Quality Assessment of Road Pavement using Lightweight Deflectometer

1st Siti Isnaini Kurniawati Djaha
BPJN X Kupang, Dept. of Highway
Dept. of Civil Engineering, Akademi Teknik Kupang
Kupang, East Nusa Tenggara, Indonesia
isnaindjaha@gmail.com

2nd Hakas Prayuda
Dept. of Civil Engineering, Faculty of Engineering
Universitas Muhammadiyah Yogyakarta
Yogyakarta, Indonesia
hakasprayuda@umy.ac.id

Abstract—**Quality assessment in existing road pavement is used to decide the right action for road preservation. In Indonesia, the quality is measured by functional parameter in riding quality using International Roughness Index (IRI) and visually using Pavement condition Index (PCI) to evaluate pavement condition. However, road quality structurally can be assessed by measuring the deflection and elasticity modulus by using light weight deflectometer (LWD) test. Three (3) segments of National arterial road in Kupang City, East Nusa Tenggara Province data are collected using Light weight defletometer test to find the elasticity modulus and then compared and analyzed with the result of IRI test on the same segments. The statistic result of mean, coefficient of variants and coefficient of correlation are obtained in this research and it is found that there is no significance relation between IRI value and stiffness modulus obtained by Lightweight Deflectometer test as shown by the value of coefficient of correlation.**

***Keywords*— IRI, LWD, Elasticity Modulus, PCI**

I. INTRODUCTION

Quality assessment of pavement is routinely checked every year to find out the deterioration level and service level within the service life. Preservation program is used to fulfill he needs of good quality pavement in the term of riding quality and driver convenience for all the road segment nationality. Several surveys were conducted by the government (Department of Bina Marga, Ministry of Civil Works and Residence) to get the result before making the preparation of planning for the next year need in preservation. Quality assurances were measured by the value of International Roughness Index (IRI) and Pavement Conditional Index (PCI) to get the functionality level of the pavement. For structural value of the material, in situ test such as Falling Weight Deflectometer (FWD) or Benkelman Beam (BB) test were conducted to get the result of deflection and elasticity modulus of pavement layer materials.

Falling Weight Deflectometer (FWD) test was recently and effectively used as deflection measurement equipment and can be used in high traffic volume. However, for low traffic volume, PUSJATAN (Indonesian Road and Bridge Research Institute) developed the Portable Falling weight Deflectometer (PFWD) or well-known as Lightweight Deflectometer (LWD) which is one of the plate bearing test [1]. Several researches had been conducted to analyse lightweight deflectometer (LWD) as test equipment for deflection in layer for subgrade, foundation and asphalt pavement. At the beginning Lightweight Deflectometer (LWD) were used to test the subgrade and then developed to be used in other layers as foundation and surface layer.

The research studied, about stiffness estimation of the soil built-in road embankment on the basis of Light Falling Deflectometer test using original program of finite difference method to confirm the sensitivity of the dynamics stiffness modulus of the ground under the loading and unloading phase. According to the result, the basic assumption of the modulus (Evd) may be accepted because the result leads to correct evaluation of average stiffness modulus of the soil into the loading phase [2].

A study was conducted using Lightweight deflectometer (LWD) to measure the surface deflection and elastic modulus of pavement layers over 11 highway construction sites in Thailand as well as to evaluate the feasible adoption by Thailand Department of Highways as a construction quality control device on the routine basis. The testing was conducted on four (4) major types of pavement materials commonly used in Thailand highways including crushed rock base, soil-aggregate sub-base, selected material, and subgrade from various sites. The study found that LWD test can provide quick test result for direct measurement of surface deflection and elastic moduli of pavement layers [3].

Before that, deflection were measured by back calculation method of Benkelman Beam test to get material static modulus. Comparison of static modulus by Benkelman Beam (BB) test and dynamic modulus by Lightweight Deflectometer test were conducted by Guzzarlapudi, et al. [4] to analyze the correlation between both results. The study compared in situ subgrade strength evaluation tool by estimating static and dynamic modulus for low volume roads in India and concluded that Lightweight Deflectometer (LWD) can be used as maintenance of the pavement which is shown by the good correlation between static and dynamic moduli of subgrade values. Beside that laboratory investigation was also conducted to get the soil properties.

