IOP Conf. Series: Materials Science and Engineering **732** (2020) 012030 doi:10.1088/1757-899X/732/1/012030

The effect of using crumb rubber on fatigue and rutting lives in flexible pavement

T A Balqis[1,*] and S Suherman[2]

[1] Post-Graduate Student of Infrastructure Engineering Study Program, Applied Master Program, Politeknik Negeri Bandung, Bandung, Indonesia
[2] Civil Engineering Department, Politeknik Negeri Bandung, Bandung, Indonesia

*taniaadnan12@gmail.com

Abstract. This research is performed to analyze effect of using crumb rubber (CR) on the overlay design of Palembang City – Betung roads. Analysis of existing road conditions using the AASHTO 1993. This analysis based on deflection data using the Falling Weight Deflectometer (FWD). While, the overlay design analysis using CIRCLY 7.0 software to determine horizontal tensile strain (εh) for fatigue live and vertical compressive strain (εv) for rutting live parameters. The result showed that using CR can increase fatigue live into 66 % and rutting lives into 22 % for contribute pavement performance. To ensure the effect of CR in pavement's performance, further research must be taken to find out if there are other effects that support.

1. Introduction

Crumb rubber (CR) from waste tires in road asphalt mixture has been a central issue since 1930s. Commonly adopted processes to produce CR modified asphalt mixture include the wet process and dry process. In the dry process, CR is not used as binder modifier but as partial substitution for fine aggregate [1]. Modifying asphalt concrete with using Crumb Rubber (CR) can provide environmental benefits. Modified asphalt concrete used for increases the strength of pavement structure with adding some additive such as chemicals, natural ingredients, and residual waste [2].

This research is performed to analyze effect of using crumb rubber (CR) on the overlay design of Palembang City – Betung roads. The results of laboratory testing with 15% CR and 6.3% bitumen content are optimum modified concrete asphalt wear mixtures. Then the resilient modulus of the modified concrete asphalt layer wear modulus was obtained at 1560.5 MPa at a normal temperature of 25°C. Previous experimental laboratory results were then used in this study to determine the effect of the CR on the performance of the pavement structure.

Horizontal tensile strain (εh) is a structural strain response that lies under the asphalt layer. Whereas the vertical compressive strain (εv) is the structural strain response above the subgrade under the pavement structure. Types of fatigue crack damage or fatigue in the asphalt layer in terms of the maximum horizontal tensile strain value. This type of permanent deformation damage or rutting occurs on the subgrade or in the lower layers of a pavement structure. While the strain used is the maximum vertical compressive strain value.

Calculation of the type of damage is reviewed based on the amount of repetitive load that is allowed to occur on the pavement structure during the 5 years' period design. In general, it can be said that with the planned added layer design, if Nf and Nd from the results of the strain response modeled are greater than the N plan. Then the overlay design can be used because the load repetition due to damage is greater than the plan repetition load.

2. Literature review

Evaluation of Pavement Structure Conditions is influenced by repetition of vehicle loads. Proper handling of the road will reduce and prevent damage to the road, thus making the road remain in a stable condition [3]. Calculation of overlay design based on Pd-T-01-2002 which refers to AASHTO 1993 outlines of the overlay pavement structure using the Falling Weight Deflection (FWD) test [4,5].

SN_{eff} is the capacity of the existing structure condition when analyzed, namely when deflection is tested [6]. Overlay design using empirical mechanistic methods emphasizes the design of the structure failure review in the form of major damage due to fatigue and rutting cracks. Damage review above is determined by looking at strain and stretch parameters. Critical horizontal tensile strain occurs at the bottom of the asphalt layer. Whereas the strain that occurs at the top of the subgrade is called a critical vertical compressive strain [7].

3. Methodology

In general, this study consists of several preparations and tests, as follows:

3.1. Evaluation existing condition

Evaluation is carried out using the Aashto 1993 method or the empirical method. Evaluation is needed so that it can be known whether a road needs repair or not. The evaluation was carried out by analyzing the road conditions from secondary data on the Palembang - Betung City Boundary Road. The data analyzed is the data layer of the existing structure pavement, value of deflection, and traffic condition [5].

3.2. Design of overlay

The overlay design is then carried out to find out how the existing road conditions are according to the results of the previous evaluation. Design is done by also using the AASTHO 1993 method [4]. Design is done by using 2 types of mixtures from laboratory testing to determine the difference from the use of crumb rubber.

