CORRELATION OF FLEXIBLE PAVEMENT REBOUND DEFLECTION DEVELOPMENT TRENDLINE WITH ITS CURVE PATTERN AFTER THE ROAD LIFE CYCLE LIMIT

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ABSTRACT

The Pavement deflection is one of the parameters in thick layer added design on flexible pavement. Any delays of road treatment that has reached its allowable serviceability would require a re-mesurement of deflection data for design review due to the development of deflection value. The development of deflection values have different trendline on every pavement structure and can not be predicted precisely. Therefore, it is necessary to study the trendline of deflection developments after the pavement reaches its life cycle (IP ≤ 2.5) and its correlation with the deflection curved pattern. Thus it can be quickly predicted the development of deflection value occured at every moment, so it is no longer required re-measurements. This research is a quantitative study using descriptive statistics through regression and correlation analysis. The output of this research is the formula and trendline of deflection chart affected by the pavement structure deflection curved pattern.

Keywords : *Allowable serviceability, deflection curve pattern, flexible pavement, rebound deflection, road life cycle, trendline of deflection.*

INTRODUCTION

Background

The Pavement deflection is one of the parameters used in "the added layer desain" of flexible pavement thickness, which is used among other method Roadworks Design System, method AUSTROADS 1992 or Asphalt Institute MS-17 in 2000, as well as the method of Highways in 2005 in Pd T-05- 2005-B. The addition of this layer is meant to withstand the load repetition until its life cycle in order to provide optimum service to road users (Suaryana, 2010). Haas & Hudson (1978) stated that the condition of the road reached the limits of service performance level that is still be allowed until the end of the design life with a number of load carryng repetitions planned. In Indonesia, the value of the service performance expressed by the Surface Index (IP). Roads that have reached the limits of services have IP value between 2 and 2.5 as a critical limit that is accepted as it is used by AASTHO (Sukirman, 1992; Dep. Kimpraswil, 2002). The decreased of road service course of the service index numbers will also be getting smaller. The new road surface usually has a service index number between 4 to 5.

The decline in road service will be faster if there is delay in the structure treatment (Dardak, 2008). Road treatment delays which have reached the life cycle plans, especially in Indonesia, due to budget allocations from administration of the road is not always on time in accordance with the planned schedule.

Data of Highways East Java Province in 2009 showed that in general the overlay program still requires a review of the initial design prior to construction commencement. This is because the originally estimated deflection value has changed, especially on the road sections that are traversed by heavy vehicle traffic during the time of delay. Consequently re-measurement deflection value is required for the purposes of design review.

Referring to the above conditions, it is important to know the trendline development of flexible pavement deflection and its correlation with the curved pattern, in order to accurately and quickly predicted the magnitude of the deflection occurring after the pavement reaches the life cycle or limit of road service (IP ≤ 2.5). Thus no longer necessary to re-measurement of the value of the deflection for the needs of design review, so it can gain time and costs efficiency in the context of road treatment.

Flexible Pavement

Flexible pavement is one of asphalt pavement type with asphaltic and granular materials (Huang, 1993; Haas-Hudson, 1978; Highways Highways, 1983), which consists of a relatively thin surface layer and is built on top of the base course and subbase course, where these layers rested on the top surface of the compacted soil (Yoder and Witczak, 1975; Sukirman, 1993).

The effect of traffic load on the flexible pavement will cause deflection associated with the magnitude of the elastic modulus of pavement layers. The modulus of elasticity of each pavement layer (Ei) is calculated based on the deflection data measured in the field. Measurement of deflection must be measured very accurately, especially when the deflection measured at a certain point within the center of the point load. Because of this deflection will be used to determine the elastic modulus of the subgrade, subgrade while contributing nearly 60% -80% of total deflection occurs, so if there is a small error will result in a very large error in the determination of others pavement layer elastic modulus (Huang, 1993) .

Studies related to the modulus of elasticity refers to the Hooke's law (Timoshenko and Goodier, 1986) where the stress components and strain components have a linear relationship, which is determined according to equation (1) the following:

$$\varepsilon_z = \frac{\sigma_z}{E} \qquad \text{.........................} \qquad (1)$$

Where:

- Ez = components of strain
- Σz = components of normal tension
- E = modulus of elasticity

From Hooke's law formula above can be illustrated that a tension which is applied to an object will experience elastic strain in the form of changes from initial conditions. These changes depend on the flexibility of the material used, in which the flexibility of the material is hereinafter referred to as the modulus of elasticity. In this case the greater modulus of elasticity of a material, the strain that occurs will be smaller. Therefore, when the applied tension has exceeded the limit of elasticity of materials, the strain that occurs will result in rupture (crack) on the material.

In the flexible pavement structure, the modulus of elasticity is expressed as resilient modulus (Huang, 1993) because the flexible pavement is a visco-elastic material. In the material which is visco-elastic, the collapse is not affected by tension exceeded limit of elasticity as well as in Hooke's law, but more due to the achievement of a number of load repetitions, as illustrated in Figure (1) below :

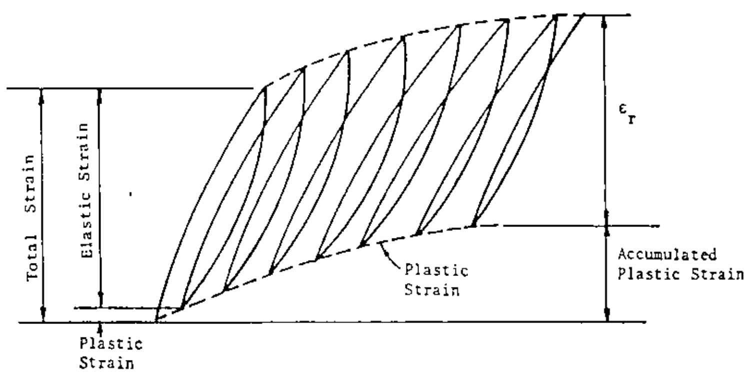


Figure 1 . Strain due to load repetition
(Source: Huang, 1993)

While the value of resilient modulus can be expressed by the formula (2) below :

$$MR = \frac{\sigma_d}{\epsilon_r} \quad \text{............................} \quad (2)$$

Where:

- MR = Modulus of elasticity
- σ_d = Components of normal tension
- ϵ_r = Components of strain

Based on the theory that illustrated in Figure (1) above, can be explained that the decline in the level of service is affected by the damage caused by repetitive strain on the surface layer of pavement. In this case the increase in strain is proportional to the deflection development value that occurs.

