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Thickness of Overlay Design with CESA5 Implementation and Benkelman Beam Deflection Through Manual Method of Road Pavement Design 2024 on Pahlawan Street, Sidoarjo Regency

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ABSTRACT

Jalan Pahlawan - Sidoarjo is a collector road with a Type 4/2 D Road with a length of 3.3 km located in Sidoarjo Regency. The road is a connecting road with a fairly high intensity of activity, which causes the quality of the road pavement to weaken. Road damage that occurs such as cracking, peeling of aggregate grains, and holes. So it is necessary to plan an overlay to increase the strength of the structure and avoid more severe damage by traffic loads. This study uses the 2024 Pavement Design Manual (MDP) method with the CESA5 approach and deflection from Benkelman Beam. Secondary data used in the form of Benkelman Beam (BB) deflection and average daily traffic data (LHR) obtained from the PU Bina Marga Service with the results of CESA4 values of 16,760,006 ESA and CESA5 of 19,990,025 ESA. The results show that the thickness of the overlay with a design life of 20 years based on the maximum deflection D0 0.376 is 5 cm, and the thickness based on the deflection curve D200 0.239 mm is 12 cm. From the analysis results, the overlay thickness is taken as 12 cm, because with a thickness of 12 cm it is expected to withstand damage due to fatigue cracks before the planned age caused by the load of passing vehicles, so that road users can operate safely and comfortably on Jalan Pahlawan - Sidoarjo.

Keywords: *Benkelman Beam; CESA; road; LHR; MDPJ 2024; overlay*

1. Introduction

Roads are transportation infrastructure that have an important role in the growth of various aspects of life. This is in accordance with Law Number 38 of 2004 on Roads, namely that roads are included in the transportation infrastructure that has the most important role in social, economic and cultural aspects, the environment, politics, security and defense, and are used for the prosperity of the people (Soesanto et al., 2023). The use of fairly high traffic is influenced by the economic activities of the community (Chen et al., 2024). Improvement or renewal of road infrastructure is a fairly important factor in supporting population mobility. Road construction has a role in improving the economic, social and cultural sectors, with good and decent road conditions that can provide comfort to road users (Apteda, 2023).

In the process of road management, roads are not immediately damaged without consequences, there are many factors that cause road damage, including high traffic use, the surrounding environment, and weather factors (Lestari et al., 2022). Factors that also affect damage are water, which occurs when water stagnates for a certain duration on the road surface so that the asphalt is not bound to each other (Ramdani et al., 2022). The types of damage on Jalan Pahlawan, Sidoarjo Regency include cracks, peeling, holes, and fatness in the road pavement (Pasetto et al., 2023). Excessive repetitive loads can make roads more easily damaged or destroyed so that the design life exceeds the limit and cannot accept the load of passing vehicles (Machado et al., 2020). Therefore, an overlay is needed because the pavement has reached its service life and has experienced significant damage (Tohidi et al., 2022). An overlay is an additional layer placed on top of the road pavement to increase the strength of the road structure so that traffic services have the same resistance as the designed design life (Manguande et al., 2020).

Based on the survey results and data obtained from the PU Bina Marga Service, the development of Jalan Pahlawan infrastructure in the Sidoarjo Regency area is a challenge to immediately carry out periodic maintenance (Setyawan & Sulistyojati, 2023), the implementation of the overlay has an important role in realizing the road maintenance program which aims to improve flexible pavement to make it stable (Yuliandra et al., 2022). There is a hole estimated to have a depth of 7-10 cm which has caused several motorbikes to fall. The overlay implementation method involves a series of stages, namely obtaining traffic load data, CBR (California Bearing Ratio) values, calculating cumulative standard axle loads (CESA) and deflection curves that can improve the strength and quality of existing road surfaces (Amakye et al., 2022).

Based on this, researchers use a method in road maintenance planning using the Road Pavement Design Manual method compiled by Bina Marga which has the advantage of flexibility in adjusting the design to accurate field conditions so that it is easy to change design parameters based on available field data (Pratama & Puspito, 2024). Therefore, this study uses the latest method, namely the 2024 Road Pavement Design Manual from Bina Marga in designing solutions for roads that have entered the design age and are severely damaged due to vehicle loads. So that the handling of road damage taken is appropriate in accordance with developments and provides comfort for road users who pass by.

