Overlay maintenance on road heavy vehicle lane by non-destructive test method

Dadang Iskandar, Sigit Pranowo Hadiwardoyo, Raden Jachrizal Sumabrata, and Hendra Ariyapijati

Published Online: 26 June 2019

Cite as: AIP Conference Proceedings 2114, 030016 (2019); https://doi.org/10.1063/1.5112420

© 2019 Author(s).
Overlay Maintenance on Road Heavy Vehicle Lane by Non-Destructive Test Method

Dadang Iskandar1, a), Sigit Pranowo Hadiwardoyo1, b), Raden Jachrizal Sumabrata1 and Hendra Ariyapijati1

1 Civil Engineering Department, Faculty of Engineering, Universitas Indonesia, Depok, West Java 16242, Indonesia

a)Corresponding author: dadangummetro@gmail.com
b) sigit@eng.ui.ac.id

Abstract. This paper presents the results of the application of non-destructive test: Falling Weight Deflectometer (FWD) to assess the bearing capacity of the rigid pavement and calculate the overlay on a composite pavement. The present study was conducted on toll roads in Jakarta Outer Ring Roads S-section (JORR-S), with vehicles lane that received relatively heavy axle loads. The main motivation of this research was to evaluate the use of FWD method against destructive testing (DT)—which is relatively time-consuming, unsafe and costly—as the support for decision making in carrying out effective and efficient toll road maintenance. The structural models were build based on the deflection of the FWD and the real traffic load measured using Weigh in Motion (WIM) data. The layers elastic moduli were estimated through back-calculation. Furthermore, the calculation of thickness overlay with bearing capacity values from the non-destructive test data was done using back calculation method. The final calculation results obtained the average thickness of the overlay of 8 cm. It can be concluded that the thickness of the pavement layer has a high influence on the approximate modulus of the bitumen layer to be added. Although the results are specific to this case, it is expected that this study will strengthen the importance of using non-destructive testing for pavement evaluation.

INTRODUCTION

Overloaded vehicle is one of the major contributors to road pavement damage in developing countries [1]. Overloaded trucks are commonly found in developing countries, including Indonesia, in which the percentage of overloaded trucks can reach over 60% from number of trucks and may be one of the important factors that reduce the pavement performance [2]. Heavy vehicle overloads contribute to the deterioration of infrastructure and increase unsafe road [3]. Overloaded can cause the load of each vehicle's axle to exceed the specified standard [4]. Moreover, the pavement performance gradually declines in line with the increase in traffic load and pavement aging [5].

The traffic load parameters, such as annual average daily traffic (AADT), percent trucks, annual average daily truck traffic (AADTT), and equivalent single axle load (ESAL), are usually used as the inputs on pavement design methods [6]. Traffic load characteristics are collected using weigh in motion (WIM) for pavement design and performance prediction by transport agencies [7].

The most commonly used pavement strength indicator to evaluate deterioration model is the structural number. Laboratory testing methods are generally costly and not always appropriate for assessing the long road network [8]. The FWD test is the most widely used non-destructive test to evaluate pavement. On this test, the pavement response to the impulse load falling weight is analyzed to evaluate the existing pavement modulus [9].

Based on the results of WIM testing which was conducted in June 2017, the traffic load on the Jakarta Toll Road Outer Ring Road Section S (JORR-S) is relatively heavy as depicted in Fig. 1. Heavier traffic loads occurred on lane A2 and lane B2 as illustrated in Fig. 1. It allegedly happened because the behaviors of truck drivers in Indonesia who tend to be impatient due to heavy queuing in one lane hence overtaking lane two, so the traffic load on lane two becomes heavier.
EXISTING CONCRETE PAVEMENT EVALUATION

Structural Evaluation

The purpose of the concrete pavement evaluation is to determine the condition of the existing pavement. There are two major focuses in the evaluation process, i.e., the structural condition of the existing pavement and the functional condition. Based on the pavement’s current condition, it can be determined which treatment would be most appropriate to prolong the pavement life and how the treatment must be implemented. It is important to properly determine the types of distress in the current pavement and their causes because any repair or rehabilitation must successfully address the problems of current distress. The initial evaluation should be conducted immediately in the pavement’s life since it is included within the pavement preservation window as shown in Fig. 2 [10].