Rebound Deflection

One of the methods used in Indonesia in “thick layer added” (overlay) design on flexible pavement is a rebound deflection method. Rebound Deflection is defined as the amount of vertical rebound deflection of a pavement surface due to the moving load (Bina Marga, 2005). In these methods should be determined the initial rebound deflection value of a pavement as well as the predictive value of rebound deflection in order pavement capable of receiving traffic load repetitions during the design life of service by adding a number of pavement layer thickness.

According Ullidtz in Huang (1993), the deflection data collection in the field can be done in two ways, both by measuring the deflection directly using the Falling Weight Deflectometer (FWD) or by measuring the rebound deflection using Benklemam Beam (BB). FWD deflection by using the deflection at the load center, while the BB rebound deflection using pavement rebound deflection (Bina Marga, 2005). Benklemam Beam is one of the most commonly used methods for measuring deflection of the pavement surface. BB tool is based on the principle of the use of a simple measuring rod and use the dial guages to measure the surface deflection under the influence of load on the pavement.

According Indonesian Highways conditions (2005), the value of rebound deflection that measured by Benkelman Beam (BB) devices should be corrected by a factor of ground water table (seasonal factors) and temperature correction and a correction factor of the load test (if not exact test load of 8.16 tons). The amount of rebound deflection can be determined by the formula (3) below :

$$Db = 2 X (d3 - d1) x Ft x Ca x FKB\text{-}BB \quad \text{...} (3)$$

Where:

- Db = Rebound Deflection (mm)
- D1 = Deflection on when the load right at this point measurements
- D3 = Deflection on when the load is at a distance 6 meters from the measurements
- Ft = Correction factor of deflection adjustment to temperature standard (35^{oc})
- Ca = Correction factors of local ground water influence (season)
- FKb-BB = Correction factors of Benkelman Beam (BB) test load

Curve Models of Road Deflection

To obtain an idea of the strain that occurs in the pavement structure is empirically done by evaluating the pattern of curved deflection of each test road pavement structure. Related to this, the amount of strain is determined from the magnitude of the tangent value of the angle formed by the curved pattern of deflection.

Every road structure has a different pattern of curved deflection, where the difference can be illustrated through the curved radius of the circle formed deflection as shown in Figure (2) below.

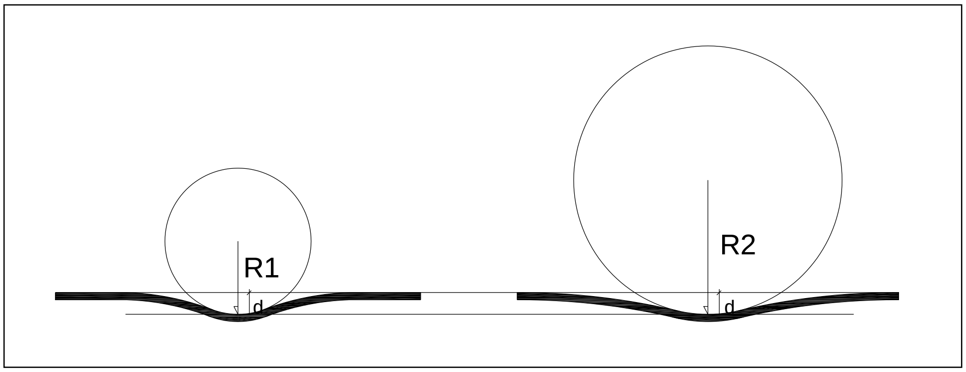


Figure 2. The pattern of rebound deflection curve of the pavement structure

The picture above shows the value of the same deflection at two differents surface of pavement structure (by "d"), has a different pattern of curved deflection which is illustrated by the difference in the value of the radius of the circle (R1 and R2). Thus it can be said that any pavement which are carrying the same load will have a different pattern of deflection curve, although the value of deflection that occurs is just as great.

RESEARCH METHODS

This research is a quantitative study, by empirically-mechanical field research on selected roads based on certain considerations. Empirical approach is done to obtain a theory of the observation data processing, while the mechanical approach is done by utilizing a mechanical device Benklemen Beam (BB) to measure the deflection. Field observation activities conducted periodically, every month for one year (12 months).

Furthermore, with reference to the consideration that 60% of road damage that occurs primarily caused by heavy vehicles (CSIR - Roads and Transport Technology, 1997), then the priority selection of research objects conducted on the road pavement traverse by the heavy load traffic. Some of the selection criteria and limitations of road test in this study defined as follows:

1) Roads in the province of East Java which has different characteristics, such as National, Provincial, and District roads with each test segment along 1 km, includes :

   - The roads Ploso - Munung (District road)

- The roads Ploso - Gedeg (Province road)
- The roads Krian - Mojosari (Province road)
- The roads Mlirip - Jampirogo (National road)
- The roads Gemekan - Jombang (National road)

2) Road section has the same initial conditions, that the road surface index value has reached the life cycle or limit of road service (IP ≤ 2.50).

3) Roads do not get pavement structure treatment during the study period (12 months).