Flemming, et al [5] was carried out a little work on detailed assessment on the potential outcomes that might be influenced by the test devices. The study from field and laboratory data showed that the correlation between LWD to the (accepted)

FWD is achievable through initial correlation of variance (CoV). In latest General Specification for Dept. of Bina Marga 2018 version for road and bridge construction that replace previous version of general specification at the year 2010 3rd revision, lightweight deflectometer (LWD) is used as the quality control parameter to measure the backfill layer, foundation layer, surface layer and other layers but they need be compared with the correlation of density from sand cone test.

Lightweight Deflectometer (LWD) test is commonly used for subgrade layers of pavement in construction phase, and for this study, the test is conducted in existing flexible pavement surface. Three (3) national road segments known for low volume traffic and have similar type of surface layers used as sample. The aim of this study is to analyze the relationship between the value of International Roughness Index (IRI) and elasticity modulus of structural by using lightweight deflectometer (LWD). Pavement conditional Index (PCI) were used to evaluate the pavement condition visually as can be seen and measured only in the surface.

II. DATA ACQUSITION

A. International Roughness Index (IRI) and Pavement Condition Index (PCI)

International Roughness Index (IRI) was developed by World Bank at 1982 and widely used as a scale for the roughness of a pavement as it is experienced by a vehicle. It is calculated by measuring the vertical profile of the road, then processing the profile through an algorithm that simulates the response of a reference vehicle to the profile and accumulating the suspension movement of the vehicle. IRI is measured by meter/kilometer and as an approximate measure of riding quality as functional parameter of the road. The scale of roughness shows the unevenness of pavement surface by number [6]. The higher its number, the poorer its condition as seen in Fig. 1(a).

The test conducted in this study were using Roughmeter level III that was placed in the mini-SUV vehicle. The censor were placed in the back left tire of the vehicle as represented by the tire ruts. Distance Measurement Instrument (DMI) were also placed in the right-back tire to identify the distance and location detection censored that were connected to satellite Global Positioning System, (GPS) were installed in the vehicle.

The Pavement Condition Index (PCI) is a numerical indicator that rates the surface condition of the pavement, with scale 0-100 as 0 being the worst condition and 100 shows the best condition of the pavement. The PCI were used to evaluate directly the deterioration of the pavement that was observed visually and thus the best action for the segments can be decided. Setiawan. et al [7] Was using PCI value to predict the remaining service life with the data of deflection by FWD and the result shows that the group of road segments that have higher PCI value tend to have higher service life.

Based on ASTM standard D 6433–07 [8], PCI is used to evaluate the pavement surface based on the distress observed visually and measured on the pavement surface. PCI cannot be used for structural measurement but provide rational basis data for determining repair needs. Shat, et al [9] developed a combination of pavement evaluation indicators such as pavement condition index, present serviceability rating and roughness index for pavement management system at the selected road of Noida urban road and set the multi-indices condition indicators that provide more reliable and efficient data to select the appropriate treatment for the fully restore of the pavement.

PCI data was obtained by measuring the distress severity level to get the distress density in every segment. In this study, Mobile Mapping Survey using Imajing are used to collect the data. Then the distress type and severity level are analyzed by operator to count the density of every segment to get the result of PCI. Figure 1(b) shows the scale of PCI value that represents the pavement condition.

B. Lightweight Deflectometer, LWD

The Lightweight Deflectometer is a device that measures the vertical deformation that is imparted by a falling mass impacting a plate resting on the ground. LWD also known as Portable Falling Weight Deflectometer (PFWD) which is one of the plate bearing tests that uses impact load that falls room certain height. A buffer is used to decrease the rise time of the applied loading in order to better match that of vehicle traffic.