2. Methods

The study was conducted on the Pahlawan Road Section of Sidoarjo Regency, which will be planned for road maintenance in the form of an overlay. Maintenance planning is carried out in poor conditions, with an age of more than 10 years for use. Pahlawan Road has a road length of 3.4 kilometers, an average road width of 8 meters, including the collector road type, and the type of pavement used is flexible pavement (asphalt). The data used includes the condition of the section located on Pahlawan Street in Sidoarjo District, Sidoarjo Regency. This calculation uses the 2024 Road Pavement Design Manual method from Bina Marga.

2.1. Data Collection

2 data were obtained, namely primary data and secondary data, from the results of the primary data the details of the results of the road dimension measurement survey were known (Daramola et al., 2024). The measurement details are as follows:

- Planned Age: 20 Years
- Road Shoulder Width: 2 meters

- Planned Pavement Type: Asphalt (AC - WC)

In addition to primary data, secondary data was obtained such as daily traffic review data (LHR) around. Data was obtained from the PU Bina Marga (BiMa) agency of East Java Province with the following details:

Table 1 Average Daily Traffic (LHR)

TIME	Number of Vehicles				EMP			
	LV	HV	MC	Number of Vehicles (hourly)	LV	HV	MC	Total SMP (Hour Volume)
					1,0	1,3	0,25	
06.00-07.00	1.161	114	7.898	9.173	1.161	148	1.975	3.284
07.00-08.00	1.463	123	7.093	8.679	1.463	160	1.773	3.396
08.00-09.00	1.596	116	6.483	8.195	1.596	151	1.621	3.368
09.00-10.00	1.796	103	2.349	4.248	1.796	134	587	2.517
10.00-11.00	1.640	104	2.761	4.505	1.640	135	690	2.465
11.00-12.00	1.046	115	3.825	4.986	1.046	150	956	2.152
12.00-13.00	1.199	121	3.525	4.845	1.199	157	881	2.238
13.00-14.00	1.721	103	3.426	5.250	1.721	134	857	2.711
14.00-15.00	1.357	109	3.715	5.181	1.357	142	929	2.427
15.00-16.00	1.507	119	4.184	5.810	1.507	155	1.046	2.708
16.00-17.00	1.778	112	5.495	7.385	1.778	146	1.374	3.297
17.00-18.00	1.556	105	2.916	4.577	1.556	137	729	2.422
18.00-19.00	1.362	100	3.263	4.725	1.362	130	816	2.308
19.00-20.00	1.368	73	2.476	3.917	1.368	95	619	2.082
20.00-21.00	1.260	83	2.143	3.486	1.260	108	536	1.904
21.00-22.00	1.200	62	3.643	4.905	1.200	81	911	2.191
22.00-23.00	621	65	1.849	2.535	621	85	462	1.168
23.00-24.00	370	50	1.211	1.631	370	65	303	738
00.00-01.00	210	46	792	1.048	210	60	198	468

TIME	Number of Vehicles				EMP			Total SMP (Hour Volume)
	LV	HV	MC	Number of Vehicles (hourly)	LV	HV	MC	
					1,0	1,3	0,25	
01.00-02.00	155	30	644	829	155	39	161	355
02.00-03.00	178	99	563	840	178	129	141	447
03.00-04.00	193	119	480	792	193	155	120	468
04.00-05.00	345	106	645	1.096	345	138	161	644
05.00-06.00	408	110	1.187	1.705	408	143	297	848

(Source: Department of Public Works and Highways of East Java Province, 2021)

2.2. Data

From the data that has been obtained, then there is processing and analysis including the design of the required pavement thickness, with the following details:

1) Determining the Condition of Road Pavement Using the Pavement Condition Index (PCI) Method