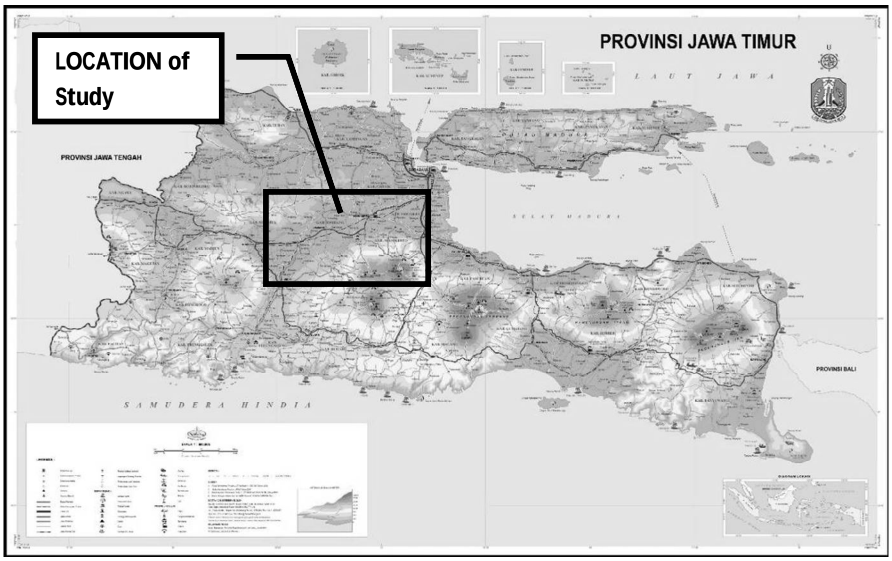


Figure 3. Map Location of Study

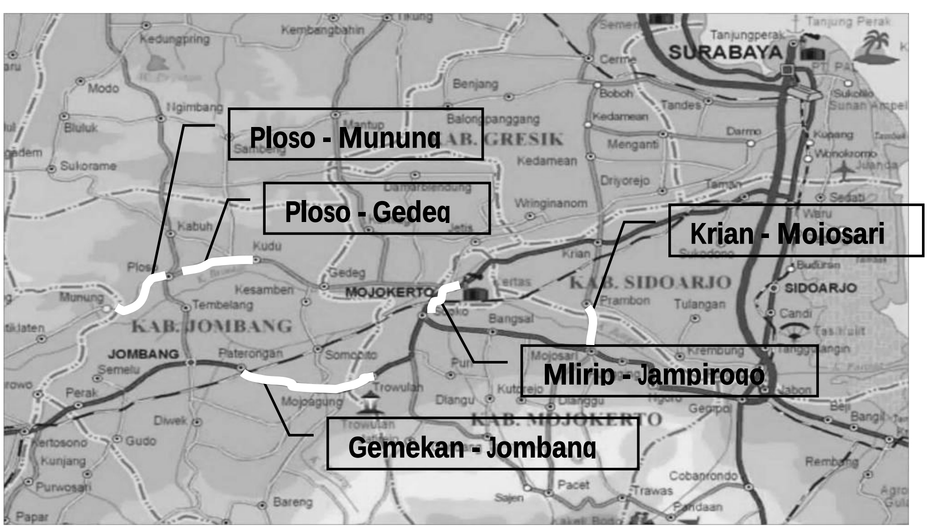


Figure 4 . Site Map of Roads Test

Basic data used in this study are rebound deflection data was measured using a Benklemen Beam (BB) devices. Rebound deflection measurements performed with the following criteria:

- Within one (1) km road length, rebound deflection data would be taken on 20 test stations with a distance of 50 meters each.
- Data collection was carried out in the path zigzagging left and right
- At each measuring station, testing data acquisition was conducted at two measurement points, respectively in the positions left and right rear wheels.
- At any measurement points were performed 3 deflection data retrieval, which is at the starting position (0.0 m); between position (0.4 m and 3 m); and the final position (6 m) from the starting point.

Data processing is performed using descriptive statistical methods through regression analysis and correlation analysis techniques. Descriptive statistical methods more regarding the collection and summarizing of data, as well as the presentation of summarization results (Trochim, 2006). Regression analysis technique used to determine the influence of one or more independent variables to the dependent variable. While the correlation analysis technique refers more to the group bivariate statistics were used to measure the strength of the relationship between two variables. In this study methods of descriptive statistics and quadratic regression analysis techniques were used to analyze the trendline of rebound deflection development and the curve pattern, while the correlation analysis technique used to determine the correlation between the trendline of the rebound deflection development with its curve pattern.

RESULT AND DISCUSSION

Characteristic of a Sample

Referring to road test selection criteria, set five of roads consisting of two national roads, two Provincial roads, and 1 district roads. Table (1) through Table (5) provides a description of the general characteristics and condition of road sections were examined in this study, which describes the average width of pavement, road shoulders, a thick asphaltic pavement layer, and drainage conditions as well as a pool of water on the road surface.

General description table 1: The Roads Characteristic of Ploso-Munung

The Roads Characteristic				**NOTE:**
Wide of road pavement (m)	**Should ers (m)**	**Thick la yer asph alt (Cm)**	**Drainage condition**	
4.50	2 X 0.50-1.00	12.00	• Drainage road works well • There is no water pool	The roads with heavy load traffic because it is an alternative road for building materials (sand) from the coast Brantas river.
				

General description table 2.The Roads Characteristic of Ploso-Gedeg

The Roads Characteristic				**NOTE:**
Wide of road pavement (m)	**Should ers (m)**	**Thick la yer asph alt (Cm)**	**Drainage condition**	
5.50 - 5.70	2x 0.50-1.00	12.00	• Drainage road works well • There is no water pool	The road with heavy load traffic for an alternative road for traffic movements in the north area of Jombang district and Mojokerto, which were dominated by industrial area, and shorter distance toward Surabaya or Lamongan
				

General description table 3. The Roads Characteristic of Krian - Mojosari

The Roads Characteristic				NOTE:
Wide of road pavement (m)	**Shoulders (m)**	**Thick layer asphalt (Cm)**	**Drainage condition**	
11.00	2 x 1.50	16.00	• Drainage road works well • There is no water pool	The roads crowded with heavy load traffic, because it can be an alternative transfer of traffic main artery due to the impact of a flaming "lapindo mud".
				