Existing Concrete Pavement Evaluation

The reason of structural evaluation of pavement is to determine the structural condition of the existing pavement, including the level of damage and residual life of the pavement. In the present study, the structural evaluation was divided into survey and testing. Survey was conducted to determine the extent of damage by visual surface assessment. Testing was done to determine the condition and level of damage that could not be observed visually. Non-destructive testing can be used to collect data without destroying pavement. Moreover, structural evaluation can be conducted on rigid and flexible pavement [11].

After a visual distress survey was conducted, non-destructive testing was done to obtain additional information about pavement which could not be examined through direct observation. The required information included the elastic modulus of concrete, the modulus of sub grade, the voids under the slab, and the efficiency of load transfer [12].
The main form of non-destructive test used in structural evaluation of pavement is deflection testing. The most common device is the falling weight deflectometer (FWD), which applies impulse loads into the pavement to simulate the wheel load, and then measures the induced deflection at different distances from the applied load point [13], as illustrated in Fig. 3.

In the present study, the FWD was used to access the structural properties of the pavement. As already mentioned, the FWD is a NDT equipment that measures the vertical deflection response of a pavement due to an impulse load, as standardized by ASTM.

The structural evaluation of asphalt overlaid concrete pavements is the same with the structural evaluation of concrete pavement. For most AC-PCC’s, road pavement distress mostly comes from the PCC layer, and the asphalt layer covering the visual inspection of the structurally damaged concrete layer. In some locations, the asphalt condition may indicate the underlying concrete condition, as much of the visible damage is spreading. In Fig. 4, the basic structural failure of the concrete is recommended from the observed cracks in the AC overlay. Therefore, the visual pressure survey is still very important for concrete pavement with asphalt layer.

Prior to placing an AC overlay over existing asphalt, it is important to repair certain types of distress in the original concrete pavement or to eliminate their causes. While the AC overlay itself can correct certain types of
distress in the pavement and restore ride quality, it cannot simultaneously fix problems such as loss of support, poor drainage [15], full depth cracks, or low load transfer between slabs. Failure to address these issues will reduce the effectiveness of the overlay.

Deflection Testing and Backcalculation Methods

The Deflection testing and Backcalculation methods are suitable for determining k-value for the design of overlays of existing pavements, the design of a reconstructed pavement on existing alignments, or the design of similar pavements in the same general location on the same type of subgrade. An appropriate design of subgrade k-values as an input to this design method is determined by following steps:

1. Measure deflections on an in-service concrete or composite (AC-overlaid PCC) pavement with the same or similar subgrade as the pavement is being designed.
2. Compute the appropriate AREA of each deflection basin.
3. Compute an initial estimate (assuming an infinite slab size) of the radius of relative stiffness, \( \kappa \).
4. Compute an initial estimate (assuming an infinite slab size) of the subgrade k-value.
5. Compute adjustment factors for the maximum deflection \( d_0 \) and the initially estimated \( \kappa \) to account for the finite slab size.
6. Adjust the initially estimated k-value to account for the finite slab size.
7. Compute the mean backcalculated subgrade k-value for all of the deflection basins considered.
8. Compute the estimated static k-value for use in design [16].

For a composite pavement, compute the \( \text{AREA}_5 \) of each deflection basin using the following equation:

\[
\text{AREA}_5 = 3 + 6 \left( \frac{d_{18}}{d_{12}} \right) + 9 \left( \frac{d_{24}}{d_{12}} \right) + 18 \left( \frac{d_{36}}{d_{12}} \right) + 12 \left( \frac{d_{60}}{d_{12}} \right)
\]

Where:
- \( d_0 \) = deflection in center of loading.
- \( d_i \) = deflection at 0, 8, 12, 18, 24, 36, and 60 in (0, 203, 305, 457, 610, 915, and 1524 mm) from plate center, inches.

Estimate \( \kappa \) assuming an infinite slab size. The radius of relative stiffness for a composite pavement (assuming an infinite slab) may be estimated using the following equation:

\[
\kappa_{est} = \left[ \frac{10^{d_{60} - \text{AREA}_5}}{150.46} \right]^{0.7220}
\]

From the FWD test results, the deflection graph for each lane and line is constructed as shown in Fig. 5 to Fig. 10.

![FIGURE 5. The deflection graph on line A and lane 1.](image-url)
FIGURE 6. The deflection graph on line A and lane 2.

FIGURE 7. The deflection graph on line A and lane 3.