The Pavement Condition Index (PCI) system is a technique for evaluating the situation of the road surface based on the type, status, and dimensions of damage that occurs which uses an index value ranking system that is in the range of 0 (zero) to 100 (one hundred) (Choiri et al., 2024). A result of 0 is stated as a road surface with an incident that is too damaged (failed) and a result of 100 is stated as a pavement in very good condition (excellent) (Widhiyatmoko & Nusantoro, 2024). The calculation of the PCI value is obtained from the results of a field condition survey for observing road conditions (Wahidah et al., 2021). The information obtained will calculate the area and proportion of damage according to the level of damage.

$$PCI = 100 - CDV \quad (1)$$

2) Traffic Growth Factor

A number used to estimate the increase in traffic from time to time is the traffic growth factor. Traffic growth factors refer to historical growth data or correlation formulations based on other applicable growth factors. According to (Amahoru & Waas, 2021), one of the factors of traffic growth is the number of private vehicle purchases, the progress of a region, and public welfare. Traffic development during the design period can be designed using the cumulative growth factor formula:

$$R = \frac{(1+0{,}01i)^{UR}-1}{0{,}01i} \quad (2)$$

Where:
R = cumulative traffic growth multiplier
i = annual traffic growth rate (%)
UR = design period (years)

3) Determining Traffic Load or Cumulative Standard Axle Load (CESA)

Cumulative standard axle load is the estimated amount of traffic load passing through a road section during the service period (Rahman et al., 2021). In calculating CESA, it is necessary to know the daily traffic volume data (LHR) and the equivalent factor (VDF) of vehicle load based on data from MDPJ 2024. The following is the formula for determining the CESA value:

$$\text{ESATH-1} = (\Sigma \text{LHRJK} \times \text{VDFJK}) \times 365 \times \text{DD} \times \text{DL} \times \text{R} \quad (3)$$

Where, ESATH-1 is the cumulative equivalent normal axis path in the initial year, LHRJK is the average daily traffic for each type of business facility (unit of facility per day), VDFJK is the load adjustment aspect in each type of commercial facility, DD is the aspect of the direction of division, while DL is the aspect of the lane division, and R is the aspect of the traffic development multiplier (Nugroho, 2022).

4) Determining the Largest Deflection (D0) and Deflection Curvature (D0 – D200)

The deflection is measured using a Benkelman Beam (BB) to determine the thickness of the overlay. There are 3 steps to determine the thickness of the overlay based on the traffic load, including a very low traffic load or equivalent to 100,000 ESA4, a very high traffic load of 100,000 ESA4.

3. Results

Maintenance of one of the infrastructures in the form of roads. In this writing, the research was carried out on the Jalan Pahlawan segment, Sidoarjo District, Sidoarjo Regency, East Java Province 61213, with a length of 3.3 km with a 4/2D road type.

The research obtained was in the form of average daily traffic capacity (LHR) research and Benkelman Beam (BB) research. Can be seen in Tables 1 and 2 below:

Table 2 Average Daily Traffic Capacity Research (LHR)

GROUP	LHR 2024	PERCENTAGE
1	76.057	72,23%
2	24.190	22,97%
3	550	0,52%
4	1.858	1,76%
5A	30	0,03%
5B	200	0,19%
6A	1.026	0,97%

GROUP	LHR 2024	PERCENTAGE
6B	719	0,68%
7A1	237	0,23%
7B2	47	0,04%
7C1	143	0,14%
8	245	0,23%

(Source: Department of Public Works and Highways of East Java Province, 2021)

Based on field observations, the types of vehicles found on the Pahlawan road section of Sidoarjo Regency are included in collector roads with heavy traffic. This is in line with the LHR data of the PU Bina Marga Service of East Java Province in 2021.