General description table 4. The Roads Characteristic of Mlirip - Jampirogo

The Roads Characteristic				NOTE:
Wide of road pavement (m)	**Shoulders (m)**	**Thick layer asphalt (Cm)**	**Drainage condition**	
9.00	2 X 1.50-2.00	12.00	• Drainage road works well • There is no water pool	The road with heavy load traffic that functions as primary arterial middle route, which connects Surabaya with other urban areas in the south and west of East Java to Central Java.
				

General description table 5. The Roads Characteristic of Gemekan - Jombang

The Roads Characteristic				NOTE:
Wide of road pavement (m)	**Should ers (m)**	**Thick la yer asph alt (Cm)**	**Drainage condition**	
14.00 (2 x 7.00)	2 X 1.50- 2.00	20.00	• Drainage road works well • There is no water pool	The road with heavy load traffic that functions as primary arterial middle route, which connects Surabaya with other urban areas in the south and west of East Java to Central Java.
				

Deflection Data Uniformity Test

Deflection data uniformity test is used to determine the degree of homogeneity of variance test data (Wignjosoebroto, 2008), which is performed by using the control chart in Minitab software version 16. The control chart can show the deviation of data (out of control) of the average value. In this case, control charts are used to test the uniformity of the data is the I-MR control chart (Individual Moving Range Chart), which is used for observation of individual data, where the population variance is estimated by the value of the data range. Individual observations may occur because the measurement on each test data is done only once (n = 1). Here is the formulation of the upper control limit (UCL), the center line (CL) and lower control limit (LCL) for individual control charts.

$$CL = \bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \quad \text{.........................} \ (4)$$

$$UCL = \bar{x} + 3\frac{\overline{MR}}{d_2} \quad \text{.........................} \ (5)$$

$$LCL = \bar{x} - 3\frac{\overline{MR}}{d_2} \quad \text{.........................} \ (6)$$

Furthermore, the control limits for control charts Moving Range (MR) is formulated as follows :

$$CL = \overline{MR} = \frac{\sum_{i=2}^{n} |x_i - x_{i-1}|}{n-1} \quad \text{.........................} \ (7)$$

$$UCL = D_4 \overline{MR} \quad \text{.........................} \ (8)$$

$$LCL = D_3 \overline{MR} \quad \text{.........................} \ (9)$$

Where :

$\overline{x}$ = Price data observation working time
$\overline{MR}$ = Price range move two observation respectively.
UCL = Upper Control Limit (the border control over)
LCL = Lower Control Limit (the border controls below)
CL = Center Limit (middle line)

Value of d2, D3 and D4 obtained from Table Factor for Constructing Variables Control Chart. Said to be uniform if the observation plots of all the data is between the upper control limit (UCL) and lower control limit (LCL) (Montgomery, 2005). For example, the deflection data uniformity test results shown in Figure (5) below.

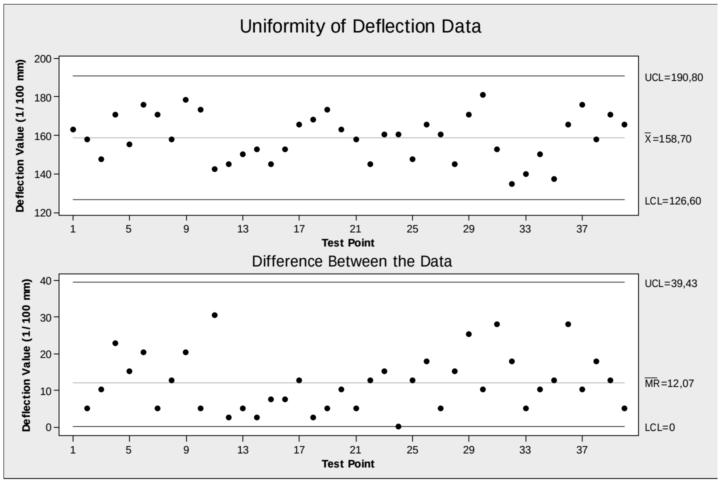


Figure 5 . Graphic of Uniformity Deflection Data

Variance figure of data above shows the upper control limit (UCL), lower control limit (LCL), and the average value of the 40 test data in the test, where the value of the abscissa (x) is a test point, while the value of the ordinate (y) is the value of deflection (1/100 mm). In the picture above can be seen the difference between the data, the value of which indicates the magnitude of the difference between the two values deflection data test.

Deflection data uniformity test results on five test roads are shown in Table (6) for each road segment.

Table 6. Uniformity of Rebound DeflectionData

The month to-	Uniformity of Deflection Data : Ploso - Munung					
	The Deflection			Trial uniformity		Conclusion
	Sun	Max	Price	Lower barrier	Upper Limit	
1	134.85	180.65	158.70	126.60	190.80	Uniform
2	151.05	200.57	178.78	139.44	218.13	Uniform
3	146.64	196.56	173.86	133.65	214.07	Uniform
4	169.74	220.93	195.00	157.89	232.11	Uniform
5	188.39	244.32	218.56	180.02	257.10	Uniform
6	187.57	245.69	212.53	175.06	250.01	Uniform
7	196.97	259.99	231.63	188.65	274.61	Uniform
8	191.71	246.86	218.83	178.35	259.30	Uniform
9	234.15	288.68	259.58	220.20	298.95	Uniform
10	222.00	267.00	250.58	221.73	279.42	Uniform
11	239.04	311.04	284.26	246.55	321.96	Were not uniform 2 Freezing-point
12	246.70	311.92	285.40	238.20	332.60	Uniform
The month to-	Uniformity of Deflection Data : Ploso -Gedeg					
	The Deflection			Trial uniformity		Conclusion
	Sun	Max	Price	Lower barrier	Upper Limit	
1	185.72	242.67	215.74	175.21	256.27	Uniform
2	200.54	251.28	228.57	182.90	274.20	Uniform
3	192.85	245.69	219.93	179.03	260.83	Uniform
4	218.24	269.43	242.76	201.23	284.28	Uniform
5	242.59	294.14	263.06	217.80	308.30	Uniform
6	226.52	278.60	250.80	208.40	293.20	Uniform
7	254.11	298.79	278.96	323.90	234.00	Uniform
8	254.74	291.51	277.06	253.07	301.06	Uniform
9	284.83	334.51	305.86	265.21	346.52	Uniform
10	279.00	333.00	305.48	267.83	343.12	Uniform
11	308.34	356.25	331.42	281.00	381.80	Uniform
12	307.46	339.12	322.90	298.29	347.51	Uniform