3.3. Model of analysis

The modeling in the analysis is carried out according to the instructions of the analysis software conducted, namely CIRCLY 2017. Data input consists of planned traffic data at Austroad 2008 and structural design in the form of thickness layer. The analysis process is carried out by modeling the pavement traffic load according to the amount of the Equivalent Standard Axle (ESA) described as design traffic following the reference from Austroads guide standard. The output is in the form of horizontal tensile strain and vertical compressive strain which are at the critical position. The fatigue damage models take the following **Equation (1)**:

$$\mathrm{Nf} = \mathrm{RF}\left(\frac{6918\ (0.856.\mathrm{V_b}+1.08)}{\mathrm{S_{mix}}^{0.36}\mu\varepsilon}\right)^5 \quad \textbf{(1)}$$

Where :

Nf : Number of load applications to fatigue failure
RF :Realibility Factor
S_{mix} : Asphalt modulus (MPa)
V_b : Mix asphalt content (%)
$\mu\varepsilon$: Maximum horizontal tensile strain (microstrain)

While the rutting models usually take the following **Equation (2)**:

$$Nd = \left(\frac{9300}{\mu\varepsilon}\right)^7 \quad (2)$$

Where :
Nf : Number of load applications to rutting failure
με : Maximum verical tensile strain (microstrain)

Nf is the allowable number of load repetitions to prevent fatigue cracking; Nd the allowable number of load repetitions to prevent rutting [8].

4. Results and discussion

The results obtained for effect of using CR are following:

4.1. Design overlay of pavement

Analysis of existing pavement conditions was carried out with Falling Weight Deflection test.

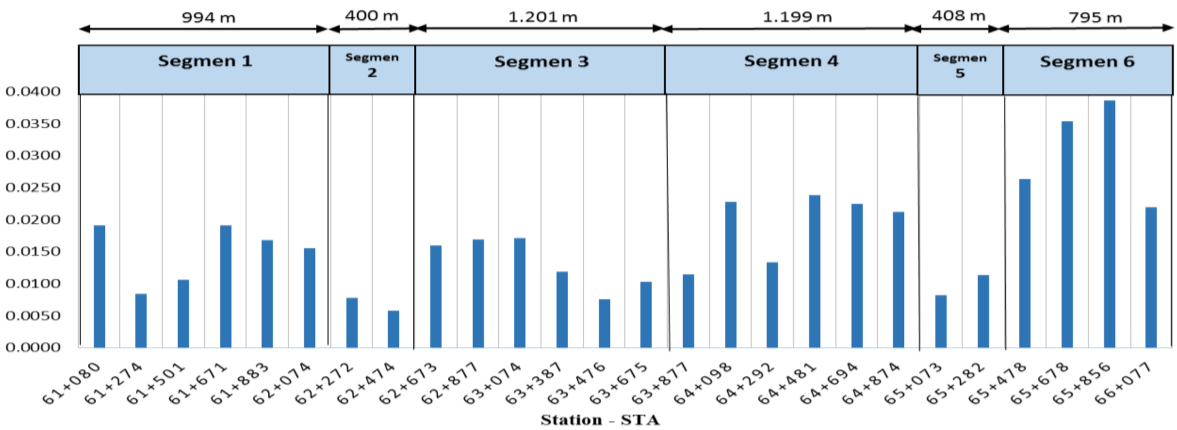

Figure 1. Segment division.

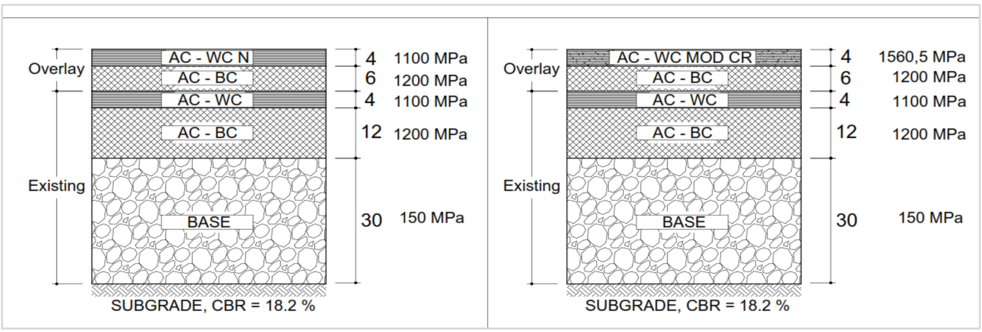

Figure 2. Overlay design.

Figure 1 shows that there are 6 segments of pavement condition from 61+080 untill 66+077 station. The pavement has deflection varies according to existing conditions. So do the segmental road simplification by classifying deflection value according to the level of uniformity. But to be more focused, then only discussed segment 1. Overlay design is shown only for segment 1, as on Figure 2. The design used two kind of AC-WC mixtures, normal and CR. The difference between two is the modulus elasticity of ACWC mixtures. The modulus elasticity for AC-WC normal is 1100 MPa while 1560.5 MPa for AC-WC modification with CR.

4.2. Strain responses
Strain responses was analyze using software CIRCLY 7.0 program from Austroads.

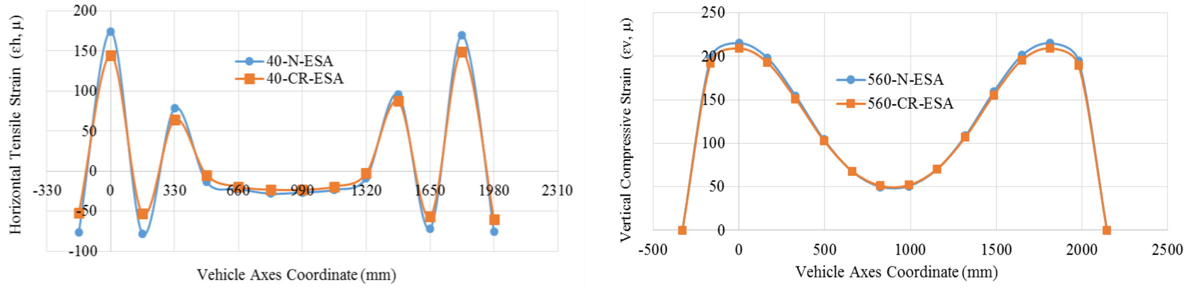

Figure 3. Result of strains.