Table 3 Benkelman Beam Data (BB)

STA CODE	STA	LOAD (KN)	D0 (μM)	D200 (μM)	ASPHALT TEMPERATURE (°C)	ASPHALT THICKNESS (MM)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	00+840	97,8	415,2	26	35	100
2	00+940	97,8	495,5	31	35	100
3	01+040	97,8	1098,4	65	35	100
4	01+140	97,8	582,3	37	35	100
5	01+240	97,8	733,5	43	35	100
6	01+340	97,8	1297,4	40	35	100
7	01+440	97,8	743,2	57	35	100
8	01+540	97,8	817,4	36	35	100
9	01+640	97,8	680,5	49	35	100
10	01+740	97,8	803,7	35	35	100
11	01+840	97,8	890,4	56	35	100
12	01+940	97,8	728,3	39	35	100
13	02+040	97,8	649,5	39	35	100
14	02+140	97,8	1700,2	45	35	100
15	02+240	97,8	635,1	45	35	100
16	02+340	97,8	527,7	52	35	100
17	02+440	97,8	585,6	17	35	100
18	02+540	97,8	660,9	21	35	100
19	02+640	97,8	636,4	28	35	100

STA CODE	STA	LOAD (KN)	D0 (µM)	D200 (µM)	ASPHALT TEMPERATURE (°C)	ASPHALT THICKNESS (MM)
20	02+740	97,8	122,7	31	35	100
21	02+840	97,8	116,4	33	35	100
22	02+940	97,8	435,2	32	35	100
23	03+040	97,8	297	31	35	100
24	03+140	97,8	345,5	37	35	100
25	03+240	97,8	541,2	35	35	100
26	03+340	97,8	588,7	33	35	100
27	03+440	97,8	467,7	45	35	100
28	03+540	97,8	263,7	33	35	100
29	03+640	97,8	362,9	42	35	100
30	03+740	97,8	220	21	35	100
31	03+840	97,8	368,9	28	35	100
32	03+940	97,8	314,3	34	35	100
33	04+040	97,8	399,5	30	35	100
34	04+140	97,8	580,4	29	35	100
35	04+240	97,8	438,3	30	35	100

(Source: Department of Public Works and Highways of East Java Province, 2022)

3.1. Description of Damage to Tracks Using the Pavement Condition Index (PCI) System

The PCI value is obtained by subtracting the corrected deduct value (CDV) from the largest potential value of perfect pavement conditions, which is 100. The PCI index value on Jalan Pahlawan, Sidoarjo Regency is shown in Table 4.

Table 4 PCI Damage Value

NO	STA	CDV VALUE	PCI VALUE	LEVEL
1	00+840	58	42	Fair
2	00+940	70	30	Poor
3	01+040	76	24	Very Poor
4	01+140	49	51	Fair
5	01+240	60	40	Fair
6	01+340	58	42	Fair
7	01+440	50	50	Fair

NO	STA	CDV VALUE	PCI VALUE	LEVEL
8	01+540	76	24	Very Poor
9	01+640	52	48	Fair
10	01+740	59	41	Fair
11	01+840	80	20	Very Poor
12	01+940	38	62	Good
13	02+040	52	48	Fair
14	02+140	86	14	Very Poor
15	02+240	87	13	Very Poor
16	02+340	85	15	Very Poor
17	02+440	78	22	Very Poor
18	02+540	80	20	Very Poor
19	02+640	73	27	Poor
20	02+740	80	20	Very Poor
21	02+840	80	20	Very Poor
22	02+940	25	75	Very Good
23	03+040	56	44	Fair
24	03+140	75	25	Poor
25	03+240	50	50	Fair
26	03+340	54	46	Fair
27	03+440	75	25	Poor
28	03+540	79	21	Very Poor
29	03+640	85	15	Very Poor
30	03+740	80	20	Very Poor
31	03+840	50	50	Fair
32	03+940	84	16	Very Poor
33	04+040	84	16	Very Poor
34	04+140	80	20	Very Poor
35	04+240	76	24	Very Poor

(Source: Personal Analysis, 2025)

From Table 4, the PCI value results for each segment are obtained, then the overall calculation is done by comparing the number of ΣPCIs and the number of segments

$PCI = \frac{1120}{35} = 32$

The PCI value on Jalan Pahlawan is 32 which is included in poor condition.

