor-Faktor Penyebab Kerusakan Dini Pada Perkerasan Jalan". Jurnal Jalan dan Jembatan Vol. 25 No.3, Bandung.

Utama, D., 2005. "Pengaruh Gradasi Agregat Terhadap Kedalaman Alur Roda Pada Campuran Beton Aspal Panas". Jurnal Transportasi Vol.5, No.1, pp 87-98, Forum Studi Transportasi Antar Perguruan Tinggi, Bandung

Xiao, F. and Amirkhanian, S.N., 2008. "Resilient Modulus Behavior of Rubberized Asphalt Concrete Mixtures Containing Reclaimed Asphalt Pavement". Road Materials and Pavement Design, Vol. 9, No. 4, pp 633 – 649, Lavoisier, Paris