The month to-	Uniformity of Deflection Data : Krian - Mojosari					
	The Deflection			Trial uniformity		Conclusion
	Sun	Max	Price	Lower barrier	Upper Limit	
1	138.29	196.18	166.19	128.03	204.35	Uniform
2	154.56	204.24	174.71	122.90	226.50	Uniform
3	150.02	201.16	171.84	130.22	213.46	Uniform
4	158.98	211.97	183.98	138.80	229.20	Uniform
5	171.60	227.56	201.26	159.50	243.00	Uniform
6	167.07	218.21	190.51	142.20	238.60	Uniform
7	196.42	247.01	220.89	180.10	261.69	Uniform
8	195.84	233.28	210.96	174.63	247.29	Uniform
9	199.36	256.32	227.74	178.60	276.80	Uniform
10	208.66	261.65	233.66	185.80	281.50	Uniform
11	222.44	279.97	248.14	204.20	292.08	Uniform
12	220.22	267.84	243.81	199.97	287.65	Uniform

The month to-	Uniformity of Deflection Data : Mlirip - Jampirogo						
	The Deflection			Trial uniformity		Conclusion	
	Sun	Max	Price	Lower barrier	Upper Limit		
1	51.19	88.91	68.23	39.75	96.71	Uniform	
2	52.52	97.17	75.04	44.42	105.67	Uniform	
3	63.05	107.18	80.62	47.30	113.94	Uniform	
4	54.00	93.00	73.05	42.57	103.53	Uniform	
5	54.12	108.24	83.08	37.60	128.60	Uniform	
6	57.00	96.00	75.00	34.70	115.30	Uniform	
7	55.85	103.32	82.24	43.01	121.46	Uniform	
8	61.43	103.32	77.91	53.72	102.09	Were not uniform	1 Freezing-point
9	64.95	119.07	90.20	46.70	133.80	Uniform	
10	62.49	113.62	85.78	55.37	116.19	Uniform	
11	56.25	118.42	89.55	55.64	123.47	Uniform	
12	71.01	107.94	90.54	62.84	118.24	Uniform	

The month to-	Uniformity of Deflection Data : Gemekan - Jombang					
	The Deflection			Trial uniformity		Conclusion
	Sun	Max	Price	Lower barrier	Upper Limit	
1	146.64	202.80	170.66	132.37	208.96	Uniform
2	140.76	204.24	177.12	131.40	222.90	Uniform
3	144.48	188.16	162.12	124.31	199.93	Uniform

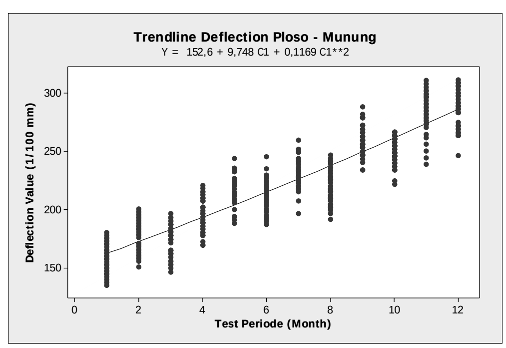
4	159.12	209.04	184.94	139.80	230.00	Uniform
5	169.68	226.24	195.23	158.46	232.00	Uniform
6	158.76	217.08	185.49	144.61	226.37	Uniform
7	170.22	221.89	197.80	153.70	242.00	Uniform
8	166.42	224.81	193.50	160.84	226.15	Uniform
9	199.85	245.10	220.11	178.46	261.77	Uniform
10	190.98	246.43	218.40	171.10	265.70	Uniform
11	196.56	252.72	227.45	175.50	279.40	Uniform
12	192.96	247.68	220.10	174.10	266.10	Uniform

Based on the uniformity test table above, it can be concluded that all the values of deflection data in the fifth roads is uniform.

The Deflection Development Trendline Analysis

Analysis of development trendlines carried out to obtain a description of deflection progress on each road test segment. Graphs and formula of deflection development trendline (Table 7) produced by quadratic regression analysis - Fitted Line Plot to the deflection values for twelve months.

Table 7. Formula and Graph of Rebound DeflectionTrendlineDevelopment

No	The Road Section	Formula of Rebound Deflection Development Trendline	Graph of Deflection Development Trendline
1.	Ploso - Munung	Y = 152.6 + 9.748 x + 0.1169 x2	