3.2. Traffic Load Analysis CESA4 and CESA5

The Pahlawan Road section in Sidoarjo is included in the East Java Province collector road section, so the traffic development value (Indonesian average) is used, namely i = 3.5% (Anugrah, 2022). With a 20-year age planning, the results of the traffic development aspect increase are:

$$R = \frac{(1+0{,}01\times i)^{UR}-1}{0{,}01\times i}$$
$$= \frac{(1+0{,}01\times 3{,}5)^{20}-1}{0{,}01\times 3{,}5}$$
$$= 28{,}28$$

The multiplier variable for the increase in total traffic volume for 2024 to 2044. The equivalent load factor (Vehicle Damage Factor, VDF) for each category of facilities is listed in Table 5.

Table 5 Vehicle Load Equivalent Aspect

GROUP	**LHR 2024**	**LHR 2044**	**VDF4**	**VDF5**
5B	200	398	1,2	1,3
6A	1026	2042	0,5	0,4
6B	719	1431	0,7	0,7
7A1	237	472	3,1	3,6
7B2	47	94	8,1	9,8
7C1	143	285	7,6	9,9

(Source: Personal Analysis, 2025)

With a design life of 20 years, the cumulative axle load value (CESA) can be seen in Table 6.

Table 6 Recapitulation of CESA4 and CESA5 Calculations

Group	LHR 2024	LHR 2044	VDF4	VDF5	CESA4	CESA5
5B	200	398	1,2	1,3	1.025.602	1.111.069
6A	1026	2042	0,5	0,4	2.192.225	1.753.780
6B	719	1431	0,7	0,7	2.825.744	3.163.230
7A1	237	472	3,1	3,6	3.940.578	5.081.057
7B2	47	94	8,1	9,8	1.849.677	2.341.132
7C1	143	285	7,6	9,9	4.926.179	6.539.759
		TOTAL			16.760.006	19.990.025

(Source: Personal Analysis, 2025)

The total result of CESA4 is 16,760,006 and CESA5 is 19,990,025. Therefore, the method applied to measure the thickness is when the traffic load exceeds 100,000 ESA4 (Ferdiansyah et al., 2024).

3.3. Overlay Thickness Analysis Derived From Maximum Deflection (D0)

The deflection in the research is the D0 deflection that has been adjusted using normal loads, seasonal improvement aspects, temperature, and deflection refinement from BB to FWD. The highest deflection value can be observed in Table 7.

Table 7 Calculation of Average D0 and D0-D200

STA	fT. D0	fT. D0 - D200	D0 Terkoreksi	D0 - D200 Terkoreksi	D0 - D200 Penyesuaian ke FWD
00+840	1,05	1,08	178,31	169,62	140,86
00+940	1,05	1,08	212,79	202,44	168,11
01+040	1,05	1,08	471,71	450,73	372,65
01+140	1,05	1,08	250,07	237,60	197,55
01+240	1,05	1,08	315,00	301,21	248,85
01+340	1,05	1,08	557,17	551,88	440,16
01+440	1,05	1,08	319,17	298,07	252,14
01+540	1,05	1,08	351,03	341,98	277,31
01+640	1,05	1,08	292,24	274,62	230,87
01+740	1,05	1,08	345,15	336,46	272,67
01+840	1,05	1,08	382,38	363,62	302,08
01+940	1,05	1,08	312,77	301,03	247,09
02+040	1,05	1,08	278,93	266,22	220,35
02+140	1,05	1,08	730,15	727,16	576,82
02+240	1,05	1,08	272,74	256,68	215,47
02+340	1,05	1,08	226,62	205,53	179,03
02+440	1,05	1,08	251,48	249,66	198,67
02+540	1,05	1,08	283,82	280,80	224,22
02+640	1,05	1,08	273,30	266,27	215,91
02+740	1,05	1,08	52,69	37,77	41,63
02+840	1,05	1,08	49,99	33,92	39,49
02+940	1,05	1,08	186,90	175,27	147,65
03+040	1,05	1,08	127,55	114,76	100,76
03+140	1,05	1,08	148,37	133,00	117,22
03+240	1,05	1,08	232,42	220,51	183,61
03+340	1,05	1,08	252,82	242,55	199,72
03+440	1,05	1,08	200,85	182,74	158,67
03+540	1,05	1,08	113,25	98,99	89,46
03+640	1,05	1,08	155,85	138,04	123,12
03+740	1,05	1,08	94,48	86,05	74,64
03+840	1,05	1,08	158,42	148,11	125,15
03+940	1,05	1,08	134,98	120,81	106,63
04+040	1,05	1,08	171,56	160,56	135,54
04+140	1,05	1,08	249,25	241,00	196,91
04+240	1,05	1,08	188,23	177,70	148,70
		Rata -Rata		239,81	199,13
		Standar Deviasi			107,5232271
		Koefisien Variasi			54%

