Comparison analysis of overlay thickness using the AASHTO 1993 method and the everseries program

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Abstract. The purpose of this research is to analyze the structural capacity of flexible pavement based on deflection data from Falling Weight Deflectometer (FWD) and to compare the results of overlay thickness calculation using AASHTO 1993 Method and Everseries Program. Two layer modelling system is applied in AASHTO 1993 Method and to determine the value of Resilient Modulus (MR), Pavement Effective Modulus (Ep) and Structural Number (SN). The overlay thickness result by AASHTO 1993 method ranged from 5 cm to 13 cm. To comparing the result, the 2-layer system modeling by Everseries Program is used. The modulus can be calculated by Evercalc subprogram using the deflection data as inputs. Furthermore, the overlay thickness calculated by Everpave subprogram produces overlay thickness range from 5 cm to 25 cm. Based on the analysis result, there is a difference overlay thickness between using AASHTO 1993 Method and Everseries Program. Everseries program produce overlay thickness thicker than AASHTO 1993 method, because there are several different parameters such as deflection data, temperature by seasonal variations and traffic loads.

1. Introduction

Jakarta’s national road is one of the most important road in logistics distribution in Java Island, Indonesia. High load that occured on these road, affect the pavement performance and frequently causing structural and functional failure. Functional failure is related to safety and comfort aspect disturbance, but structural failure related to ability of pavement to carry traffic loads. If pavement encounter structural failure, then those segments of pavement could not carry traffic load. This situation compounded if functional failure occured that will affect safety and comfort of road users. To avoid this situation, inspection and control periodically needed to ensure these road can accomodate the traffic demand. The purpose of a pavement structure is to carry traffic safely, conveniently and economically over its extended life. The pavement must provide smooth riding quality with adequate skid resistance and have adequate thickness to ensure that traffic loads are distributed over an area so that the critical stresses and strains at all pavement layers and at the top of subgrade are within the capabilities of the materials [1]. The performance of the pavement therefore related to its ability to serve traffic over a period of time, namely “design life” [5]. The purpose of this research is to analyze the structural capacity
of flexible pavement based on deflection data from Falling Weight Deflectometer (FWD) and to compare the results of overlay thickness using AASHTO 1993 Method and Everseries Program.

2. Research Methodology

2.1. Overlay analysis using AASHTO 1993 Method
The Methodology of Structural analysis consists of the collection of some principal data in the Daan Mogot Tangerang section, which consists of traffic data (AADT), the axle-loading data resulted from WIM survey in 2013, the FWD’s deflection data, the pavement thickness data and the pavement temperature data. The average Traffic Growth was calculated based on the “time series” AADT data, the Truck Factor for each vehicle type was calculated using the axle-loading data [5], [8]. The cumulative ESAL actual and the “future” cumulative ESAL will be determined considering the AADT data, the average growth factor and the Truck Factor for each vehicle. Hence, the AASHTO 1993 method can be applied to obtain the SN_f and SN_eff (future and effective values, respectively), and the overlay thickness for several survey sections [1], [5], [8].

2.2. Overlay Analysis using Everseries Program
The Everseries is a series of computer program which consists of three subprograms, namely evercalc, everstress, and everpave. This program could analyze the flexible pavement structures based on the mechanistic approach. The damage levels are calculated on two primary distress type, namely fatigue cracking and rutting. This program is also capable of considering the seasonal variations and the stress sensitivity of the pavement materials by WSDOT, 2005 [10].

2.2.1 Evercalc Program. The Evercalc program can calculate the “elastic” moduli of pavement layer, determine the coefficient of stress sensitivity of unstabilized materials, stresses and strains at various depths, and optionally normalizes the asphalt mix modulus to a standard laboratory condition [10]. The Everstress program is capable of determining the stress, strains and deflections in a multi-layered elastic system under circular surface loads. This program will also take into account any stress dependent stiffness modulus.

2.2.2 Everpave Program. The Everpave program is a flexible pavement overlay design based on the multilayered elastic system. The determination of the overlay thickness is based on the required thickness to bring the damage levels to an acceptable level under a design traffic condition. The damage levels are calculated on two primary distress type, namely fatigue cracking and rutting [10]. This program is also capable of considering the seasonal variations and the stress sensitivity of the pavement materials. The determination of the overlay thickness is based on the required thickness to bring the damage levels to an acceptable level under a design traffic condition. The damage levels are based on two primary distress types, fatigue cracking and rutting, which are the most common criteria for mechanistic analysis based on overlay design. The program is also capable of considering the seasonal variation and stress sensitivity of the pavement materials [8]. For fatigue cracking failure, the Finn’s model Finn, F.N, 1977 is commonly used [4].

The model used linearly shifts Monismith’s laboratory model by Monismith, 1969 [6], which is shown below:

\[
\log N_f = \log SF + \log \alpha + \log \varepsilon + \log \left( A = \frac{E_{AC}}{\text{Atmospheric Pressure}} \right)
\]  

(1)

Where,

- \( N_f \) = Number of Axle Load Applications to Failure,
- \( SF \) = Shift Factor
- \( \varepsilon \) = Horizontal Tensile Strain at The Bottom of The HMA Layer (in/in × 10^6),
The stage of this research was shown above, that consists of: the preparation phase, the data collection: existing rigid pavement, traffic data, axle load data and the FWD deflection data, and the data analysis and the calculation process, which are based on overlay calculation [5]. The case study selected was the one section between Daan Mogot Tangerang, located in Jakarta Province’s national road, and maintenance with the overlay flexible pavement. Another data collected were the existing pavement condition, the traffic volume, the air and pavement temperature, and the FWD deflection data. All the data collected were then analyzed and calculated by using the AASHTO 1993 method and Everseries Program [2].