Value	Condition
< 4	Good
4-8	Fair
8-12	Poor
> 12	Very Poor

(a)

(b)

Fig. 1. (a) The Scale of Roughness Index; (b) The Scale of Pavement Condition Index

The estimation of dynamic modulus (ELWD) is based on Boussinesq equation relating to the static deflection of an elastic half space subjected to an axisymmetric surface loading as given by Eq 1 [5, 10]

$$E_{LWD} = \frac{(1-v^2)K.P.r}{d} \quad (1)$$

Where, K is plate rigidity factor, 2 for flexible plate and π/2 for rigid case. P is for applied stress, r for plate radius and d is the deflection.

A study conducted by Elhakim et al. [10] is to investigate the seismic waves propagated by Lightweight deflectometer (LWD) test on clay, silt and gravel soils. It showed that the usable frequency ranges from 10-300 Hz for surface waves, which can be used for low strain modulus characterization at the top 0,3-0,5 m thick soil layer.

The experiment was performed on asphalt concrete (AC-WC) pavement layer with an accelerometer used to collect the data written by censored that is placed in distance of 0, 200 mm and 900 mm as can be seen in Fig. 2. A monitor and LWD software connected to accelerometer were used to digitalize the wavelength and graph that was formed by load impact that were fell.

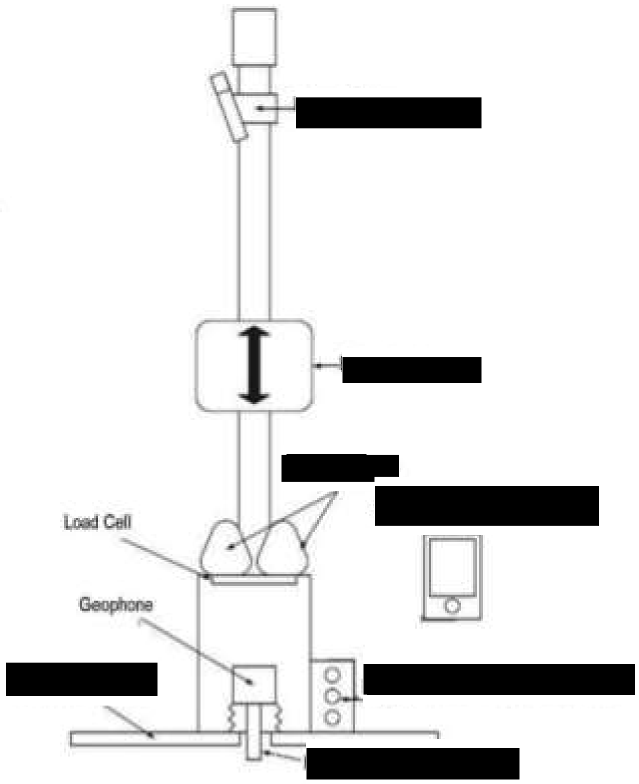


Fig 2. LWD Test

III. Test Procedure

Data that were conducted in this IRI, PCI and LWD tests were part of the surveys programme that were funded by state budget of 2018 as basis data for preservation planning to the next year. This study took three (3) road segments of arterial roads in Kupang City, with relatively low-medium traffic volume as sample as seen in the Map (Fig. 4). IRI and PCI were installed on the same vehicle and thus collecting data in the same time. The result of IRI were used to decide the location of LWD test that LWD test was only conducted on the location with IRI value greater than 6 m/km. so this study was aimed to prove the relationship between IRI value and the stiffness modulus or elasticity moduli obtained by LWD.

Lightweight deflectometer equipment were installed at the pavement surface as seen in Fig. 3, with distances between censored determined 0, 200 mm and 900 mm. Lightweight Deflectometer Software were connected to the censored by the accelerometer to get the real time elasticity modulus and deflection by the censores. Fig. 3 shows the real experimental setup in the field survey.

