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Design Of An Overlay On The Baureno Highway Section, Bojonegoro Regency Sta 89+700-91+700, Using The Manual Design Method For Road Pavement 2017 (Bina Marga)

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Abstract

Roads also play a significant role in supporting the economic, social, cultural, and environmental fields. In order to achieve balance and equity in inter-regional development, form, and strengthen national development, roads are developed through a regional development approach as part of the national transportation system (Law No. 38 of 2004 concerning roads). One of the developing regencies in East Java is Bojonegoro Regency, and the government there is accelerating infrastructure development to foster greater synergy and advance the region. Highway Baureno is a highway that uses flexible pavement and is one of the national roads passed by motorcycles and heavy transport cars to go to the city of Lamongan. Vehicle congestion on Baureno highway from the direction of Bojonegoro causes road transport problems caused by private vehicles. In addition, heavy vehicles impact the road's condition, resulting in cracks, potholes, and bumpy roads. Considering these conditions, planning an additional layer (overlay) to expedite traffic and overcome existing problems is necessary.

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1. Introduction

Roads, as part of the national transportation system, have an essential role, especially in supporting the economic, social, and cultural as well as environmental, and are developed through a regional development approach to achieve balance and equalization in inter-regional development, form and strengthen national unity to make sure defense and federal security, and form a spatial structure to realize the national target development (UU No. 8 Tahun 2004 regarding roads). The road is one of the elements of land transportation designated to facilitate the movement of people and goods. The government thoroughly carries out the provision and management of roads as part of its obligations in providing public services (Oglebey, 1954).

Infrastructure development is accelerated from urban centers to remote villages, focusing on road construction. The purpose is to facilitate the efficient distribution of goods between different locations, ultimately contributing to the local communities.

Each region has certain conditions and characteristics that can differentiate road construction needs from one area to another. Therefore, in road design, the study of road construction must consider aspects that influence road design to anticipate the impacts of road construction.

Baureno is a highway that uses flexible pavement; the condition of the road is currently damaged and cracked; Baureno highway is an arterial road based on its function and is one of the national roads that is passed by both motorbikes and heavy vehicles from Bojonegoro to Lamongan, the density of vehicles on Baureno highway has caused road transportation problems which are caused by private vehicles and heavy vehicles so that the impact on road conditions is quickly damaged namely many cracked, potholed and bumpy roads. By looking at these conditions, an additional layer design is necessary to expedite traffic and overcome existing problems.

2. Material and Methods

This study is preceded by preparation to facilitate and launch an investigation. The process of this study is presented in Figure 1.

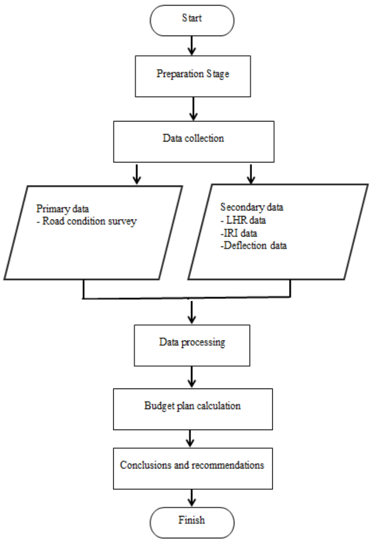

Figure 1. Flowchart

2.1 Theoretical Framework

Baureno road uses flexible pavement, passed by motorbikes and heavy vehicles. Because of that function, the road is damaged. This study is carried out to design additional layer thickness for the Baureno highway. The design consists of traffic volume analysis, lanes distribution analysis, deflection analysis, and overlay thickness design analysis. Thickness design approach analysis used the manual of pavement design in 2017. This research also produces budget estimate planning and the work volume of the overlay.

2.2 Research Location

This study is located on the Baureno highway. The location connects Bojonegoro Regency and Lamongan Regency. The condition of this road is narrowed, and side cracks and potholes dominate some damage.