Figure 3 shows the results of strains along the axis of the vehicle cross section the road The vehicle axis used in the analysis is Single Axle with Dual Tyres (STDT). This figure shows that the maximum strain occurs at coordinates X = 0.0 mm and X = 1,850 mm. This provides that the critical point for both of strains is in the center of the axles between the wheels.

4.3. Comparing strain responses
Comparison of strain response is done by the difference in strain values in the normal and CR mixtures. Strain ratio is performed both in tensile strain and compressive strain.

Table 1. Strain responses value.

Name of mixture	Horizontal tensile strain (εh)	Vertical compressive strain (εv)	% difference of εh	% difference of εv
Normal CR	174.6 μ 144.8 μ	215.3 μ 1.2 μ	**20.6 %**	**2.9 %**

Table 1 shows that the percentage difference in strain occurred by 20.6% for Horizontal tensile strain (εh) and 2.9% for Vertical compressive strain (εv). Both values indicate that there is an increase in performance of the modelled pavement structure. An increase is seen with the strain value parameter that occurs decreases in the CR mixture compared to the normal mixture.

4.4. Performance of pavement
The performance of the pavement is seen from the allowable number of load repetition (N) on Equation 1. for fatigue damage and Equation 2. for rutting damage. N based on the two equations is then compared with the allowable design number of load repetition for 5 years' period (N design).

Table 2. Performance of pavement.

Name of mixture	N design	N fatigue (Nf)	N rutting (Nd)	% Nf compared of pavement performance	% Nd compared of pavement performance
Normal CR	1.065.720	3.03×10^6 5.05×10^6	2.81×10^{11} 5.05×10^{11}	66 %	22 %

Based on Table 2. That modified asphalt mixture with CR gave effect to the improvement of pavement structure performance by 66.3% for fatigue (Nf) damage and 22.4% for rutting damage (Nd).

5. Conclusion and recommendation
Based on the results of the study it was found that:

- Performance of pavement with using CR reduces the horizontal tensile strain (εh) from 174.8 μ to 144.8 μ, a decrease occurred by 20.6%
- Performance of pavement using CR reduced vertical compressive strain (εv) from 215.3μ to 209.2μ, a decrease occurred by 2.9%
- The results of comparison between the two materials showed that using CR can increase the parameters damage of fatigue live into 66.3% and rutting lives into 22.4% to contribute pavement performance.
- To ensure the effect of CR in pavement performance, further research must be taken to find out if there are other effects that support

Acknowledgment
The author acknowledges to UPPM POLBAN that already support the funding for commencement the research and Bandung Research Center of Roads and Bridges that support the laboratory for the research.

References
[1] Xie Z, and Shen J 2013 Long-term performance of SMA mixtures added with crumb rubbers in dry process *Airfield and Highway Pavement 2013: Sustainable and Efficient Pavements* 1145-1155
[2] Isnanda I, Saleh S M and Isya M 2018 Pengaruh Substitusi Polystyrene (Ps) Dan Abu Arang Tempurung Kelapa Sebagai Filler Terhadap Karakteristik Campuran Ac-Wc *Jurnal Teknik Sipil* **1**(3) 637-646
[3] Zurni R, Pradipta W and Kusnandar G R 2017 Studi Penanganan Ruas Jalan Bulu–Batas Kota Tuban Provinsi Jawa Timur Menggunakan Data FWD dan Data Mata Garuda *Rekayasa Hijau: Jurnal Teknologi Ramah Lingkungan* **1**(1)
[4] AASHTO 1993 *Guide for Design of Pavement Structure* (Washington D.C.)
[5] Departemen Permukiman dan Perencanaan Wilayah, 2002 *Pedoman Perencanaan Tebal Perkerasan Lentur Pt T-01-2002-B* (Jakarta: Direktorat Jenderal Bina Marga)
[6] Aji A H F, Subagio B S, Hariyadi E S, and Weningtyas W 2015 Evaluasi Struktural Perkerasan Lentur Menggunakan Metode AASHTO 1993 dan Metode Bina Marga 2013 Studi Kasus: Jalan Nasional Losari-Cirebon *Journal of Civil Engineering* **22**(2) 147-164
[7] Suherman 2017 *Guidebook Teaching: "Reliability Anylisis Modul 4: First Order Reliability Method* (Bandung: Department of Civil Engineering. Politeknik Negeri Bandung)
[8] Austroads 2008 *Guide to Pavement Tecnology Part: 2 Pavement Structural Design* (Sidney, Australia)