Fig 3. Experimental setup in field survey

Fig. 4. Road segment location in map

TABLE I. RELATIONSHIP BETWEEN THE VALUE OF IRI WITH ELWD

Segment		Mean	Std. Devation	n	COV	Coeff. Correlation	PCI Average	Visually
24.22k	IRI (m/km)	4.438	2.106	13	25.423	0.047	99.92	Bump
	ELWD (MPa)	772.538	268.500					
24.13k	IRI (m/km)	7.022	1.889	13	37.598	0.1	91.85	Bump and Cracks
	ELWD (MPa)	834.462	198.230					
25.13k	IRI (m/km)	7.660	2.764	27	187.575	0.217	95.78	Plastic Deformation
	ELWD (MPa)	737.667	312.317					

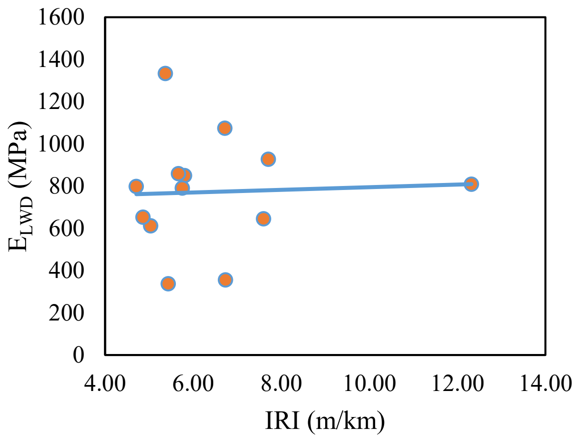
IV. RESULT AND DISCUSSION

The result of LWD test are analysed with IRI value to know the distribution of this two variables. Fig. 5 shows the scatter plot of the data distribution between IRI and modulus elasticity of LWD. As seen in in Fig.5 that there is linear curve on the data sets that shows that the value between IRI and ELWD move along together to the positive direction. This series of datasets, mean, standard deviation, covariance and coefficient of correlation of the sample were analysed using Microsoft Excel software as seen in Table I.

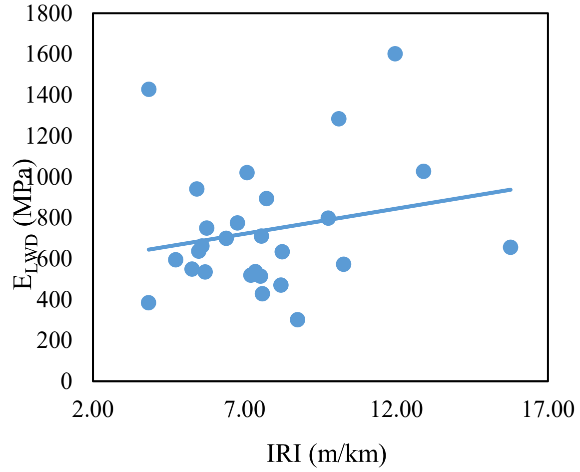
Table I shows that there are positive relationship between the Value of IRI with ELWD as seen from the result of covariance. However this result cannot be used as the parameter as how far the relationship can get. Coefficient of correlation from the covariance value were obtained and the result depicts poor connection between the variables with range value 0.047 – 0.217.

Coefficient of correlation from the covariance value were obtained and the result depicts poor connection between the variables with range value 0.047 – 0.217. Thus can be concluded that the changed of IRI value have a slight correlation with ELWD. The evaluation result of road functional with International Roughness Index (IRI) only performed the riding quality for road user, meanwhile to evaluate the structural parameter of the pavement material was slightly affected by that.

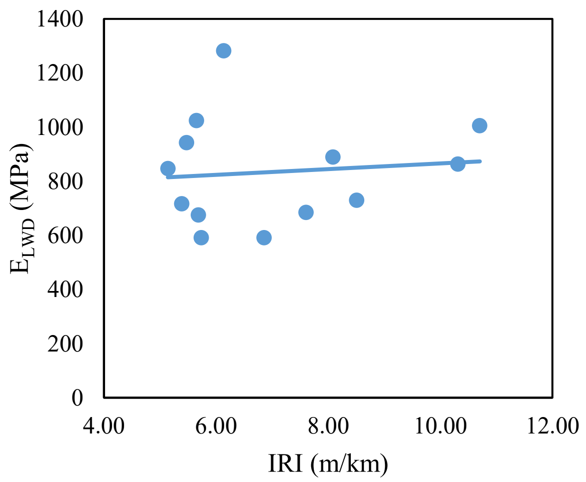
Several factors should also be considered while using the result of the LWD test whether the stiffness moduli were only affected by material properties or also by the instruments. Also seen on the Table I, PCI value only shows the excellent value from the mean data, but visually there are several deterioration in the pavement surface that can be the cause of IRI value is greater than 6 m/km.