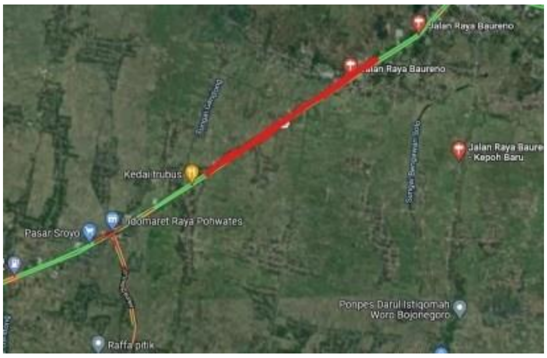

Figure 2. Research Locations

2.3 Data

The data consists of primary and secondary data. Preliminary data is taken directly on the condition of the field, which is road damage, based on observation and direct measurements in the area. Meanwhile, secondary data support research data, traffic data, international roughness index (IRI), and the deflection of FWD tools.

Table 1. Traffic Volume of Baureno Road, Bojonegoro in 2020 Data (B2PJN Jawa Timur-Bali)

Classification	Vehicle's Classification	Number of Counts
1	Motorcycle	14529
2	Passenger Cars	2610
3	Other Two-Axle, Four Tire Single Unit Vehicles	451
4	Four or More Axle Single-Unit Trucks	841
5a	Mini Busses	0
5b	Busses	10
6a	Truck with 2 Axle-4	254
6b	Truck with 2 Axle-6	1538
7a	Truck with 3 Axle	348
7b	Multi Trailer Truck	5
7c	Semi Trailer Truck	52
8	Non-Motorized Vehicle	81

Table 2. International Roughness Index (IRI) of Baureno Road, Bojonegoro in 2020 Data (B2PJN Jawa Timur-Bali)

Section	STA	IRI Value	Section	STA	IRI Value
1	89+700 - 89+800	3,3	11	90+700 - 90+800	6,3
2	89+800- 89+900	3,3	12	90+800 - 90+900	4,6
3	89+900-90+000	4,8	13	90+900 - 91+000	5,4
4	90+000-90+100	2,1	14	91+000 - 91+100	5,8
5	90+100 - 90+200	3	15	91+100- 91+200	4,6
6	90+200 - 90+300	5,5	16	91+200 - 90+300	4,9
7	90+300 - 90+400	6,8	17	91+300 - 90+400	4
8	90+400- 90+500	5,4	18	91+400 - 91+500	5
9	90+500 - 90+600	3,4	19	91+500 - 91+600	5,6
10	90+600 - 90+700	3,3	20	91+600- 91+700	3,4

Table 3. The deflection of FWD tools (B2PJN Jawa Timur-Bali)

STA	D_0	D_{200}	STA	D_0	D_{200}
89+700	684	473	90+800	648	528
89+800	852	632	90+900	782	631
89+900	584	457	91+000	455	347
90+000	435	314	91+100	521	378
90+100	359	243	91+200	647	533
90+200	532	405	91+300	775	649
90+300	425	316	91+400	539	425
90+400	560	428	91+500	425	317
90+500	638	521	91+600	684	473
90+600	750	583	91+700	852	632
90+700	533	385			

Table 4. Recorded loads and asphalt temperatures at each stationing (B2PJN Jawa Timur-Bali)

STA	Weight (kN)	Temperature Asphalt°C	STA	Weight (kN)	Temperature Asphalt°C
89+700	39,64	38,2	91+800	39,55	38,2
89+800	39,52	38,2	91+900	39,23	38,2
89+900	39,29	38,2	91+000	39,27	38,2
90+000	39,61	38,2	92+100	39,38	38,2
90+100	40,02	38,2	92+200	39,64	38,2
90+200	39,33	38,2	92+300	39,56	38,2
91+300	39,21	38,2	92+400	39,73	38,2
91+400	39,54	38,2	92+500	39,47	38,2
91+500	39,75	38,2	92+600	39,61	38,2
91+600	39,58	38,2	92+700	39,89	38,2
91+700	39,65	38,2			