FIGURE 8. The deflection graph on line B and lane 1.
Estimate $k$ assuming an infinite slab size. For composite pavement, compute an initial estimate of the $k$-value using the following equation:

$$\hat{k} = \frac{Pd_{12}}{d_{12}^2(f_{est})^2}$$  \hspace{1cm} (3)

Where:
- $k$ = backcalculated dynamic $k$-value, psi/in
- $P$ = load, lb
- $d_{12}$ = deflection measured 12 in (305 mm) from center of load plate, inch
- $d_{12}'$ = non-dimensional coefficient of deflection 12 in (305 mm) from center load plate:
  $$d_{12}' = 0.12188 e^{-0.79432 e^{-0.07074 k_{est}}}$$  \hspace{1cm} (4)

From the results of FWD data, the overlay calculation is then performed by first calculating ESA using the formula:

$$ESA_{TH-1} = (\Sigma LHR_{JK} \times VDF_{JK}) \times 365 \times DD \times DL \times R$$  \hspace{1cm} (5)

where:
- $ESA_{TH-1}$ = equivalent single axle in the first year.
- $LHR_{JK}$ = load factor
- $VDF_{JK}$ = vehicle damage factor
- 365 = number of days in a year
- $DD$ = the direction distribution factor
- $DL$ = the lane distribution factor
R = cumulative traffic growth multiplier factor.

RESULT AND DISCUSSION

The calculation of overlay was done by dividing the 14 sections where the length of each section was 2000 m. It was done by using the back-calculation principle based on the results of FWD calculations with results as presented in Table 1.

**TABLE 1. Results of added layer calculation**

<table>
<thead>
<tr>
<th>Lane 1</th>
<th>Lane 2</th>
<th>Lane 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sect 1</td>
<td>Sect 2</td>
<td>Sect 3</td>
</tr>
<tr>
<td>Position</td>
<td>Position</td>
<td>Position</td>
</tr>
<tr>
<td>19+550 - 21+455</td>
<td>19+550 - 00+550</td>
<td>19+550 - 08+745</td>
</tr>
<tr>
<td>21+552 - 23+453</td>
<td>00+590 - 00+582</td>
<td>09+375 - 09+242</td>
</tr>
<tr>
<td>23+551 - 25+550</td>
<td>00+597 - 00+615</td>
<td>09+480 - 09+775</td>
</tr>
<tr>
<td>25+651 - 27+452</td>
<td>00+581 - 00+594</td>
<td>09+237 - 09+433</td>
</tr>
<tr>
<td>27+550 - 29+452</td>
<td>00+592 - 00+583</td>
<td>09+415 - 09+267</td>
</tr>
<tr>
<td>29+551 - 31+453</td>
<td>00+568 - 00+561</td>
<td>09+033 - 08+909</td>
</tr>
<tr>
<td>31+551 - 33+554</td>
<td>00+599 - 00+573</td>
<td>09+516 - 09+103</td>
</tr>
</tbody>
</table>

From the results of the calculation, the use of 8.5 cm thick layer of added layer can be used for all segments in the JORR-S. It is expected that this added layer will provide additional structural strength so that it can increase the service life of the pavement.

CONCLUSIONS

A probabilistic approach to FWD back-calculation is used as an alternative due to the characteristics of DT method, namely time consuming, expensive and unsafe. From the results of the calculation, the effective thickness of the overlay layer ranges from 7.5 cm to 8.5 cm. It is recommended to further research to compare the results of this calculation to the result of calculation using the DT method so as to gain a more comprehensive information.

ACKNOWLEDGMENTS

The study is supported by TADOK Grant 2018 funded by DRPM Universitas Indonesia No.1363/UN2.R3.1/HKP.05.00/2018. The author thanks the various parties who contributed to the success of the study and especially the Directorate of Research and Community Development, Universitas Indonesia. The authors are also grateful to PT. HUTAMA KARYA for his assistance in obtaining the data. The laboratory work was completed in the Material and Structure Laboratory Universitas Indonesia.

REFERENCES

Jihanny, BS Subagio and ES Hariyadi. The analysis of overloaded trucks in Indonesia based on weigh in motion data (east of Sumatera national road case study). 2018;02006:1–6.


Pavement L, Program P. DISTRESS IDENTIFICATION Performance Program. 2014;(May).


D Iskandar, SP Hadiwardoyo, Sumabrata RJ, Fitriasari IN. Road Maintenance Strategy with Characteristic of Drainage Condition based on Pavement Performance. 2018;040010.