(a)



(b)



(c)

Fig. 5. (a) Segmen 24.11k ;(b) segment 24.13k ;(c) segment 25.13k

VI. CONCLUSION

International Roughness Index (IRI) and Lightweight Deflectometer (LWD) test were performed in the national road to get pavement quality evaluation as for using in planning and programming for the next year construction in road preservation. The result of three (3) road segments as sample as shown from this study depict a positive relationship between IRI value and ELWD from the covariance. However, from the coefficient of correlation value of the data can be seen that IRI value was not giving a significance effect to the ELWD which in this study the LWD test only conducted on the points with IRI value greater than 6 m/km (fair condition).

The value of road functionality that is represented by roughness index may give slight effect to structural condition of the pavement. Thus the structural condition of pavement layers is not only decided by the functional value of pavement surface.

This study may be used as consideration that the value of IRI may be used to determine the points to conduct LWD test but it would be best if LWD test can be conducted also for the surface with IRI value less than 6 m/km to get the comparison with this study. Also it may be wise to know the history of the pavement construction before conducting the test, and get the material properties of the location. LWD test should also be conducted in an even surface because it may affect the plate contact with the surface that distributes the impact load.

ACKNOWLEDGMENT

This research was partially supported by Balai Pelaksanaan Jalan Nasional X Kupang, Department of Highway, Ministry of public work and residence, especially, division of planning and evaluation who provided data and insight of this research.

REFERENCES

[1] D. H.Stamp, M.A. Mooney," Influence of Lightweight Deflectometer Characteristics on deflection measurement", Geotechnical Testing Journal, Vol.36, 2013.

[2] W. Gosk, "Stiffness estimation of the soil built-in road embankment on the basis of Light Falling Weight Deflectometer test", Advances Transportation Geotechnics 3, Procedia Engineering, Vol. 143,2016, pp 395-402.

[3] P. Jitareekul, A. Sawangsuriya, P. Singthatiraj, " Integration of Pevement Layer evaluation using Lightweight Deflectometer for road safety control", Transportation Geotechnics and Geoecology, Procedia Engineering, Vol.189, 2017, pp 111-117.

[4] S. D. Guzzarlapudi, V. K. Adigopula, R. Kumar, "Comparative studies of Lightweight deflectometer and Benkelman Beam deflectometer in low volume roads", Journal of Traffic and Transportation Engineering, Vol. 3 (5), 2016, pp 438-447.

[5] P. R. Flemming, M.W. Frost, J.P. Lambert, " Review of Lightweight Deflectometer for routine in situ assesment of pavement material stiffness", Transportation research record, Journal of Transportation research board, January 2007, pp 80-87.

[6] Indonesian National Standard Pd 03-2016-B," Method for Deflection testing using Lightweight Deflectometer", Metode Uji Lendutan menggunakan Light weight deflectometer, Pedoman Bahan Konstruksi Bangunan dan Rekayasa Sipil, Ministry of Public Work and Residence.

[7] A. Setyawan, J.Nainggolan, A. Budiarto," Predicting the remaining service life of road using Pavement Condition Index", Procedia Engineering, Vol.125, PP 417-423, 2015.

[8] ASTM standard D 6433-07, 2008, "Standard Practice For Roads and Parking lots Pavement Condition Index", ASTM International, West Concshocken, PA 19428-2959, USA.

[9] Y. U Shah, S.S. Jain, D. Tiwari, M. K. Jain, "Development of overall pavement condition index for urban road network", Procedia, Social Behavioral Science, Vol. 104, 2013, pp 332-341.

[10] A.F. Elhakim, K. Elbaz, M.I. Amer,"The use of Light Weight Deflectometer for in situ evaluation of sand degree of compaction", Housing and Building National Research Center, Vol.10, PP 298-307, 2014.