2.4 Analysis Method

In the conducted research, data analysis was performed to (a) calculate traffic volume; (i) plan additional layer thickness, (ii) calculate cumulative equivalent single axle load (CESAL), (b) calculate design thickness overlay based on the 2017 Pavement Design Manual; (i) overlay design procedure, (ii) existing thickness, (iii) deflection control, (iv) normalizing deflection values to Standard Load and Curvature Function (CF) Calculation, (v) determining AMPT and asphalt temperature, (vi) determining Deflection Temperature Correction Factor, (vii) determining the conversion of D0 FWD Value to D0 BB, (viii) determining the average maximum deflection of D0 BB, Standard Deviation, Reliability, and Overlay Thickness Based on Maximum Deflection, (ix) calculation of Average CF and determination of Overlay Thickness, (x) calculation of IRI value. (d) analysis of budget planning.

For several regions in Indonesia, such as Java Island, Sumatra, and Kalimantan, as well as the national average in Indonesia, the traffic growth rate factor has been established by the Ministry of Public Works and Housing,

Table 5. The traffic growth rate factor

Class	Java	Sumatera	Kalimantan	Indonesia Rate
Arterial and urban	4,8	4,83	5,14	4,75
Rural Colector	3,5	3,5	3,5	3,5
Country Road	1	1	1	1

Based on Table 5, since Baureno Highway is a road on Java Island and is categorized as an arterial road, the annual growth rate (i) for that road is 4.80%, and this value will be used as one of the inputs to calculate the average daily traffic. The labor coefficient is the ratio of labor input to output. The value is the labor time required to produce a specific output unit.

In analyzing the traffic volume, it is necessary to calculate the traffic growth rate factor, which is calculated using the equation.

$$R = \frac{(1+0{,}01\ i)^{UR}-1}{0{,}01\ x\ i} \quad (1)$$

R : Traffic growth factor
i : Annual growth rate
UR : Planned road lifespan

$$LHR = (1 + i)^{n} \text{ x Jumlah Kendaraan} \quad (2)$$

$$LHR_{smp} = (LHR) \text{ x Faktor ekivalen} \quad (3)$$

LHR : Average Daily Traffic (vehicles/day/2 directions)
i : Traffic development
n : Number of planning years
LHR_{smp} : Equivalence of LHR in passenger car units

Directorate General of Highways through Road Pavement Design Manual (MDP) No. 02/M/BM/2017

Table 6. Lane Distribution Factor (D_L)

Number of lanes in each direction.	Commercial vehicles in the design lane (% of commercial vehicle population)
1	100
2	80
3	60
4	50

Based on the Manual Design of Pavement Number 02/M/BM/2013, the value of CESA (Cumulative Equivalent Standard Axles) determines the planning of an economically viable additional layer thickness. For CESA values below 105, there is no need to check asphalt fatigue, and the approach with maximum deflection (d1) is sufficient. For traffic loads with CESA values greater than 105 but less than 107, the potential for asphalt fatigue exists, and the Curvature Function approach (d1-d2) is used. However, for CESA values exceeding 107, the AASHTO method is employed.

The Cumulative Equivalent Standard Axle Load (CESA) is the predicted cumulative sum of axle loads on the design lane during the design life. The value of CESA is determined using the following Equation;

$$CESA = \sum_{Traktor-Trailer}^{Mp} m\ x\ 365\ x\ E\ x\ C\ x\ N \quad (4)$$

CESA : Cumulative Equivalent Standard Axle Load
m : The number of each vehicle type
365 : The number of days in one year

E	:	Equivalent axle load
C	:	Vehicle distribution coefficient
N	:	Adjusted planning life factor for traffic development

In designing the thickness of the overlay using the MDP 2017 method to rehabilitate existing pavement that has experienced damage, the overlay serves as a form of treatment to address road conditions such as surface normalization, non-structural repairs, and improving comfort.