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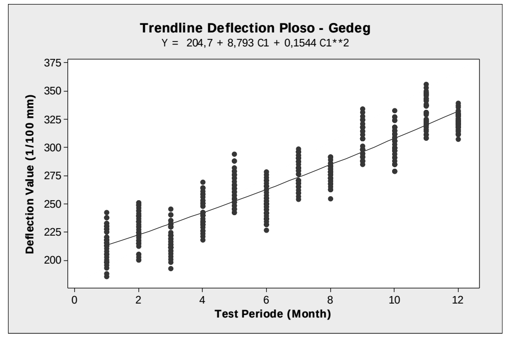
<tr><td>2.</td><td>Ploso -
Gedeg</td><td>Y = 204.7 + 8.793 x + 0.1544 x2</td><td>
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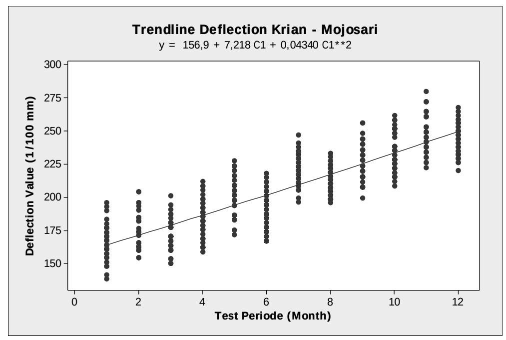
<tr><td>3.</td><td>Krian -
Mojosari</td><td>Y = 156.9 + 7.218 x + 0.0434 x2</td><td>
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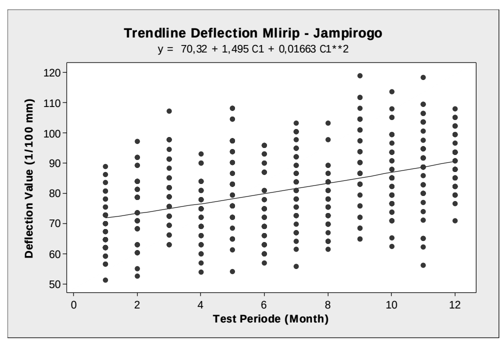
<tr><td>4.</td><td>Mlirip -
Jampirogo</td><td>Y = 70.32 + 1.495 x + 0.01663 x2</td><td>
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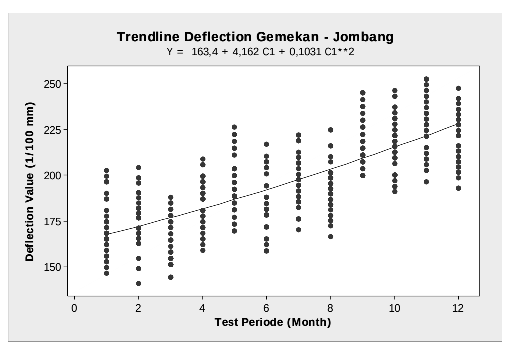
<table>
<tr><td>5.</td><td>Gemekan -
Jombang</td><td>Y = 163.4 + 4.162 x + 0.1031 x2</td><td>
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Based on the overall results of a regression model test to the rebound deflection trendline that has been carried out on the fifth road, the equations of deflection development pattern was obtained as shown in Table (8) below

Table 8. Formula of Rebound Deflection Development

No	The Roads Section	Formula of Deflection Development
1	Ploso - Munung	Y = C + 9.748 x + 0.117 x2
2	Ploso - Gedeg	Y = C + 8.793 x + 0.154 x2
3	Krian - Mojosari	Y = C + 7.218 x + 0.043 x2
4	Gemekan - Jombang	Y = C + 1.495 x + 0.017 x2
5	Mlirip - Jampirogo	Y = C + 4.162 x + 0.103 x2

Note:

- Y is Rebound Deflection values in the month -x
- X is the time (month) measuring.
- C is constant, namely the initial deflection

To illustrate the pattern of development of the deflection of each road segment from the same initial conditions, then the value of the constant (C) in each regression equation or model is substituted with the value of the initial deflection (d = 0). Furthermore, based on the formula development deflection (Table 8) above can be shown differences in the pattern of deflection trendline on each road segment for 12 (twelve) months.

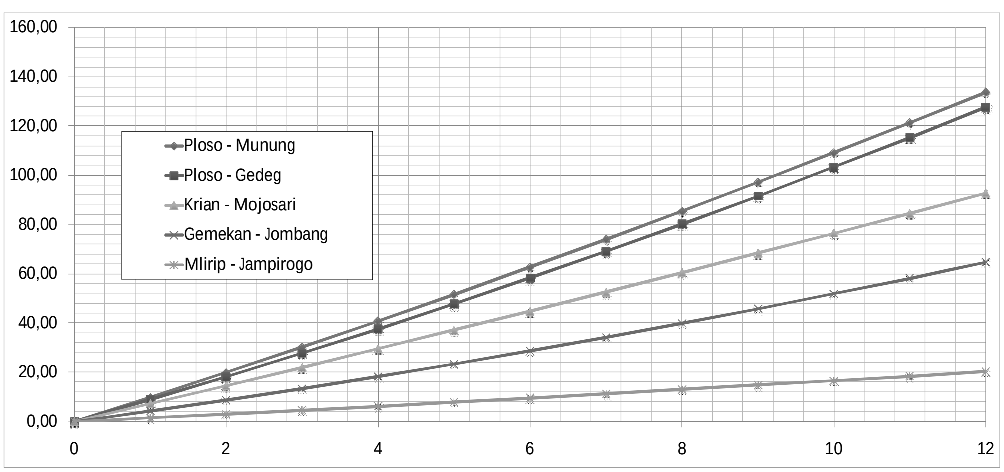


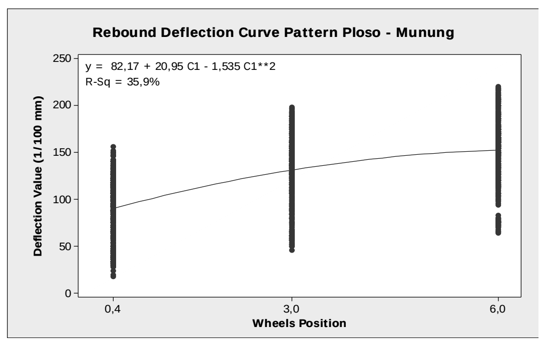
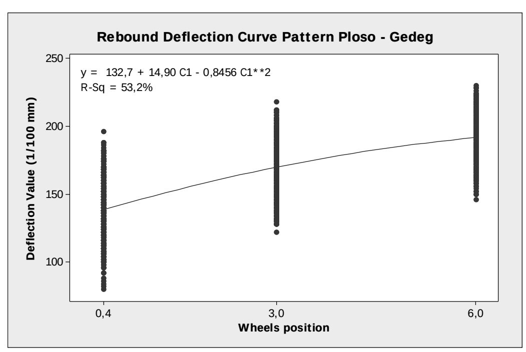
Figure 6 . The Trendline of Rebound Deflection Development on Fifth Roads Test