3. Presentation Data

3.1. Deflection Analysis and Resilient Moduli

\[ E_{HMA} = \text{Hot Mix Asphalt Moduli} \]
\[ a = \text{Constant} \]
\[ b = \text{exponent for strain} \]
\[ c = \text{exponent for Moduli} \]
\[ E_{ac} = \text{The Stiffness Modulus of The HMA Layer (ksi).} \]

**Table 1. HMA Thickness [4], [6], [10]**

| Shift Factor | Comment |
|--------------|---------|
| 4            | HMA thickness is greater than 8 inches (200 mm) |
| 7            | HMA thickness ranges from 4 and 8 inches (100 and 200 mm) |
| 10           | HMA thickness is less than 4 inches (100 mm) |

*Source: Everseries User’s Guide, 2005*

The b and c coefficients are negative and the sign should be included in entering their values. Atmospheric pressure is in the same unit as the stresses (14.696 psi or 101.4 kPa). The default values for a, b, and c are 2.428E+16, -3.291, and -0.854, respectively from the original equation the fatigue equation used in this program has the following format by Finn dan Mahoney, 1969 [4]. Rutting Equation Constants, the rutting equation two used in the program has the following format by thickness design of the asphalt method, 1982 [7], [9].

\[ Nr = ae^{b} \]  \hspace{1cm} (2)
or,
\[ \log Nr = \log a + b \log \varepsilon \]  \hspace{1cm} (3)

*Where:*

\[ Nr = \text{Loads to failure in rutting, number of loads for subgrade rutting to reach 0.5 inches (13 mm)} \]
\[ \varepsilon_v = \text{Vertical compressive strain at the top of the subgrade (in microns, } 10^6) \]
\[ a = \text{Constant} \]
\[ b = \text{Exponent for Strain} \]

The coefficients a and b are negative and the sign should be included when entering their values into the equation. The default values for a and b and are 1.077E+18 and -4.4843, respectively.
Deflection data were obtained from survey in 2013 using the Falling Weight Deflectometer (FWD) equipment. These FWD’s deflection data will be used in the structural analysis and will be combined with the AADT data, axle load (WIM) data and pavement thickness. For example, the $d_1$ (maximum deflection) of FWD deflection data for Daan mogot road direction in the fast lane is shown in Figure 1.

![Deflection Data, from Tangerang to Daan mogot (line 1)](image)

**Figure 1.** FWD Deflection data from Tangerang to Daan Mogot

### 3.2. Traffic Data

The Historical traffic data was classified into ten vehicle categories, based on Bina Marga’s Classification, i.e. Vehicle category 2 until vehicle category 7C [8]. For example, the distribution of traffic data for Daan Mogot Tangerang section direction is shown in Figure 3. The Truck Factor for each type of vehicle is calculated using the axle-loading data from WIM Survey. Weigh-in-Motion survey (WIM) is a survey that used for traffic data collection or traffic controls in pavement and bridge engineering and has a higher accuracy data and can be conducted without interrupting the traffic flows [10]. From the previous study, the truck factor that analyzed from the WIM survey in Indonesia is extremely greater than the standar truck factor from Bina marga [12]. By considering this result, this study used the truck factor value from WIM analysis that conducted in 2013 as a reference.

### 3.3. Existing Pavement Condition Data

The existing road pavement structure consist of 2 (two) layers, that is flexible pavement. The Everseries program used 3 (three) or more deflections to calculate the resilient modulus of each layer. Depending on the system considered i.e. 2 (two) layer, 3 (three) layer, 4 (four) layer, or more. The Everseries program will carry out an iteration until the difference between the assumed and calculated deflection was minimum or optimum [5], [8], [10].

The assumptions in analyzing the “existing” Stiffness Modulus using The Everseries Program and AASHTO 1993 Method to compare only the 2-layer models.

![Surface (Laston) Sub Base (Sirtu) Sub Grade (Lempung) in Indonesia](image)

**Source:** Bina Marga’s, 2013
Figure 2. Typical Structure Pavement of Daan Mogot to Tangerang

Traffic Data (Line 1)

| Year | AADT (Vehicle/Day) Line 1 |
|------|---------------------------|
| 2009 | Light Vehicles            |
| 2010 | Light Vehicles            |
| 2011 | Light Vehicles            |
| 2012 | Light Vehicles            |
| 2013 | Light Vehicles            |
|      | Heavy Vehicles            |

Source: Bina Marga’s, 2013

Figure 3. Traffic From Daan Mogot to Tangerang

4. Result and Discussion

4.1. Overlay Thickness
The overlay thickness was calculated based on fatigue cracking and rutting failure criteria, which are both commonly used for the Mechanistic analysis. Pavement system under dual tire loads is analyzed by a multilayered elastic program which can consider the stress sensitivity of unbound materials [4], [6], [7], [8], [10].
The two tables above showed that the overlay thickness calculated by the Everseries program is greater than calculated by the AASHTO 1993 method. It is shown that the Everseries program gives the highest overlay thickness compared to the others.

5. Conclusions
Considering all results presented above, some conclusions could be drawn:
1. In the 2-layer system modeling AASHTO 1993 and Everseries Program, overlay thickness by AASHTO 1993 method ranged from 5 cm to 13 cm and overlay thickness range from 5 cm to 25 cm using everseries program.
2. Based on the analysis result, Everseries program produce overlay thickness thicker than AASHTO 1993 method, because there are several different parameters such as deflection data, temperature by seasonal variations and traffic loads.

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