The overlay thickness design procedure based on traffic is as follows: (a) Light traffic and pavement with HRS generally do not experience fatigue cracking, so the fatigue overlay performance is not required. The overlay thickness design is sufficient with the deflection approach (D0). (b) Traffic volume greater than 100,000 ESA4. On roads with traffic volumes greater than 100,000 ESA4, the asphalt layer has a potential for fatigue cracking. Therefore, the deformation criteria (maximum deflection approach, D0) and fatigue cracking criteria (curvature deflection approach, D0-D200) should be considered.

Suppose the deflection data is obtained from the Falling Weight Deflectometer (FWD). In that case, the data should be converted to Benkelman Beam deflection data by multiplying the obtained values with the adjustment factor, as shown in Table 7. Meanwhile, for pavement structure, refer to Table 8.

Table 7. The adjustment factor for deflection (D0) from Falling Weight Deflectometer (FWD) to Benkelman Beam (BB) (Road Pavement Design Manual 2017)

The existing asphalt thickness (mm)	Factor	The existing asphalt thickness (mm)	Factor
0	1	160	1,26
20	1,12	180	1,28
40	1,14	200	1,29
60	1,16	220	1,31
80	1,18	240	1,33
100	1,2	260	1,34
120	1,22	280	1,35
140	1,24	300	1,36

Tabel 8. Pavement Structure (Road Pavement Design Manual 2017)

	Pavement Structure								
	FFF1	FFF2	FFF3	FFF4	FFF5	FFF6	FFF7	FFF8	FFF9
Preferred solution					Note 2				
Cumulative 20-year axle load on plan lanes (10^6ESA5)	< 2	≥ 2-4	> 4-7	> 7-10	> 10-20	> 20-30	> 30-50	> 50-100	> 100-200
Pavement Thickness 9mm)									
AC WC	40	40	40	40	40	40	40	40	40
AC BC	60	60	60	60	60	60	60	60	60
AC Base	0	70	80	105	145	160	180	210	245
LPA Class A	400	300	300	300	300	300	300	300	300
Note	1		2			3			

3. Result and Discussion

3.1. The result of the analysis is the Average Daily Traffic, Equivalent Load Factor, and Cumulative Equivalent Single Axel Load of Baureno Road

The Baureno Road section in Bojonegoro is a national road, and it plays a significant role in facilitating the movement of motor vehicles such as trucks, buses, and private cars.

From the initial planned LHR data presented in Table 1, with a vehicle growth rate of 0.48%, the value of average daily traffic for each vehicle classification can be obtained (Table 6). Furthermore, using the Lane Distribution Factor (Dl) presented in Table 6, the value of lane distribution (DL) for Baureno Highway is determined to be 80%. For a two-way road, the direction distribution factor (DD) is 0.50 because the number of commercial vehicles tends to be the same in each direction, resulting in the Equivalent Load Factor (VDF). This VDF is divided into 2, namely VDF4 and VDF5, which are then used to determine CESA4 and CESA5.

Table 9. The result of the analysis is the Average Daily Traffic of Baureno Road in Bojonegoro in the years 2022 and 2032

Classification	Vehicle's Classification	Number of Counts (Vc/day)		
		2020	2022	2032
1	Motorcycle	14529	15957	25502
2	Passenger Cars	2610	2867	4581
3	Other Two-Axle, Four-Tire Single Unit Vehicles	451	495	792
4	Four or More Axle Single-Unit Trucks	841	924	1476,2
5a	Mini Busses	0	0	0
5b	Busses	10	11	18
6a	Truck with 2 Axle-4 Tires	254	279	446
6b	Truck with 2 Axle-6 Tires	1538	1689	2700
7a	Truck with 3 Axle	348	382	611
7b	Multi Trailer Truck	5	5	9
7c	Semi Trailer Truck	52	57	91
8	Non-Motorized Vehicle	81	89	142