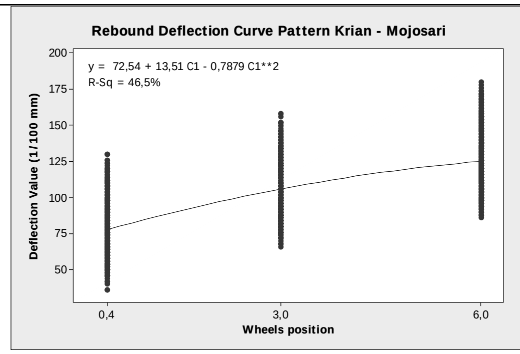
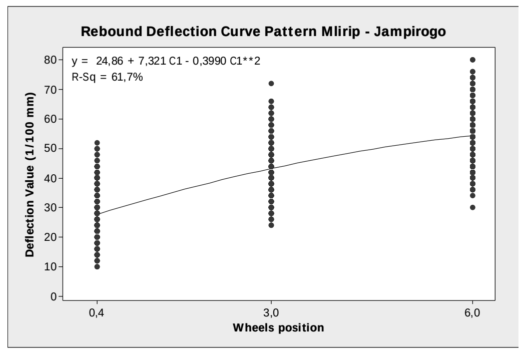
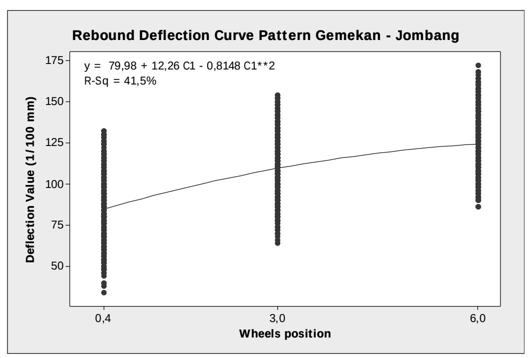
The graph above indicated that the road Ploso-Munung has the highest deflection development trendline, reaching 76.30% from its initial state, respectively Ploso-Gedeg 55.58%, Krian-Mojosari 52.11%, Gemekan-Jombang 36.09%, and Mlirip-Jampirogo with the lowest growth, reaching 26.20%.

The Pattern of Deflection Curved Analysis

Analysis of the deflection curve pattern performed by statistical method using quadratic regression Scatter Plot. Determination of deflection curve pattern obtained through the measurement of rebound deflection on the wheel position 0.4 m; 3 m; and 6 m from the starting position. Chart patterns and formulas of the deflection curve on the fifth road test is shown in Table (9) the following :

Table 9. Formula And Graphs of The Rebound Deflection Curve Pattern

No	The Roads	Formula of The Rebound Deflection Curve Pattern	Graphic of The Rebound Deflection Curve Pattern
1.	Ploso - Munung	Y = 82.17 + 20,95x - 1,54x2	
2.	Ploso - Gedeg	Y = 132.70 + 14,90x - 0,85x2	
3.	Krian - Mojosari	Y = 72.54 + 13,51x - 0,79x2	

			
4.	Mlirip - Jampirogo	Y = 24.86 + 7,32x - 0,40x2	
5.	Gemekan - Jombang	Y = 79.98 + 12,26x - 0,82x2	

By using graphs and formulas curved deflection pattern as in Table (10) above, can then be determined the value of the deflection curved tangent. Tangent value of deflection curve obtained from angle tangent formed by the difference in the value of deflection at position 6 m with a value of deflection at a position 0.4 m divided by the value of 5.6 m (the difference in distance from 6 to 0.4 m) as shown in the following figure.

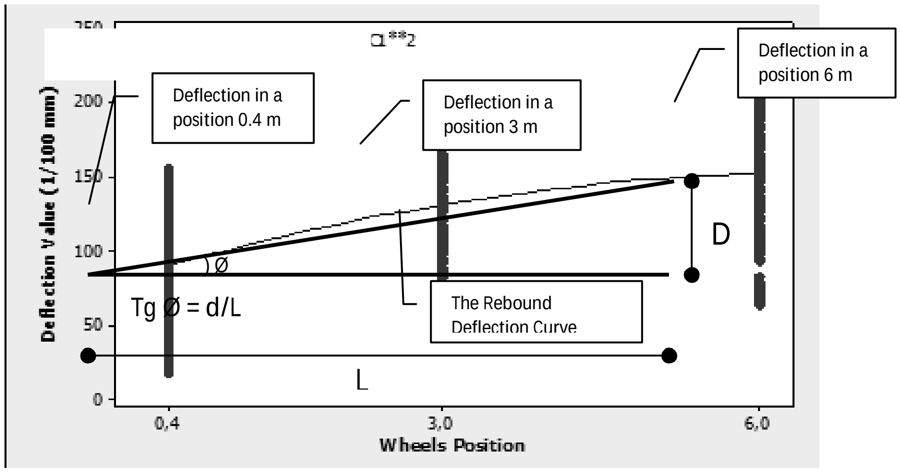


Figure7 . The Method Of Determining Curve Pattern Tangen

The Calculation results of the deflection curved pattern tangent of each roads test is shown in Table (10) below.