(Source: Personal Analysis, 2025)

3.4. Overlay Thickness Analysis Derived From Deflection Curve (D0 – D200)

The data used for the deflection curve is data that has been checked for seasonal and temperature correction factors. The calculation of the deflection curve (D0-D200) is shown in Table 7 with the following data obtained:

Average D0	= 199.13 µm
tandard Deviation	= 107.52 µm
Coefficient of Variation	= 54%
Average D0-D200	= 239.81 µm
	= 0.239 mm
LHR 2024	= 16,760,006 ESA4
	= 19,990,025 ESA5

The overlay thickness is determined using the graphs in Figure 1 and Figure 2, and includes the following deflection curve values and traffic design loads (CESA5):

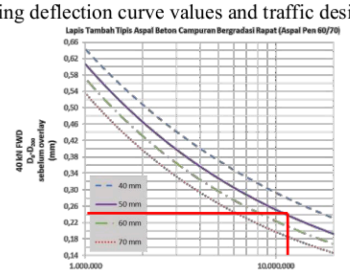

Figure 1 Determine the thickness of the thin layer
(Source: Personal Analysis, 2025)

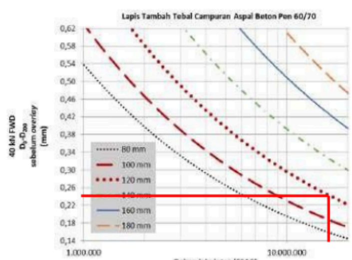

Figure 2 Set the layer thickness to add thickness
(Source: Personal Analysis, 2025)

4. Discussion

Based on the graphs in Figure 1 and Figure 2, the overlay thickness required for the curved deflection traffic load originating from the thin and thick layers is 50 mm or 5 cm and 120 mm or 12 cm. Compared to the analysis results using MDP 2017, MDP 2024 is more able to achieve the desired thickness (Hardiansyah et al., 2024).

AC/WC Surface Coating	5 Cm
Existing Pavement	25 Cm

Figure 3 Thin Overlay Add-On Layer Thickness Plan Design
(Source: Personal Analysis, 2025)

AC/WC Surface Coating	7 Cm
Layer Between AC/BC	5 Cm
Existing Pavement	25 Cm

Figure 4 Thickness Plan Design Layer Add Thick Overlay
(Source: Personal Analysis, 2025)

With the large number of births, it will affect the growth of various industrial sectors, so that the traffic growth rate is also high. From these factors, the road carries a lot of traffic load which causes unavoidable damage. From the results of the research analysis, several suggestions are given as follows.

1. The calculation method used in this study is the 2024 Road Pavement Design Manual Method which uses the latest method issued by Bina Marga. It is recommended to calculate the previous method or various other methods such as the Pd T-05-2005-B Method, and others to analyze the many elements of difference obtained from the results of the calculation of the thickness of the additional layer.
2. Daily Traffic Data (LHR) is secondary data obtained from agencies, it is hoped that it is better to use LHR data obtained directly from field surveys for better results.

5. Conclusion

Based on the results of the analysis that has been carried out, it can be concluded that the additional thickness required for the road being analyzed with a road length of 3.4 km and a pavement width of 8 m using the 2024 Road Pavement Design Manual method using a design life of 20 years, namely a thickness of 5 cm for thin overlays and also a thickness of 12 cm for thick overlays using AC -WC. The results of CESA4 and CESA5 obtained were 16,760,006 ESA for thin overlays and 19,990,025 ESA for thick overlays. The results of this study indicate an effective thickness with a productive overlay thickness level for road sections that have dense conditions.

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