Table 10. Equivalent Load Factor on Baureno Highway

Classification	Vehicle's Classification	Number of Counts	VDF 4	VDF 5
5a	Mini Busses	0	0,3	0,2
5b	Busses	15	1	1
6a	Truck with 2 Axle-4 Tires	393	0,3	0,2
6b	Truck with 2 Axle-6 Tires	2355	0,7	0,7
7a	Truck with 3 Axle	539	7,6	11,2
7b	Multi Trailer Truck	8	36,9	90,4

The cumulative equivalent single axle load value is obtained from analyzing average daily traffic and Equivalent Load Factor on Baureno Highway. It represents the cumulative sum of axle loads based on the VDF (Vehicle Distribution Factor) for each commercial vehicle passing through.

From the calculations for each vehicle category, the total value of CESA 4 is 12.068.677,50, while the value of CESA 5 is 17.296.734,18.

Table 11. Cumulative Equivalent Single Axel Load (CESA)

Classification	Vehicle's Classification		VDF 4	VDF 5	ESA 4	ESA 5
5a	Mini Busses	0	0,3	0,2	0	0
5b	Busses	18	1	1	25.681,86	25.681,86
6a	Truck with 2 Axle-4 Tires	446	0,3	0,2	195.695,79	130.463,86
6b	Truck with 2 Axle-6 Tires	2700	0,7	0,7	2.764.909,28	2.764.909,28
7a	Truck with 3 Axle	611	7,6	11,2	6.792.338,91	10.009.762,61
7b	Multi Trailer Truck	9	36,9	90,4	473.830,36	1.160.820,17
7c	Semi Trailer Truck	91	13,6	24	1.816.221,29	3.205.096,40
				CESA	**12.068.677,50**	**17.296.734,18**
				CESA Total	**29**	**365.411,68**

3.2. The result of the analysis of thickness overlay design based on the Manual for Pavement Design 2017

After obtaining the CESA values, these values are used to determine the overlay design procedure. The overlay procedure is based on traffic, where the traffic volume is more significant than 100,000 ESA4 but less than or equal to 20,000,000 ESA5. Based on the data calculation, Jalan Raya Baureno has a service life of 20 years with a planned ESA of 29.365.411,68. Referring to Table 8, the obtained existing thickness is 100mm.

Next, corrections are made to the deflection of Jalan Raya Baureno. After the deflection correction is performed, the next step is deflection normalization. The deviation in the recorded actual load values leads to this. Therefore, the recorded deflection must be normalized to the standard load of 40 kN. Deflection curvature is expressed at the inflection point of the curvature or CF (Curvature Function) based on the shape of the deflection curve. In calculating worker productivity with labor utilization rate, it is necessary to observe the value of total adequate time, contribution time, ineffective time, and total observation time. The calculation is carried out for all labor.

Table 12. Summary of normalized deflections

No.	D_0 Normal	D_{200} Normal	No.	D_0 Normal	D_{200} Normal
1	690,2	477,2	12	655,3	534
2	859,7	639,6	13	797,3	643,3
3	589,3	465,2	14	463,4	353,4
4	438,9	317,1	15	529,3	384
5	353,8	242,8	16	652,8	537,8
6	541	411,8	17	783,6	656,2
7	433,5	322,3	18	542,6	427,8
8	566,5	432,9	19	430,7	321
9	642	524,2	20	690,7	477,6
10	758	590	21	854,3	633,7
11	537,7	388,3			

Table 13. Summary of CF (Curvature Function) calculations

No.	D_0 - D_{200}	No.	D_0 - D_{200}
1	213	12	121,3
2	220,1	13	154
3	124,1	14	110
4	121,8	15	145,3
5	111	16	116
6	129,2	17	127,4
7	112,6	18	114,8
8	133,6	19	109,7
9	117,8	20	213,1
10	168	21	220,6
11	149		

The ratio of AMPT and Asphalt Temperature can be calculated by dividing the value of AMPT by the asphalt temperature. In this case, the average AMPT in Indonesia is 410°C, and the asphalt temperature at each stationing is 38.20°C. Therefore, the ratio of AMPT and Asphalt Temperature is:

Ratio = AMPT / Asphalt Temperature

$$= 410°C / 38,20°C = 10,71 \cong 1,10$$

Thus, the ratio of AMPT and Asphalt Temperature is 1,10.