Table 10. Tangen of The Deflection Curve Pattern of Each Road Test

No	Road Section	Formula	x_1	y_1	x_2	y_2	X	Y	Tanθ of Curve Pattern	Rank
1	2	3	4	5	6	7	8=6-4	9=7-5	10=9/8	11
1	Ploso – Munung	$y = 82{,}17 + 20{,}95X - 1{,}54X^2$	0,4	90,30	6	152,43	5,6	62,13	11,09	1
2	Ploso – Gedeg	$y = 132{,}70 + 14{,}90X - 0{,}85X^2$	0,4	138,52	6	191,50	5,6	52,98	9,46	2
3	Krian - Mojosari	$y = 72{,}54 + 13{,}51X - 0{,}79X^2$	0,4	77,82	6	125,16	5,6	47,34	8,45	3
4	Mlirip - Jampirogo	$y = 24{,}86 + 7{,}32X - 0{,}40X^2$	0,4	27,72	6	54,38	5,6	26,66	4,76	5
5	Gemekan - Jombang	$y = 79{,}98 + 12{,}26X - 0{,}82X^2$	0,4	84,75	6	124,02	5,6	39,27	7,01	4

Description :

x_1 = Wheel Position at 0.4 m from the Test Point
x_2 = Wheel Position at 6 m from the Test Point
y_1 = Rebound Deflection in Position x_1
y_2 = Rebound Deflection in Position x_2
X = Distance from x_1 to x_2
Y = Different Deflection in x_1 and x_2
Tan α = Different Deflection in x_1 and x_2 divided by a distance

From the above table it appears that road section Ploso - Munung has the most value of deflection curved pattern tangent, followed by road section Ploso-Gedeg, Krian-Mojosari, Gemekan-Jombang, and Mlirip-Jampirogo with the smallest deflection curve pattern tangent value.

Correlation analysis between the deflection development trendline with its curve pattern

The correlation analysis between the deflection development trendline with its curve pattern performed by statistical methods such as correlation analysis using the Pearson Product Moment correlation technique. Variables which were tested there level of correlation are a curve pattern tangent value data and percentage of the deflection development that occurred during the twelve months test as shown in Table (11) following :

Table 11. The Curve Pattern Tangen And The Percentage of Deflection Development

No	The Roads	The Curve Pattern Tangen	The Percentage of Deflection Development in 12 months
1	Ploso - Munung	11.09	76.30
2	Ploso - Gedeg	9.46	55.58
3	Krian - Mojosari	8.45	52.11
4	Gemekan - Jombang	7.01	36.09
5	Mlirip - Jampirogo	4.76	26.20

By using the Pearson correlation method, measuring the degree of correlation between two variables can be assumed with a value of (-) 1 and (+) 1 to two variables x and y, then the significance of the correlation between the two variables can be calculated by formula (10) follows :

$$\rho = \frac{\sum_{i=1}^{n}(x_i - x)(y_i - y)}{(n-1)s_x s_y} \qquad \text{.........................} \ (10)$$

Where:

X = Samples mean for the first variable
Sx = Standard deviation for the first variable
Y = Samples mean for the second variable
Sy = Standard deviation for the second variable
N = Column length

From the calculation of the Pearson formula approach supported by software-Minitab version 16, the value of the correlation between the tangent of the deflection curved pattern with the percentage growth of the deflection development as follows:

- Pearson correlation (ρ) = 0.979

• P-Value = 0.004

Based on the results of the correlation analysis above, it appears that there is a positive correlation between the pattern of curved and its deflection development with a significance value of 0.979.

Thus it can be stated that the road section of Ploso – Munung which has the most large curve pattern tangent value, indicates that these roads had the greatest strain (Timoshenko and Goodier, 1986), so it is also have the most great deflection development. On the contrsary, Mlirip-Jampirogo road that has a smallest value of tangent having the lowest strain, so that the deflection development also the lowest.

To determine the value of rebound deflection at a given time after the achievement of the road service life limit, can be determined with the formula and the chart of the deflection development trendline based on the deflection curve pattern tangent value shown in the figure (11) below.

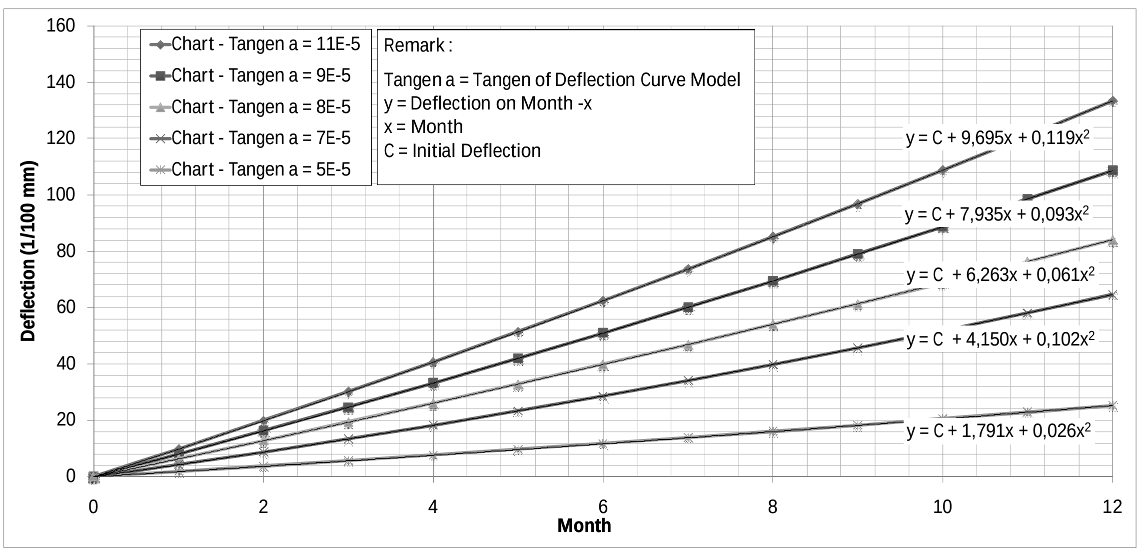


Figure 11. Graphs and formulas trendline deflection

CONCLUSION

Based on the data processing analysis and its interpretation, the following conclusions can be drawn as following :

- Rebound deflection development Trendline after the limit of road service have a tendency to increase quite sharply with the difference trendline patterns for each road section.

- There is a significant positive correlation between the deflection developments trendline with its deflection curve pattern, that is equal to 0.979. This may imply that the pattern of deflection curve associated with the deflection development trendline of pavement.
- Deflection curve pattern with greater tangent value proportional to the magnitude of rebound deflection development that occurs, and vice versa.
- To predict the value of rebound deflection at a given time after the expiration of the road service of life can be determined based on the deflection trendline chart and formula (Figure 11)

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