Based on the AMPT and Asphalt Temperature correction factors, the temperature correction factor for deflection D_o is obtained as 1.02, and the temperature correction factor for deflection D_{200} is 1.05. Therefore, the temperature-corrected deflection factor Do (Do_{tt}) is calculated, and the results are shown in Table 14 and CF curvature factor corrected by the temperature correction factor (CF tt) as shown in table 15.

Table 14. Summary of the calculation of D_0 temperature correction factor (Do_{tt})

No	Corrected D_o due to temperature	No	Corrected D_o due to temperature
1	704,1	12	668,4
2	876,9	13	813,24
3	601,1	14	472,66
4	447,67	15	539,78
5	360,87	16	665,85
6	551,82	17	779,27
7	442,17	18	533,45
8	577,83	19	439,31
9	654,84	20	704,51
10	773,16	21	871,38
11	548,45		

Table 15. Summary CF curvature factor corrected by the temperature correction factor (CF tt)

No.	CF corrected by temperature	No.	CF corrected by temperature
1	223,65	12	127,05
2	231,1	13	161,7
3	130,1	14	115,5
4	127,89	15	152,56
5	116,55	16	120,75
6	135,66	17	133,77
7	116,76	18	120,54
8	140,28	19	115,18
9	123,69	20	223,75
10	176,4	21	231,63
11	156,45		

The Deflection Adjustment Factor (D0) to Benkelman Beam (BB) with an existing asphalt thickness of 100mm is 1.20. By using the deflection adjustment factor, the converted values of D0 FWD to D0 BB are obtained as follows:

D0 1 BB = D0 1 tt x 1,20
= 704,1 x 1,20
= 718,18

D0 2 BB = D0 1 tt x 1,20
= 876,90 x 1,20
= 1052,28

D0 3 BB= D0 1 tt x 1,20
= 601,1 x 1,20
= 721, 32

D0 4 BB = D0 1 tt x 1,20
= 447,67 x 1,20
= 537,20

To determine the thickness of the next pavement layer, an analysis of the average D0 BB maximum deflection, standard deviation, reliability, and overlay thickness based on the maximum deflection values are conducted. The respective values are as follows: D_o rata-rata BB = $\frac{\text{D01 BB+ D02 BB+.....D021 BB}}{21}$

$$= \frac{15523{,}94}{21} = 739{,}23\ \mu m$$

Standar Deviasi (s) $= \sqrt{\frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n-1}}$

$$= \sqrt{\frac{12107018{,}47.240992713{,}12}{21-1}} = 177{,}65\ \mu m$$

Reliability = 92 %.

From the obtained reliability values, the value of ZR = 1,405.
Therefore:
Representative D0 = Average D0 BB + (ZR * s)
= 739.23 + (1.405 * 177.65)
= 966.98 µm
= 0.9 mm

The representative value of D0 is 0.9 mm. When this value is vertically drawn upwards and the CESA 4 value is 12.068.677,50, the overlay thickness based on the maximum deflection is 0 mm.

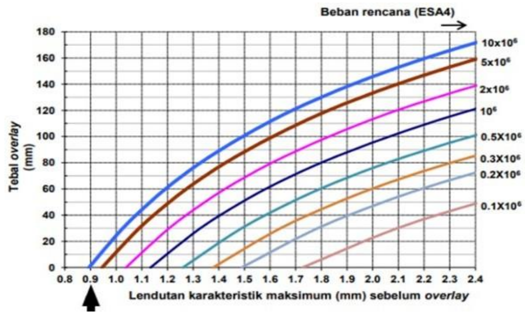

Fig.3. Determining overlay based on maximum deflection

Next, the calculation of the Average CF and determination of Overlay Thickness are carried out as follows:

$$CF_{Average} = \frac{\text{CF1 tt+ CF2 tt+.....CF21 tt}}{21}$$

$$= \frac{3180{,}96}{21} = 151.47\ \mu m = 0.15\ mm$$

From the calculation, the average CF of 0.15 is drawn horizontally to the left, and the value of CESA 5 of 15,080,367.302 is drawn vertically upwards. The two lines intersect at a point, indicating an overlay thickness of 70 mm in (Figure 4.), and an overlay thickness of 80 mm in (Figure 5.).

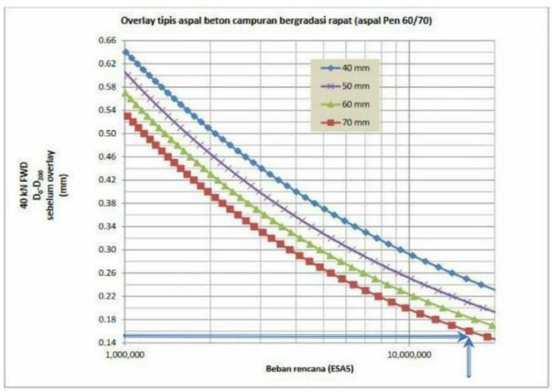

Fig.4. Determination of Overlay Thickness (Thin)

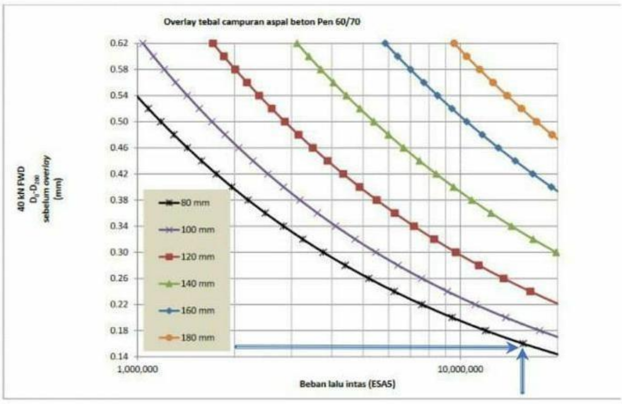

Fig.5. Determination of Overlay Thickness (Thick)

Based on Table 2, which contains the IRI data from B2PJN on the section of Jalan Raya Baureno STA 89+700-91+700, the average IRI value is 4 m/km. Therefore, a minimum overlay of 40mm is required to reduce the IRI from 4 m/km to 3 m/km.

4. Conclusion

From the analysis, it can be concluded that according to the Manual for Pavement Design (MDP) 2017, the maximum deflection of Baureno Highway requires an overlay of 0 mm. However, a thin overlay of dense graded asphalt (binder Pen 60/70) of 80 mm is obtained in the curve section. Based on conventional overlay thickness, the recommended thickness for Pen 60/70 is 70 mm. Considering the IRI value, the minimum overlay thickness for Baureno Highway is 40 mm.

5. Acknowledgement

First and foremost, I would like to express my gratitude to God Almighty, who makes everything beautiful in His time. I would also like to thank my parents and the entire family. I am grateful to Ir. Hary Moetriono, M.Sc, as my primary supervisor, for guiding the research process. I would also like to acknowledge the entire academic community of the Civil Engineering Study Program, Faculty of Engineering, Universitas 17 Agustus 1945 Surabaya.

6. Author's Note

I, at this moment, declare that the article entitled "Design Of An Overlay On The Baureno Highway Section, Bojonegoro Regency Sta 89+700-91+700, Using The Manual Design Method For Road Pavement 2017 (Bina Marga)" is an original work and has been defended in the examination to obtain a Bachelor's degree in Civil Engineering at the Civil Engineering Study Program, Faculty of Engineering, Universitas 17 Agustus 1945 Surabaya

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